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WARC ENDS!
SEE PAGES 9 AND 62.3

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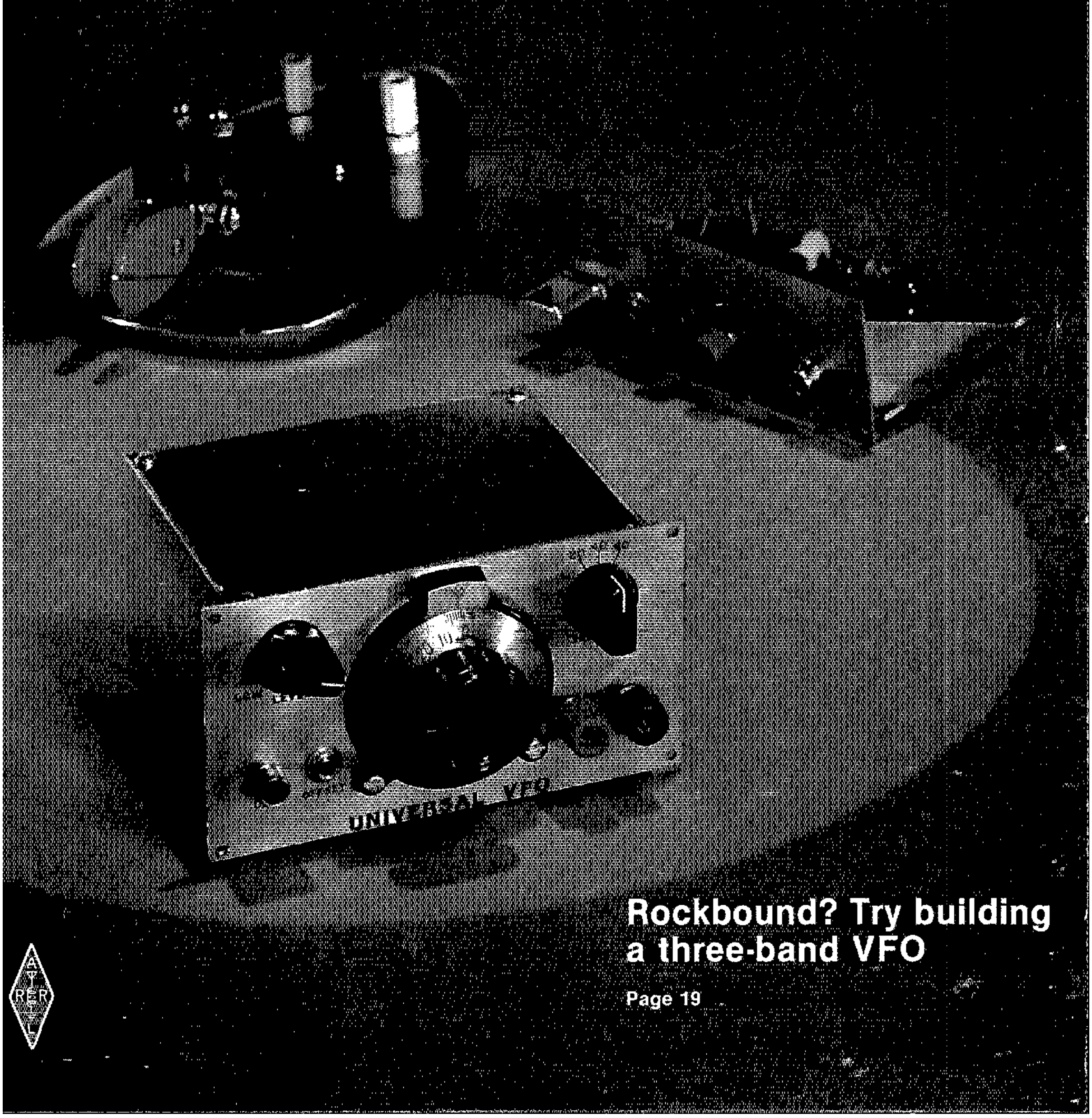

Rockbound? Try building a three-band VFO

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January 1980
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THE COVER

Here's a 3-band VFO to match last month's solid-state QRP transmitter. See page 19.

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A Universal Digital Frequency Readout

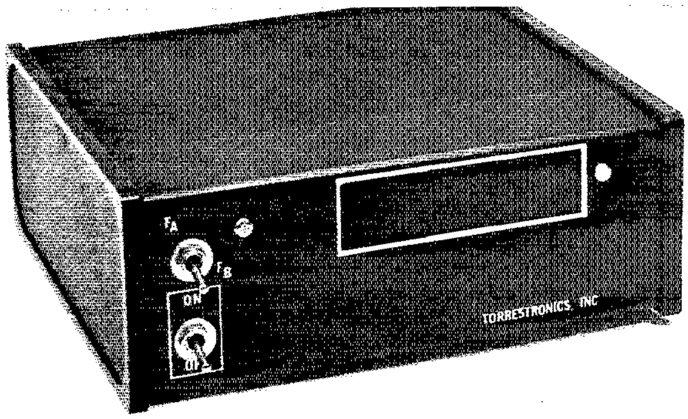
Weary of counting frequency calibration marks on your analog readout VFO dial? Why not go digital? Here is a simple-to-build four-digit frequency display.

By Alfonso Torres,* KP4AQI and Gerd Schrick,* WB8IFM

Digital frequency displays for amateur equipment have been available for a number of years. Most circuits have been designed for use with specific pieces of equipment. The complexity of these designs is reflected on the price tags — around $200. On the other hand, a straight frequency counter can be purchased for under $100. Some amateurs use these counters to indicate their operating frequency. This works fine for a cw transmission; however, an ssb signal tends to "juggle" the numbers. And, on receive, there is nothing to be measured!

This article describes a relatively inexpensive and simple-to-build digital readout that is adaptable to almost any piece of amateur equipment which is of the superheterodyne variety.[1] It can also be used as an ordinary frequency counter. The design has evolved over more than six years of building similar circuits. This design makes use of CMOS, TTL and low-power Schottky devices.

The measurement principle is simple; the frequency of the VFO is counted and the frequency of the i-f is added or subtracted from the VFO count (depending on the equipment frequency-mixing scheme). The frequency dial of the equipment is either complemented or replaced by the digital readout. Although the circuitry described has the potential of being



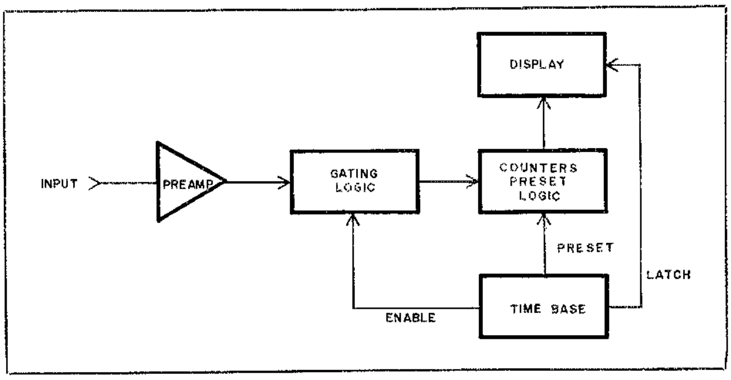


Fig. 1 — Block diagram of the Universal Digital Frequency Readout.

*c/o Torrestronics, Inc., 4850 Hollywreath Ct., Dayton, OH 45424

[1][Editor's Note: It should be noted that this digital display may not be more accurate than the analog VFO dial since other oscillators within the equipment that affect the actual frequency of operation are not counted.]

squeezed into a small space within existing equipment, it was decided to build the unit in a separate enclosure. This allowed for the use of larger size circuit boards, which are easier to assemble. After all, working on crowded IC circuitry is not everyone's cup of tea!

The Circuit

A block diagram of the digital frequency display is shown at Fig. 1 and the detailed schematic at Fig. 2. The preamplifier/buffer consists of a two-transistor circuit (Q1 and Q2) which provides gain, isolation and an impedance match between the input and the first TTL counter. A combination common-emitter and common-collector circuit, using 600-MHz f_T transistors, provides a counter sensitivity of 30 mV up through 50 MHz.

The particular time-base scheme used in this display required that a divide-by-eight "prescaler" (U5) be used. This arrangement has the advantage of reducing the last-digit flicker by slowing down the operation of U14 through U17.

The heart of the readout consists of the counter, preset, latch and display circuitry. Four counters (U14 through U17) are connected in cascade to form a four-decade ripple up/down counter. Thirty-two diodes and as many individual pc-board switches permit the use of any two preset intermediate frequencies which can be selected by a front-panel switch. The counter outputs are connected to U10 through U13 which contain latches and seven-segment LED drivers. Three MAN 72 and one MAN 52 are used for the display. These are seven-segment, common-anode LED type readouts.

U1 functions as the time-base oscillator with the 2.4576-MHz crystal and associated components. Several stages of oscillator buffering are provided by gates in U1. The output of the oscillator is applied to a divide by 16 (2^4) IC and on to a CMOS divide by 2^{14} IC. Thus the crystal frequency is divided by a total of 2^{18} or 262,144. U4, a 68-pF capacitor and the transistor inverter generate the preset, latch and count information from the 2^{12}, 2^{13} and 2^{14} divisions of the divider chain. A 3:4 counting duty cycle results and the crystal frequency can be computed in the following manner;

$$F_{xtal} = \frac{1}{n} \times \frac{3}{4} \times 100 \times 2^{18}$$

where

n is the prescale factor,

3/4 indicates the counting duty cycle,

100 is the resolution (100 Hz) and

2^{18} is the oscillator division factor.

Listed in Table 1 are the crystal frequencies and display update rates for given prescale factors. A 3:4 counting duty cycle is assumed. Any of the combinations, of course, could be selected.

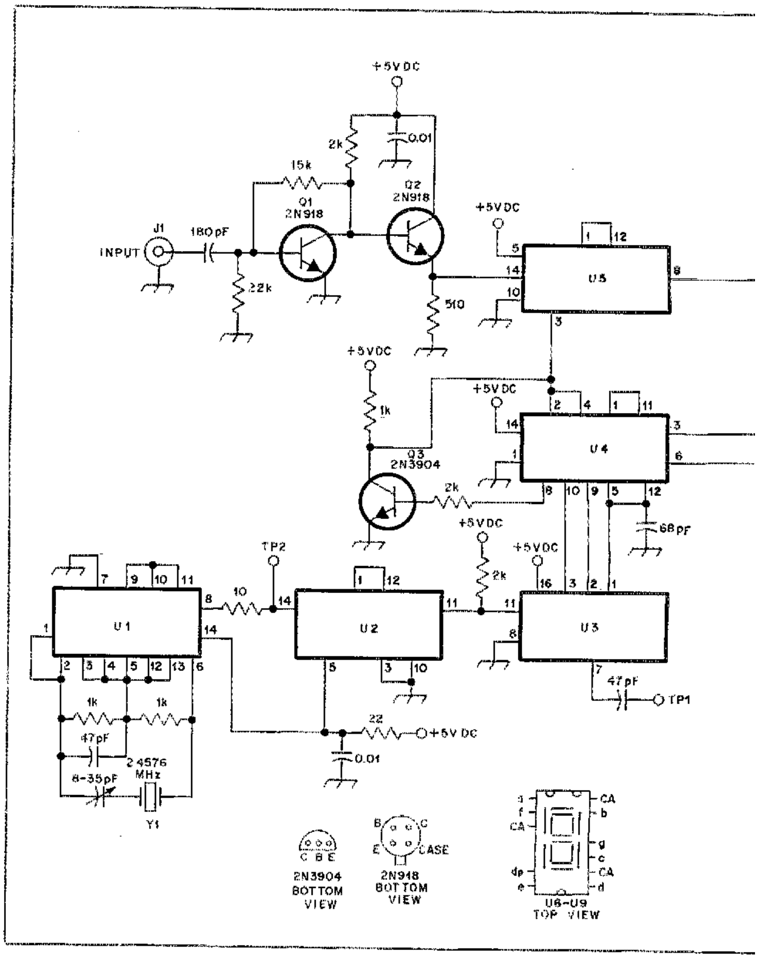


Fig. 2 — Schematic diagram of the digital frequency readout. Component values shown on the schematic but not called out in the parts list are for text or parts placement reference only.
F1 — Fuse, 1/2 A.
J1 — Phono jack.
S1 — Toggle switch, spst.
S2 — Toggle switch, spdt.
S3-S6, incl. — DIP switches, 8 spst sections per switch.

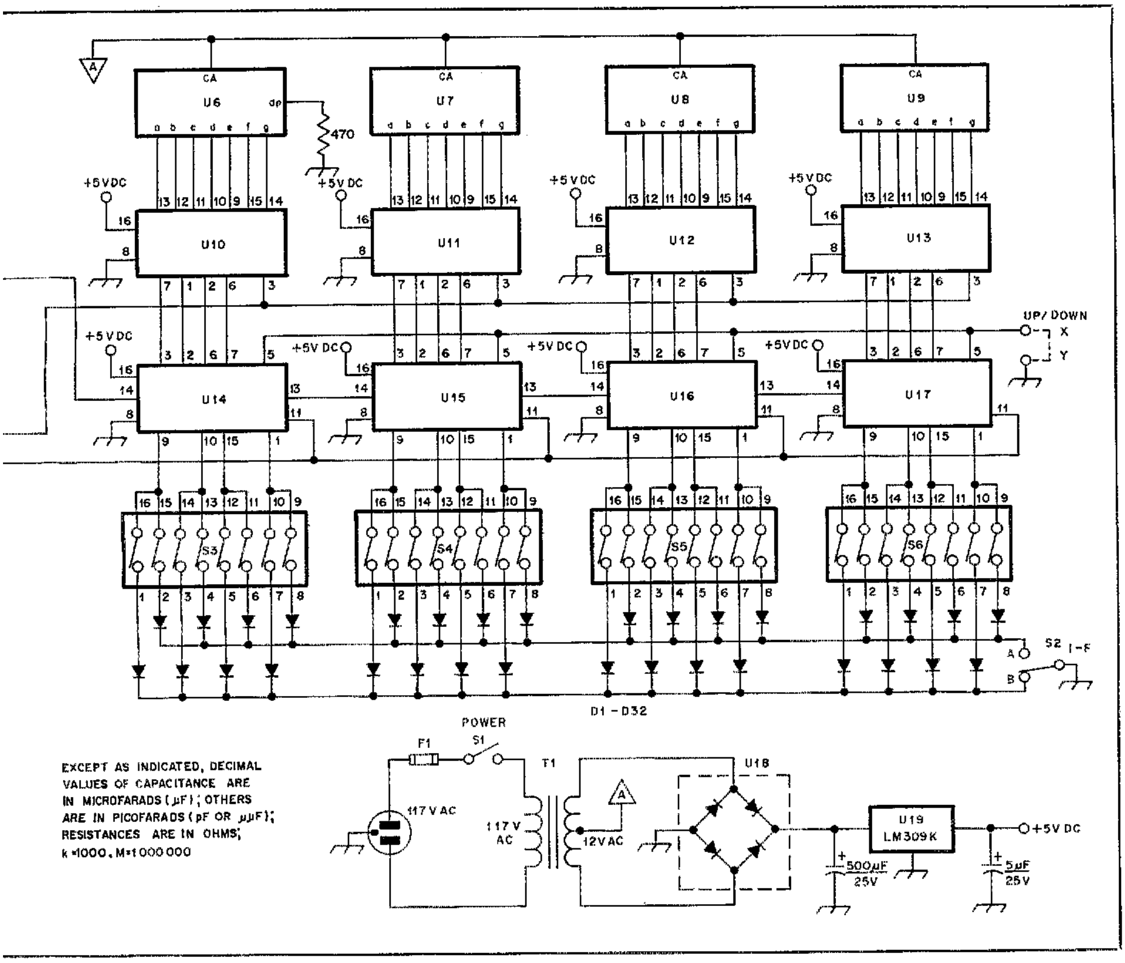
For prescale factors up through n = 5, the update rate is sufficiently fast so that no latching would be needed; instead, the counters could provide storage during their off-count time. Using prescale factor of six through 10 an intermediate storage/latch becomes mandatory or an intolerable amount of flicker would result. However, even a prescale factor of n = 10 resulting in 7.5 readings per second is still quite fast, and thus the readout follows nicely even when the frequency of operations is changed rapidly.

The crystal chosen for a prescale factor of eight is of the same type used in the Fairchild F8 microprocessor. Stability of this crystal, which in turn determines the accuracy of the readout, is quite good with a maximum frequency deviation of 0.01 percent between 0 and 70°C. This would translate to a frequency deviation of 300 Hz on the 15-meter band for a change in room temperature of 10°C or 18°F.

The power supply consists of a 12.6-V ac center tapped, 1.2-A transformer, full-wave bridge-rectifier assembly, filter capacitor and three-terminal regulator. Logic and switching circuits are provided with regulated 5 V dc. The displays are supplied with 6.3-V rectified full wave dc from the center tap of the transformer. A 1/2-ampere fuse protects both supplies. Maximum direct current drawn from the power supply is 600 mA and this occurs when all four digits are lit up with the numeral eight.

Construction

The majority of the components that



T1 — Transformer, 117-V ac primary, 12.6-V ac secondary, 1.2 A, center tapped.
U1, U4 — 74LSOO.
U2, U5 — 74LS93.
U3, U14-U17, incl. — 9374
U6 — MAN 52.
U7-U9, incl. — MAN 72.
U10-U13, incl. — 74LS190.
U18 — Full-wave bridge rectifier assembly.
U19 — LM309K regulator.

make up the universal digital frequency readout are mounted on the three circuit boards: the main counter board, the display board and the oscillator board. Double-sided boards with plated-through holes are used for the main counter and display boards. Plated-through holes are not a requirement if the builder remembers to solder the leads to corresponding pads on both sides of the board. The display board is joined to the main counter board at a right angle with the aid of four 4-pin "L" connectors.

Etching patterns for the three circuit boards are shown in the "Hints and Kinks" section of this issue. Parts placement guides are shown in Fig. 4. Arrangement of the boards and power supply components within an enclosure is not critical.

The authors are making available assembled units, complete parts kits or circuit boards for those builders who might be interested. Send an s.a.s.e. to the address given on the first page of this article.

Programming

Programming the digital readout is as simple as addition or subtraction. The four DIP switches (one for each digit) control the starting point of the counters. DIP switches 1 and 2 will produce an "8" depending on whether the front panel switch is in the F_A or F_B position. Refer to the table and Fig. 4. If all of the DIP switches are in the off position the display will be blanked. All switches in the on position, for either F_A or F_B, will produce all zeroes on the display.

As an example, assume that you have a Drake R-4C receiver. Initially, set the DIP switches so that the display reads 000.0. Connect the input of the digital display to the INJ. OUT jack on the receiver and tune the receiver to 14.000 MHz. The display should read 645.0. To make the display read 000.0, disconnect the readout from the receiver and program in the numbers 355.0 (this is the difference of 000.0 and 645.0). Reconnect the readout and the display should indicate 000.0. Tune the receiver to 14.010 MHz. If the display does not indicate 010.0, the counter is counting in the wrong direction. By connecting or disconnecting a wire between points x and y on the main board, the direction of the count can be changed.

Calibration

The calibration procedure described

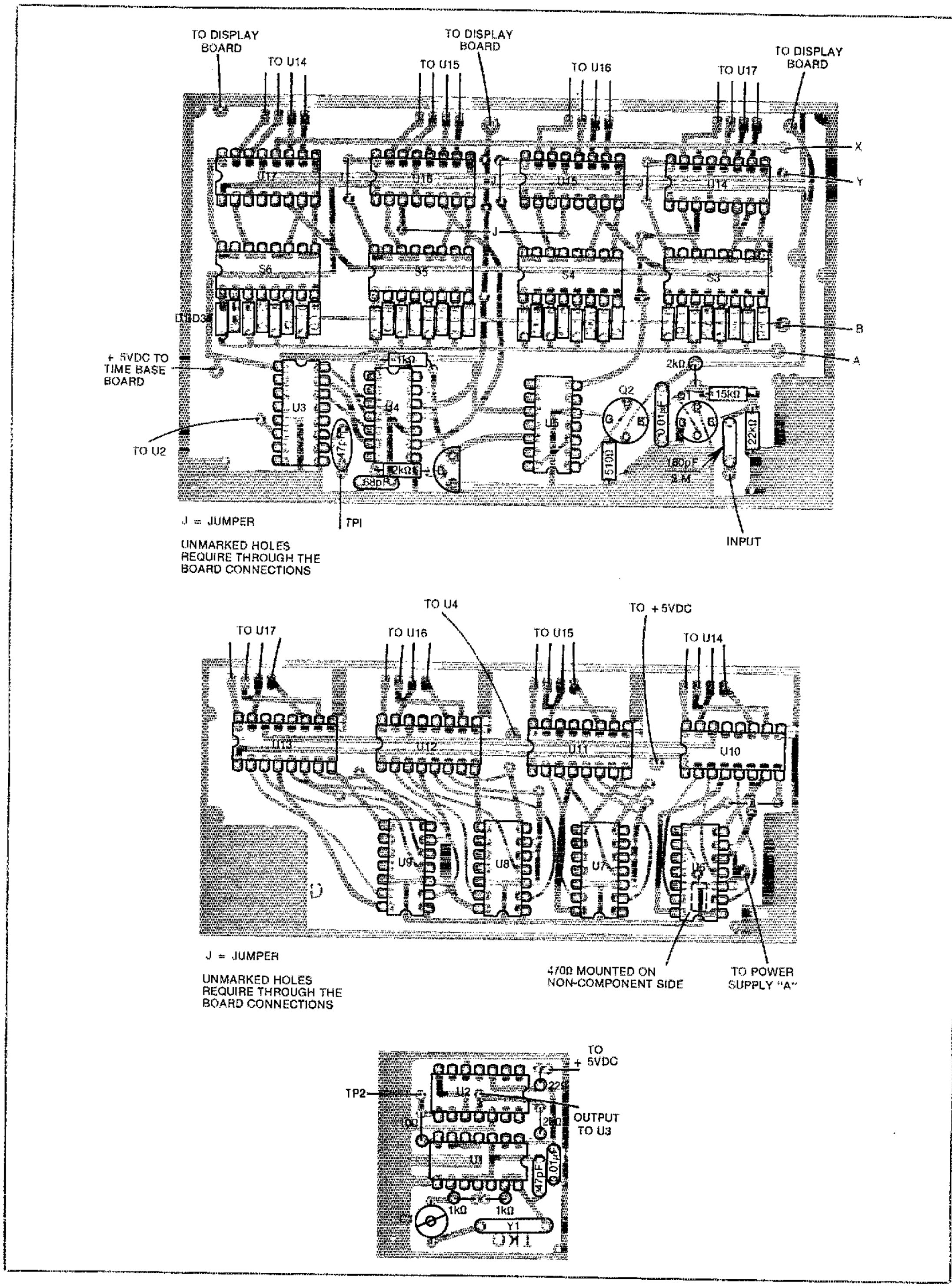


Fig. 3 — Circuit-board layouts for the main, display and oscillator boards. The main and display boards are double sided with a foil pattern on each side. Here the two sides are shown superimposed to aid in parts location. The oscillator is built on a single-sided board. Etching patterns for these boards are shown in the "Hints and Kinks" section of this issue.

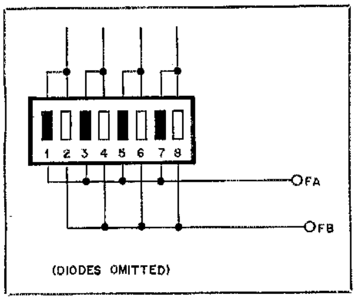


Fig. 4 — Numbering of the DIP switches and related information for programming of the counter.

Table 1

n	$f_{(kHz)}$	Rate
1	19,660.8	75
2	9830.4	50
3	6553.6	25
4	4915.2	18.75
5	3932.16	15
6	3276.8	12.5
7	2808.69	10.71
8	2457.6	9.4
9	2184.53	8.33
10	1966.08	7.5

where n is the prescale factor, $f_{(kHz)}$ is the crystal frequency and rate is the display update rate. A 3/4 time base duty cycle is assumed.

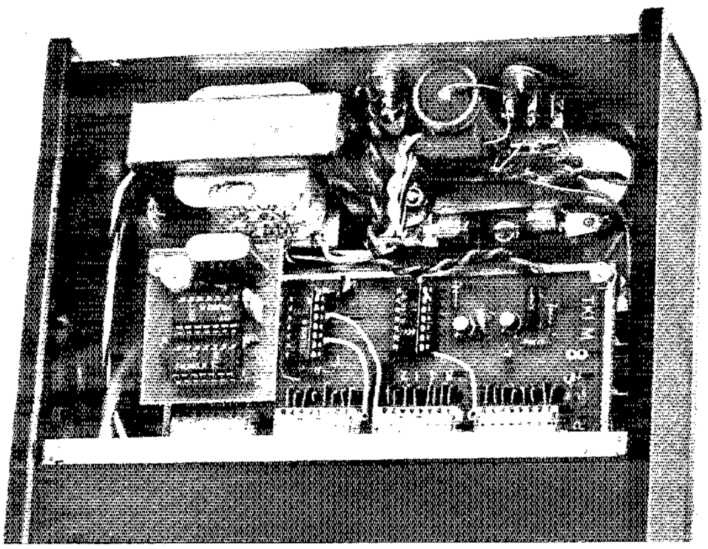


Fig. 5 — This is a photograph of the inside of the completed frequency readout. The oscillator is mounted above the main board by means of a spacer and associated hardware.

here requires no external calibration source or measuring equipment. It is assumed at this point that the digital readout is connected to the receiver and that the appropriate intermediate frequency has been programmed into the counter. To calibrate the counter some high-order harmonics of the crystal time base are injected into the input of the receiver. In this case, signals available from test point TP1 emanate from the Q_4 stage of U3. A 9.6-kHz square-wave signal which is rich in harmonics is present at this point. A wire is run from TP1 to the receiver antenna terminal. Tune the receiver, preferably on one of the higher bands (15 or 10 meters) to one of the many harmonics that appear every 9.6 kHz. Assume that a beat note is located at 21,390.5 kHz. Divide this frequency by 9.6 kHz. The number 2228.18 is obtained. Since this number (which is the order of the harmonic) contains a fractional part (0.18), the time base is not properly set.

Having computed the harmonic order, we can determine the frequency which should be read while observing the beat note: 2228 × 9.6 = 21,388.8. Since the display indicates a number rather close (1.7 kHz) to this frequency, the VFO can be set to the correct frequency and the crystal trimmer adjusted for the proper beat note — for most ssb equipment this would be 1500 Hz. To find this exact frequency take one-half of the difference between the upper- and lower-sideband BFO crystals in the receiver. Should the zero-beat method be used, this frequency must be subtracted from the new frequency for usb and added to the new frequency for lsb. There is some mutual dependence between the display and the beat note so that the readout has to be observed closely and corrected to the proper frequency as the crystal trimmer is adjusted. QST

Strays

SAFETY FIRST

□ There are reasons for accidents involving radio gear, but never *good* reasons. A recent incident at a commercial radio station illustrates the dangers present in radio equipment. The station engineer bypassed safety knockout switches on the station transmitter and accidently came in contact with about 5000 volts while working on it. The resulting shock knocked the engineer into a wall and inflicted third-degree burns on his hand, face and arms. Take no chances with electricity. Even a low-voltage shock can be serious — sometimes fatal.

Heed the ARRL safety code: While there's no reason for you to be involved in a ham-related accident, that possibility always exists if you are not thinking safety. Following the ARRL safety code will make your ham experience more enjoyable. Read it and practice it.

1) Kill all power circuits completely before touching anything behind the panel or inside the chassis or the enclosure.

2) Never allow anyone else to switch the power on and off for you while you're working on equipment.

3) Don't troubleshoot in a transmitter when you're tired or sleepy.

4) Never adjust internal components by hand. Use special care when checking energized circuits.

5) Avoid bodily contact with grounded metal (racks, radiators) or damp floors when working on the transmitter.

6) Never wear headphones while working on gear.

7) Follow the rule of keeping one hand in your pocket.

8) Instruct members of your household how to turn the power off, and how to apply artificial respiration. Instruction sheets on the latest approved method of resuscitation can be obtained from your local Red Cross office.

9) If you must climb a tower to adjust an antenna, use a safety harness. Never work alone.

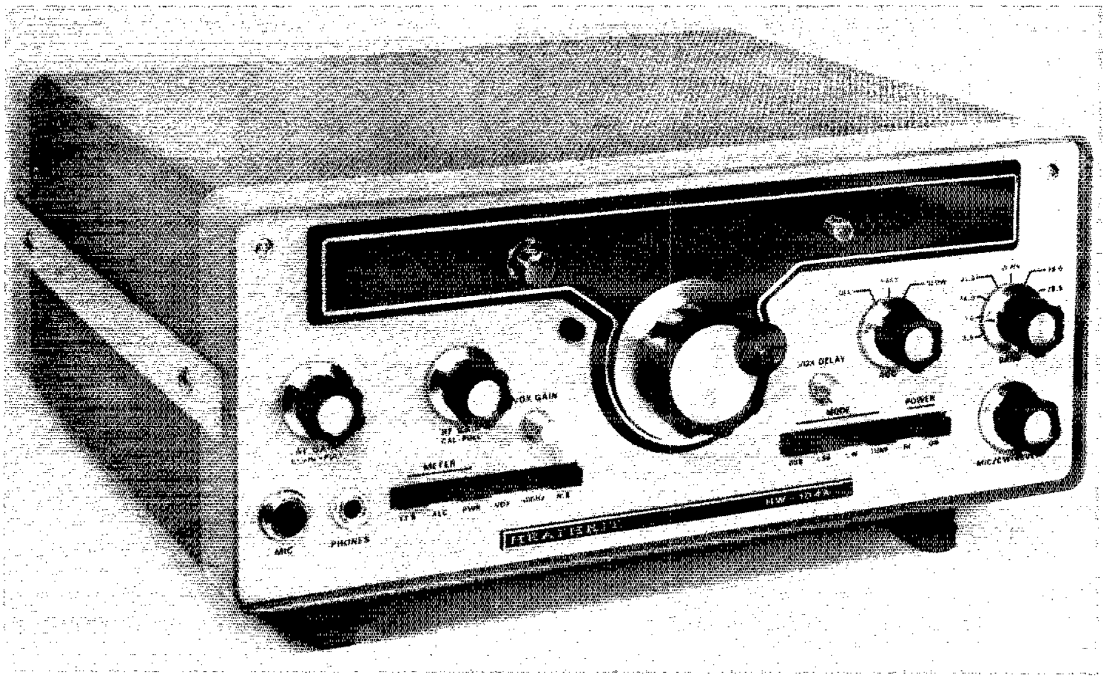
10) If you must climb into a tree, or work on a roof, remember that you're not standing on the ground. That first step down can be a very long and painful one. Never work alone.

11) Develop your own safety technique. *Take time to be careful. Death is permanent.*

Adding Receiver Incremental Tuning to the HW-104 or SB-104 Transceiver

Leapfrog may be a great game for the kids, but a real pain in the knob for transceivers without RIT! Add this simple circuit to your '104 and fret no more.

By Norman Bradshaw,* W8EEF



The front-panel view of the HW-104 shows the placement of the RIT function control switch and potentiometer. Each control is located 4-1/2 in. (114 mm) from the outer edges of the cabinet. Other possible locations are discussed in the text. *(photo courtesy of Harold Hansen)*

One desirable feature that's missing in the Heath HW-104 and SB-104 transceivers is receiver incremental tuning or RIT. This function may be added to these units by inclusion of the circuitry shown in Fig. 1. The tuning range is approximately plus/minus 1500 Hz from the normal (RIT off) receive or transmit frequency. The incremental tuning is activated only during receive periods. During transmission, the VFO frequency is unaffected.

One question comes to mind when attempting to install the circuit components in the '104 — where to mount the front-panel controls. This is answered by fitting the potentiometer and push-button switch into the red plastic bezel, with the pot on the left-hand side and the switch on the right. The front-panel layout photo depicts this installation. Two other alternatives exist. If your transceiver does not have the noise-blanker accessory, consider using the noise-blanker push-button switch to activate the RIT function. The original 100-kΩ VOX-gain control may be used for the RIT control. Since the VOX gain is seldom changed once adjusted, this function may be relegated to an added potentiometer mounted on a bracket and secured to the VFO enclosure. Then extra

*646 E. Glenlord Rd., Saint Joseph, MI 49085

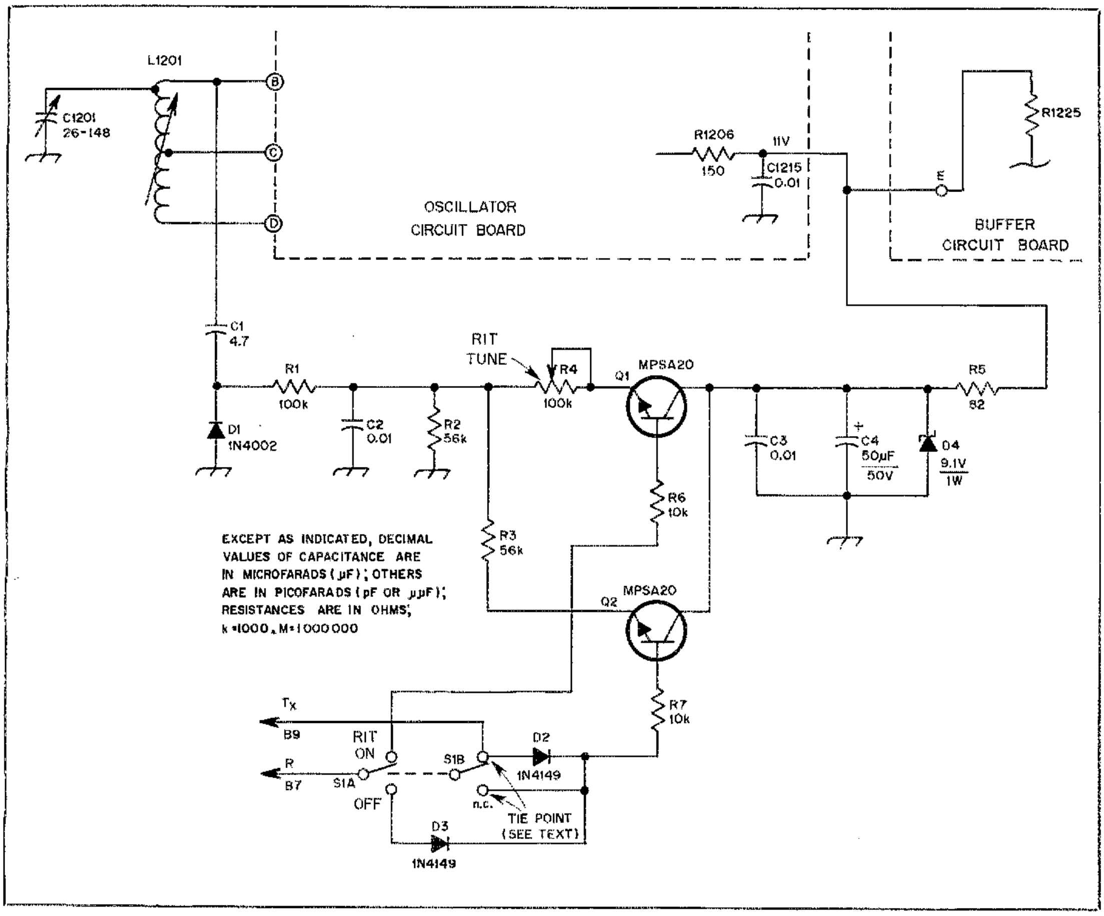


Fig. 1 — Circuit diagram of the RIT modification. All resistors are 1/4 W. Low-numbered components are additions. Only one-half of S1 is used for switching. The other section is used for component tie points, as explained in the text.

C1 — 4.7 pF.
C2, C3 — 0.01 µF.
C4 — 50 µF, 50 V, electrolytic.
D1 — 1N4002.
D2, D3 — 1N4149 or 1N914.
D4 — 9 1-V, 1/2-W Zener diode.
Q1, Q2 — MPSA20.
R1 — 100 kΩ.
R2, R3 — 56 kΩ.
R4 — 100 kΩ.
R5 — 82 Ω.
R6, R7 — 10 kΩ.
S1 — Dpdt push button.

holes in the front panel will not be required.

Circuit Description

With the RIT switch off, transceiver operation is unaltered from its original state. With the push button in (RIT on), the receiver control line (B7) turns Q1 on through S1A. This allows the 11-V supply at the collector of Q1 to be applied to R4, the RIT-frequency control. By varying the voltage applied through R4 to D1, the diode-junction capacitance is altered. This variable capacitance, in conjunction with C1, is felt at the VFO FET gate thereby changing the oscillator frequency. R2 is necessary for balancing purposes so that when R4 is centered, one half of the voltage available through Q1 will be impressed upon D1. This provides the zero or center frequency position of the RIT control.

The transmit-control line (B9) is coupled to Q2 via D2. R2 and R3 act as a voltage divider with the transceiver in the transmit mode to return the VFO to the center frequency, regardless of the setting of R4. This same action occurs via S1A and D3 during receive when the RIT is switched off. D2 and D3 act as an OR gate so that the receive and transmit control lines do not interfere with one another.

Installation

The RIT pc board is mounted between the oscillator circuit board and the tuning capacitor, C1201. First, drill a 1/4-inch (6-mm) hole in the bottom of the VFO enclosure. (SB-104 owners will have to plan a different exit-hole location as the VFO enclosure mounts directly on the chassis in that unit.) Locate this hole so that the four-wire cable used for interconnection will come straight down from the RIT pc board when it is installed. A one-inch square (25-mm) piece of sticky-back foam rubber is attached to the foil side of the board for purposes of insulation and to space the RIT board from the oscillator board. The ground-bus wire is soldered to the ground lug on the tuning capacitor. This should be a short, stiff lead which will aid in rigidly mounting the circuit board. The other side of the board is held in place by the four-wire cable and by the 4.7-pF capacitor (C1) which is connected to L1201. A short piece of hookup wire is run from the +11-V position on the RIT board to the exposed resistor lead of either R1225 or R1226 on the buffer cir-

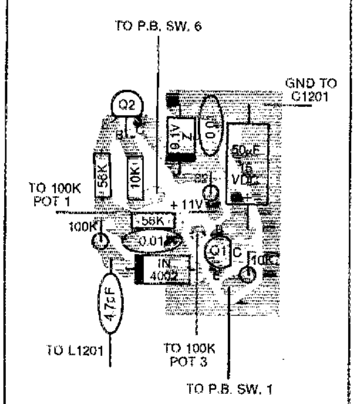


Fig. 2 — Parts placement diagram for the RIT circuit, shown from the component side. Shaded areas represent copper foil as viewed from the component side. The etching pattern is shown in the "Hints and Kinks" section of this issue.

cuit board. *Caution* — be sure to connect to the +11-V side of this resistor. The two 1N4149 diodes are mounted on the push-button switch, S1. Only one half of the dpdt switch is needed for actual switching; the other half is used for tie points. Color code or otherwise mark the leads for the new circuit to ensure proper connections. The four-conductor cable used in this installation has approximately 4 inches (102 mm) of plastic covering left on the end inside the VFO compartment. No grommet was used in the exit hole. The value of C4 is not critical — any value from 10 μF to 100 μF will suffice.

A short, shielded lead is connected from the VFO output jack on the inside of the back panel to one of the spare jacks located there. This enables the VFO output to be available for use with a frequency counter when realigning the VFO. Realignment is necessary because the additional capacity presented to the VFO tank due to the presence of C1 and D1 changes the VFO calibration slightly.

When using a frequency counter for realignment, adjust the VFO for a display of 5.5 MHz with the HW-104 dial at "0" and for a 5.0-MHz indication with the dial at "500." These steps will have to be repeated several times before the VFO will track properly. Alternatively, the VFO alignment procedure described in the instruction manual for use without a frequency counter is adequate. However, the counter method is much simpler. Once the realignment of the VFO is completed, you're ready to go! QST

Feedback

☐ Disregard the parts-layout guide for the "Single Channel VHF Monitor Receiver" (Bryant, Fig. 3, December 1979 *QST*, page 26), and use the information of Fig. 1 here instead. The reassignment of component numbers from the author's original to *QST* style was completed in the schematic diagram but was not carried through in the layout guide. The etching pattern as published in the December "Hints and Kinks" section is correct.

☐ Heavy borders (denoting Committees and Working Groups of particular interest to amateurs) were left off the boxes in the diagram in "WARC Countdown" (December *QST*, page 73). The following boxes should have had heavy borders: 5BA, Below 4 MHz; 5BB, 4-27.5 MHz; 5C, 27-960 MHz; 5D, 960 MHz-40 GHz; 5E, Above 40 GHz; 6A, Coordination Procedures; and 7, General Administrative.

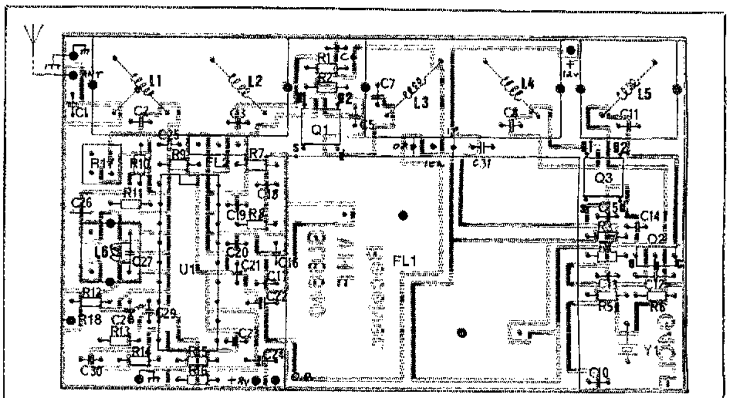


Fig. 1 — Corrected parts-placement guide for the single-channel vhf receiver, as viewed from the component side of the board. The shaded area represents an X-ray view of the etched pattern on the opposite side of the board. The board has copper on both sides, with clearance holes for component leads being the only copper removed on the component side.

☐ In "Tune Up Swiftly, Silently and Safely" (December *QST*, page 41), R1 in Fig. 1 should be 180 k. In Table 1, the first line should read:

Fwd	*Ref*	*SWR*
50	0	1.0

☐ Details for T1 of Fig. 2, page 12, of December 1979 *QST* ("Transmitter Fundamentals"), were not given in the caption. T1 consists of 36 turns of no. 28 enamel wire on an Amidon FT-50-61 (125 mu) toroid core (90 μH). The secondary winding has 4 turns of no. 28 wire over all of the primary winding.

☐ Two items were omitted from the obituary notice of Edmund B. Redington, W4ZM, which appeared in December 1979 *QST*, page 27. For 13 years, Ed served as assistant director of the Roanoke Division of the ARRL, which gave him its service award in 1975. He also served as president of the Foundation for Amateur Radio, which has formed a scholarship fund in his memory.

☐ Percy Crosthwaite, VE5RP, is the immediate past SCM of Saskatchewan, not Alberta as reported in "Canadian Newsfronts" (December 1979 *QST*, page 75).

☐ Members of ARRL advisory committees are appointed by the President, not by the Board of Directors, as stated in "Contest Mysteries Unraveled," November *QST*, page 64.

☐ On page 69 of December *QST*, the call sign of John Champa should be K8OCL.

☐ OSCAR 8 orbit numbers listed in November 1979 *QST*, page 113, starting with 2 Nov. are in error. Subtract 400 orbits. Orbit for 2 Nov. should be 8458AJ, 3 Nov. 8472J, etc. QST

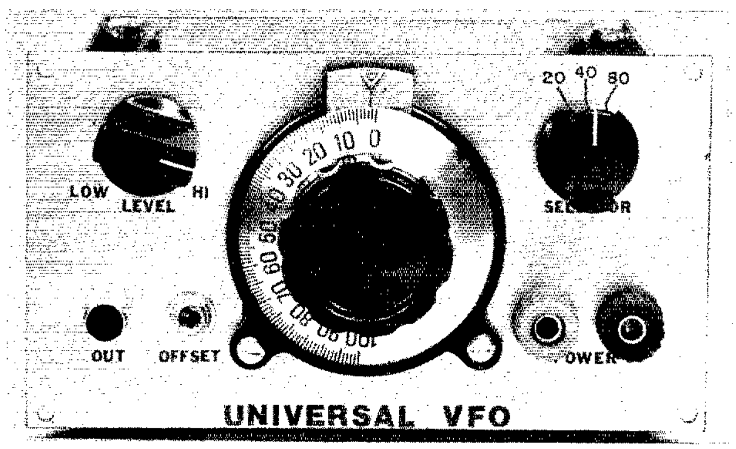
• *Basic Amateur Radio*

A Beginner's 3-Band VFO

Crystal control can be constrictive for the QRP operator or Novice. Build this stable but simple VFO if you're tired of being "rock bound." Learn some basics, too!

By Doug DeMaw,* W1FB and Bob Shriner,** WAØUZO

If you built the QRP solid-state transmitter from December 1979 *QST* you're apt to be singing the "quartz-crystal blues" by now. There's probably nothing more annoying to a cw operator than being a prisoner to a few crystal frequencies; invariably, or so it may seem, there's a QSO in progress on the crystal frequency which is available. The logical solution to the problem is to construct a VFO. This will give you freedom to roam throughout your segment of the chosen amateur band. Our project this month is an uncomplicated VFO which provides direct output on 80, 40 and 20 meters by virtue of band switching. The foundation unit is again the "Universal Breadboard" from Basic Radio in September 1979 *QST*.



Exterior view of the completed 3-band VFO. Double-sided pc board material is used for the panel and box walls in this version by Circuit Board Specialists.

What Is a VFO?

The term "VFO" stands for *variable-frequency oscillator*. Other names for similar circuits are "PTO" (permeability-tuned oscillator) and "LMO" (linear master oscillator). A PTO is similar to a VFO except that the frequency is changed by means of a movable powdered-iron or ferrite slug in a tuned-circuit coil. The VFO, on the other hand, is generally tuned by adjusting a variable capacitor. Some VFOs employ a varactor or VVC diode for tuning purposes. These diodes are subjected to different amounts of dc voltage which change their internal capacitances. VVC means *voltage-variable capacitance*. The primary difference between a VVC or varactor diode and a tuning capacitor is that one is tuned electrically and the other is tuned manually. The result is the same — an excursion in operating frequency.

From the December 1979 installment of this series we learned that in order for a crystal to oscillate we must supply feedback voltage in the oscillator stage; some of the oscillator output power is routed to the input of the oscillator (collector-to-base for a bipolar transistor, drain-to-source for an FET and plate-to-grid in a tube type of oscillator). This changes the stage from an amplifier to an oscillator.

The foregoing concept applies also to a VFO. The major difference between a crystal oscillator and a VFO is that the crystal comprises the resonant cricuit in the first example, while a coil and capacitor are used as the resonant circuit (resonator) in a VFO, PTO or LMO. It might be worth mentioning that linear master oscillators (LMOs) provide *linear* tuning, hence the name. More specifically, for each degree of mechanical or electrical tuning there will be an identical shift in frequency in terms of Hz, kHz or MHz. Some VFOs don't act quite that way. Instead, a large part of the tuning range is "crunched" at one end of the dial, while the remaining part of the frequency coverage is spread out over the other end of the dial. This is a *nonlinear* tuning characteristic. A linear response makes it easier to calibrate the VFO dial and provides smoother tuning when changing the operating frequency.

VFO Design Points

Let's examine the fine points of VFO operation. Categorically, here are the primary design objectives for good performance.

1) Good frequency stability versus time. Most designers prefer to have less than 100 Hz of frequency drift (change) from a cold start to a period an hour later.

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2) Purity of the output waveform. This means that we want *only* the desired output frequency. Harmonics, parasitics (random oscillations) and noise should be kept to the lowest level possible.

3) Acceptable mechanical stability. The circuit should contain components which will not cause changes in operating frequency when the VFO is subjected to vibration or shock.

4) Adequate VFO output voltage or power. The VFO should be capable of supplying sufficient output voltage or power to properly excite the stage in the transmitter or receiver to which it is connected.

5) Satisfactory electrical isolation between the oscillator and the VFO-chain load. This means that one or more buffer (isolating stages) or amplifier stages should be employed between the VFO-chain oscillator and the first stage of the transmitter. This helps prevent *frequency pulling* (chirp) when the transmitter is keyed. The chirp is caused by load changes at the VFO-chain output which are reflected to the oscillator. The more buffering (isolation) used, the lower the chances for unwanted "pulling."

6) Electrical shielding of the VFO circuit. Ideally, the VFO and its buffer stages are contained in an enclosure which provides isolation from stray rf and air currents.

These six performance goals have been taken into account for our workshop project of this installment.

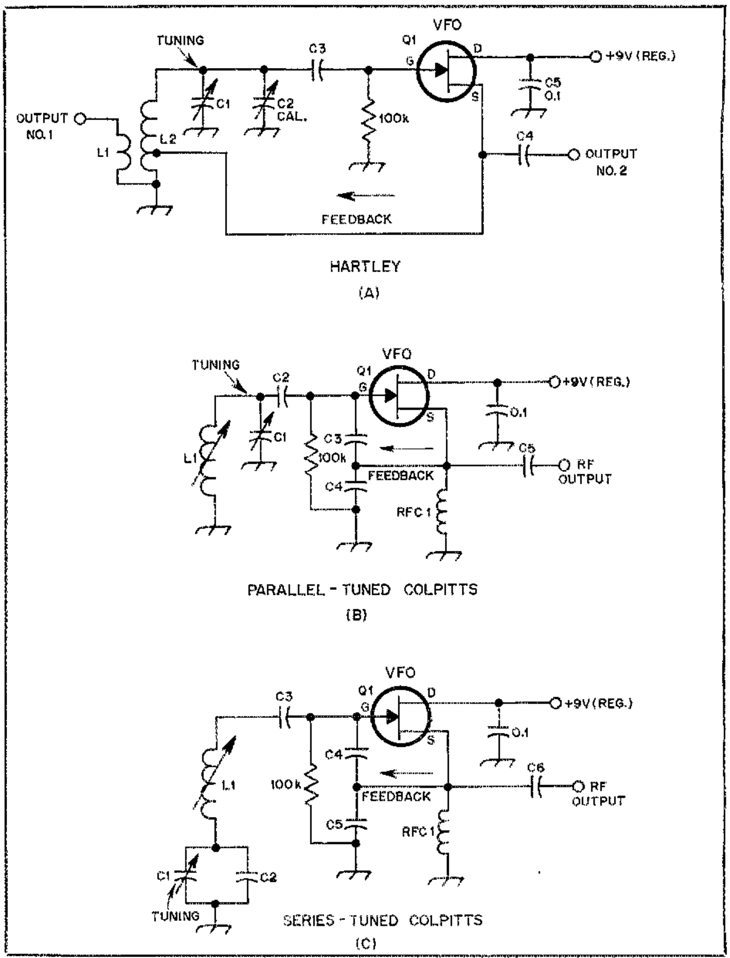


Fig. 1 — Examples of currently popular VFO circuits. A Hartley oscillator is shown at A. The circuit at B is that of a parallel-tuned Colpitts oscillator. A series-tuned Colpitts circuit is shown at C. Feedback here is from source to gate.

Types of VFO Circuits

Rather than devote countless pages of text to the myriad types of VFOs which exist, let's turn our attention to the more common ones used by amateurs. We will avoid a discussion of vacuum-tube VFOs, as they are less efficient, overall, and more difficult to stabilize (heat) than their transistor equivalents are. Instead, let's examine the circuit at A in Fig. 1. Here we have what is known as a Hartley oscillator VFO. Years ago this type of circuit (but with a tetrode-tube oscillator) was referred to as an "ECO." The output is taken in our circuit from the source terminal of Q1. Part of the output energy is fed back to the gate of Q1 via L2. This technique supplies the necessary *positive feedback* to make Q1 oscillate. The percentage of power (typically, 25 percent or less) fed back is determined by the placement of the coil tap on L2. The closer the tap is to the transistor gate the greater the feedback. Generally, the tap is located between 10 and 25 percent of the total coil turns. The tap point is made nearest to the grounded end of L2. A good rule is to use no more feedback than is necessary to ensure reliable oscillator starting. Too much feedback can cause oscillator drift and spurious oscillations apart from the desired ones. C3 should be made small enough in value to minimize the coupling between the tuned circuit (L2-C1-C2) and the gate of Q1. However, it must be large enough to permit Q1 to oscillate reliably. Using a small-value capacitor at C3 will aid in keeping the Q (quality factor) of the tuned circuit high. This is desirable in the interest of frequency stability and purity of the output wave form from Q1. Output can be taken from a small winding near the ground end of L2 (output no. 1, L1) or by means of capacitive coupling from the Q1 source via C4. If the L1 method is used, the winding should be very small (minimum turns) to minimize loading of the tuned circuit. Similarly, if rf output is taken through C4, the capacitor should be the lowest value which will provide ample excitation to the following stage. In a practical VFO the value of C4 ranges from 20 to 100 pF for operation from 160 through, say, 20 meters. C5 is used as an rf-bypass capacitor. The drain should not have rf energy present in this circuit. C1 is for main tuning and C2 is used to calibrate the VFO dial. (In this application C2 is called a "trimmer."

A more popular variety of oscillator is shown at B of Fig. 1. Here we have a parallel-tuned Colpitts VFO. It is called "parallel" because L1 and C1 *are* in parallel. Instead of a coil tap, as in Fig. 1A, the feedback is provided by means of a capacitive divider (C3 and C4). The effect is the same as when a coil tap is used. The ratio of the values at C3 and C4 will determine the amount of feedback energy. If C3 is small in value and C4 is large, the feedback amount will be small. If the situation is reversed the feedback will be high. Some VFOs of this type use a 1:1 capacitor ratio (see Fig. 2). RFC1 is

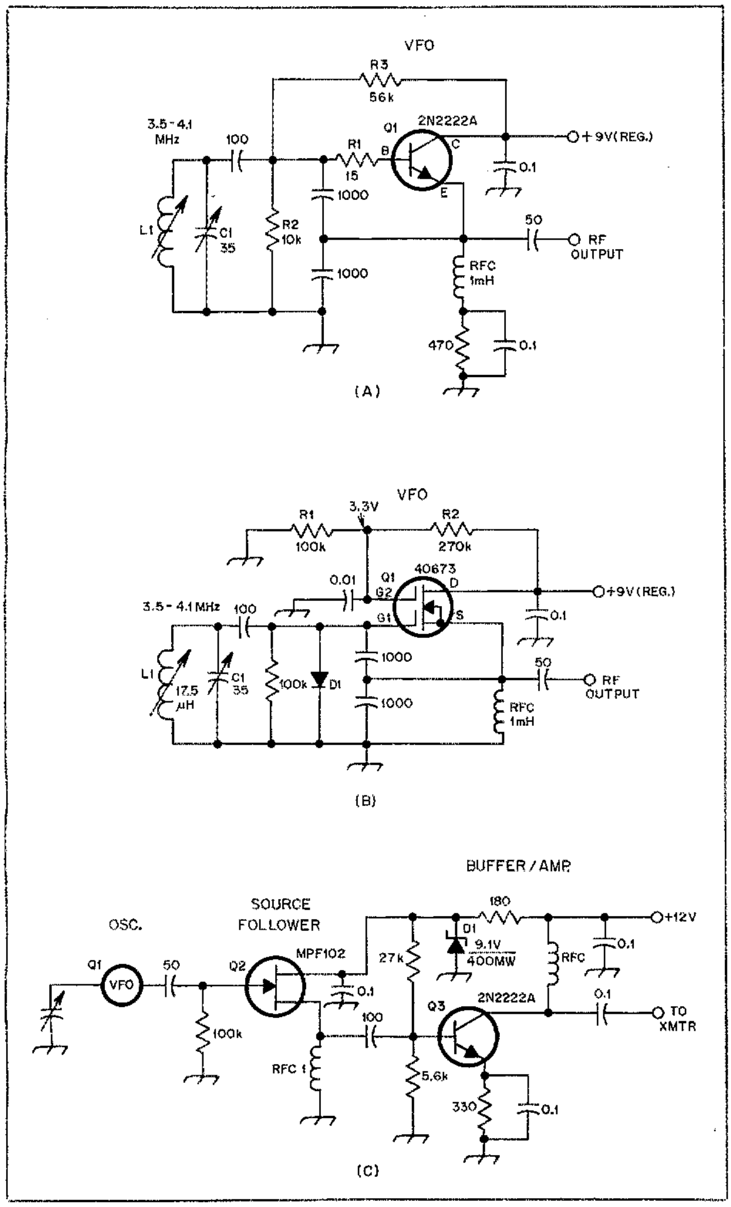


Fig. 2 — A practical 80-meter VFO which uses a bipolar transistor is shown at A. The diagram at B illustrates the same type of oscillator in which a dual-gate MOSFET is used. VFO buffering is depicted at C, where Q2 and Q3 help to isolate the oscillator from the load (see text).

employed to keep the source of Q1 *above rf ground.* The coil tap in Fig. 1A serves the same purpose. If RFC1 were not used, or if it were too low in inductance for the operating frequency, the transistor would not oscillate. C2 and C5 in this circuit should be as small in value as practical, consistent with reliable oscillation and ample output power. A trimmer capacitor is not shown in this circuit, since L1 in this example is slug tuned: The slug can be adjusted to provide VFO dial calibration.

At C of Fig. 1 is a variation of the parallel-tuned Colpitts VFO. It is called a *series-tuned* Colpitts oscillator. It is known in some circles as a series-tuned Clapp oscillator. It differs from the circuit of Fig. 1B only in the tuned-circuit arrangement. It offers the advantage of higher inductance at L1, which is sometimes desirable in terms of frequency stability at the higher operating ranges. Furthermore, C1 need not be as large in Fig. 1C to obtain the same tuning range as C1 provides in Fig. 1B.

JFETs are shown in the circuits of Fig. 1, but dual-gate MOSFETs or bipolar transistors can be used with good results (see Fig. 2). The basic advantage in using JFETs is that the parts count is lower than with the other transistor types. All the oscillators in Fig. 1 are capable of excellent stability. Care must be given to the type of capacitors used in the tuned circuit and feedback networks. Generally speaking, disc-ceramic capacitors are unsatisfactory unless they are the temperature-compensating variety. Polystyrene capacitors are highly recommended in the interest of frequency stability. A second choice would be silver-mica units. If slug-tuned coils are used in the oscillator tuned circuit, make certain that they are mechanically firm and that the slug core material is suitable for the operating frequency. The wrong core can spoil the coil Q. Ideally, for minimum long-term drift, the coil slug should *just* enter the coil when set for the required inductance. The farther it is inserted in the coil winding the greater the chances for drift caused by heat; the core properties change with temperature, and the greater the core penetration the larger the change in inductance.

Practical Circuits

Fig. 2A illustrates a practical VFO in which a 2N2222A bipolar transistor is used. With the values shown the approximate operating frequency is from 3.5 to 4.1 MHz. The nominal inductance at L1 should be 17.5 µH. R2 and R3 provide necessary forward bias at Q1 to ensure oscillation. If vhf parasitic (random) oscillations occur in a VFO, R1 can be added as a parasitic suppressor. Alternatively, a single miniature ferrite bead (950 mu) can be slipped over the Q1 base lead near the transistor body to prevent vhf oscillations.

Fig. 2B illustrates a practical VFO in which a dual-gate MOSFET is used. Gate no. 2 has forward bias applied by means of R1 and R2 (necessary). A 0.01-µF bypass capacitor is used at gate 2 to keep that terminal of Q1 at rf ground. The drain is bypassed in a like manner. D1 has been added to show how improved stability can be obtained when using an FET in an oscillator. The diode should be a high-speed (high frequency) type, such as a 1N914 silicon unit. It prevents the positive half of the sine wave at gate no. 1 from swinging beyond specific limits imposed by the diode. This in turn limits the FET transconductance, which keeps the transistor junction capacitance relatively constant. Without D1 acting as a clamp, the positive sine-wave excursion will cause the internal capacitance to vary considerably. This increases the junction heating, which also affects the internal capacitance.

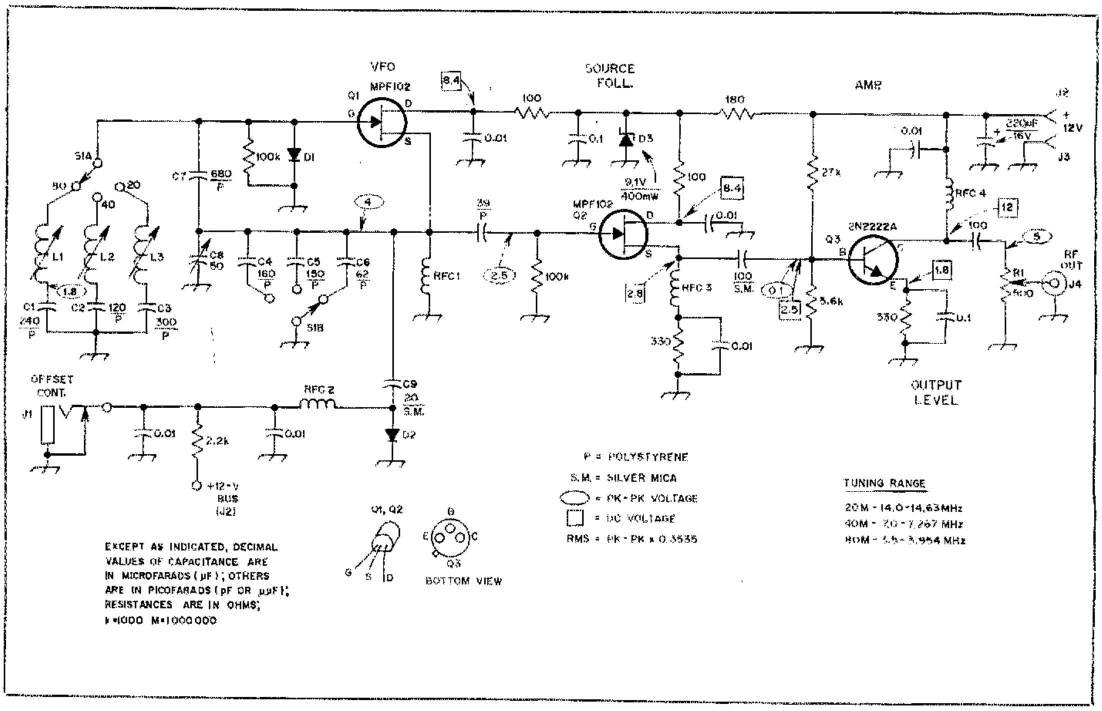


Fig. 3 — Schematic diagram of the Basic Radio VFO. Capacitors are disc ceramic unless otherwise indicated. Polarized capacitors are electrolytic or tantalum. Fixed-value resistors are 1/4- or 1/2-watt composition. Rf and dc voltage notations are included on the diagram as an aid to troubleshooting.

C1-C7, incl. — Numbered for text discussion and parts-placement purposes.
C8 — Miniature 50-pF variable (Hammarlund HF-50 or equiv.).
D1, D2 — High-frequency switching diode, 1N914 or equiv.
J1 — Miniature closed-circuit phone jack.
J2, J3 — Insulated binding post, one red (+) and one black (−).
J4 — Single-hole-mount phono jack.
L1 — 30-μH nom. inductor, slug tuned (J. W. Miller 42A335CBI or equiv. hi-Q type).
L2 — 7.5-μH nom. inductor, slug tuned (J. W. Miller 42A826CBI or equiv. hi-Q type).
L3 — 1.3-μH nom. inductor, slug tuned (J. W. Miller 42A156CBI or equiv. hi-Q type).
Q1, Q2 — Motorola MPF102 JFET (or 2N4416).
Q3 — 2N2222 or 2N2222A, any brand. Use 2N5179 as substitute if necessary.
R1 — 500-Ω linear-taper composition control.
RFC1-RFC4, incl. — 120-μH miniature rf choke (J. W. Miller 72F124AP or equiv.).
S1 — Double-pole, 2-position single-wafer phenolic wafer switch. The unit shown in Fig. 4 has several unused contacts.

Another advantage of D1 is that through a reduced junction-capacitance change there will be much lower harmonic output from the VFO: rapid changes in internal capacitance contribute substantially to the generation of harmonic currents. D1 can be added to any of the FET oscillators shown in this article. They do not aid performance when applied to the bipolar-transistor oscillators. This is because the base-emitter junction of a bipolar transistor serves a similar function to that of D1. A simple explanation of D1 is that it is a "bias stabilizing component."

VFO Isolation

Buffering of the oscillator is seen in our circuit of Fig. 2C. Q1 is followed by an FET *source-follower.* Input to that stage is applied to the gate and output is taken from the source. This type of circuit, whether it's a tube (cathode-follower) or transistor variety, does not have a voltage gain. Rather, some of the applied signal is lost. The theoretical output is 0.9 times the input voltage. This checks out when a resistor is used in place of RFC1. However, slightly greater output voltage is usually obtained when a choke or tuned circuit is used in the source circuit (see voltage notations in Fig. 3). The drain is at rf ground by virtue of the 0.1-μF bypass capacitor. The prinicpal advantage of the FET source-follower is that it exhibits a high input impedance — 1 megohm or greater. This assures minimum loading of the oscillator, and hence excellent isolation from the VFO-chain (Q1, Q2 and Q3) load. Remember, the *load* is the transmitter to which we will attach the circuit of Fig. 3.

Output from Q2 of Fig. 2C is fed to the base of Q3, which functions as a broadband Class A amplifier. Q3 adds to the isolation we desire between the oscillator stage and the load. It also amplifies the VFO signal.

Voltage Regulation

A stable dc operating voltage is vitally important to VFO stability. For that reason we have shown a Zener-diode regulator in Fig. 2C and Fig. 3. The voltage is regulated at 6.8 to 9.1 volts in most VFOs. The appropriate Zener diode is chosen for the desired operating voltage. Not only is the oscillator supply voltage regulated, but regulation is applied to the drain of Q2 and the base of Q3. This helps to prevent load changes within the VFO chain when variations in the supply voltage occur. A stable operating voltage is the most important external consideration for the VFO stage, since even slight changes in drain voltage can cause a significant shift in operating frequency.

Drift Characteristics

There are two significant drift traits that we must concern ourselves with when designing or building VFOs. One is known as *short-term drift.* When a VFO is turned on after a period of non-use, the components and the transistors are considered "cold." Thus, we hear the expression "cold start." When the operating voltage is applied there is heating within the transistors until their junctions reach a stabilized operating temperature. Short-term drift generally completes its cycle during the first three minutes of operation. In severe cases the drift can be many kHz. The usual cause of excessive short-term drift is too much feedback or unnecessarily high forward bias on the transistor. It is always best to use the least amount of feedback and forward bias possible, consistent with good performance. The VFO should be operated at minimum power dissipation to enhance stability. The power can always be built up *after* the oscillator stage, easily and inexpensively.

Long-term drift is caused by a host of operating events. One contributing factor is rf current which flows through the various components in the oscillator. Such components are the VFO coil, the coupling capacitors and the feedback capacitors. These rf currents cause internal heating of the components, however miniscule the amount may be. Heat will cause the inductance to change slightly. It will also lead to changes in critical capacitance. Since the heating is gradual until it stabilizes, the frequency drift is also gradual. Ordinarily, long-term drift slows down or stops after a period of one hour. From that time on a properly designed homemade VFO shouldn't drift more than 50 to 100 Hz per hour. After long-term stabilization is reached, most VFOs will drift upward and downward ("hunting") in frequency a few Hz in random fashion. Few VFOs will remain "rock solid" all of the time after warmup.

Ambient temperature changes also play a big role in long-term stability. This concerns the temperature within the VFO compartment. If the VFO assembly is part of a large piece of equipment, such as a solid-state transmitter or receiver, numerous components and transistors external to the VFO will heat up, causing a continual change in cabinet internal temperature. This temperature change is induced gradually into the VFO compartment until the entire system stabilizes.

We can learn from the foregoing statements that best long-term stability can be achieved if the VFO chain is kept isolated from sources of heat. Many amateurs use their VFOs outboard from the transmitter or receiver to enhance stability. It is well to note that radical changes in room temperature will also have a marked effect on long-term VFO stability. The extreme example is seen in a mobile installation, where the temperature can change in a startling manner on a hot day after the air conditioner is activated, or on a winter day after the car heater is turned on.

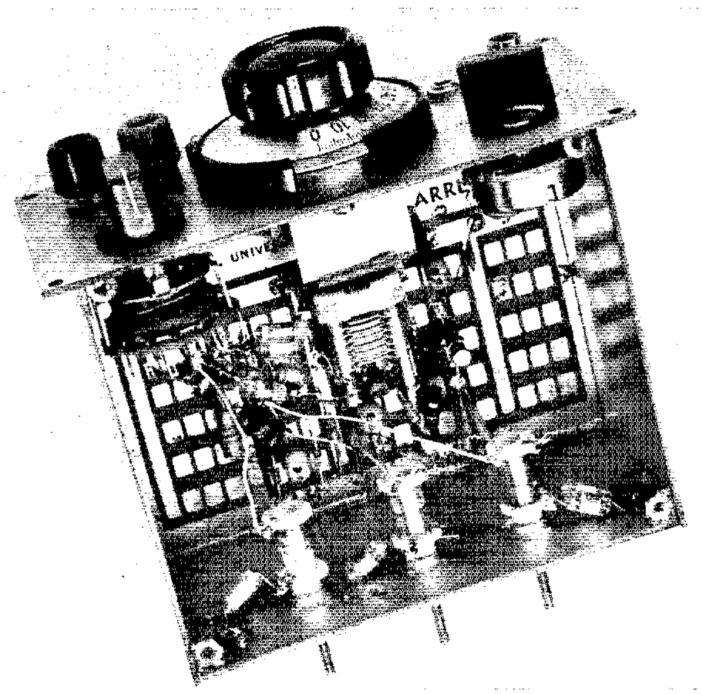


Fig. 4 — Interior view of the VFO. The polystyrene capacitors between C8 and S1 are paralleled groups which were needed to arrive at the standard values specified for C4, C5 and C6 of Fig. 3. Single units are recommended.

This Month's Project

We will construct a VFO which has output on any of three bands — 80, 40 or 20 meters. It can be used with most solid-state transmitters, but has been designed specifically for the QRP rig from December 1979 *QST* (Basic Radio). Simplicity of construction is provided by means of the Universal Breadboard and double-sided pc board, the latter of which is used for the cabinet, panel and top cover.[1]

The circuit for our 3-band VFO is given in Fig. 3. Q1 is the oscillator. The operating frequency is chosen by means of the band switch, S1A-S1B. Part of the feedback network (C4, C5 and C6) is changed by the switch, S1B. Similarly, the tuned circuits for the three bands are connected to Q1 via S1A. D1 has been included to reduce harmonics and stabilize the oscillator, as discussed earlier in this article.

D2 serves quite a different purpose. It operates as an electronic switch to offset the VFO operating frequency during receive periods. Were this not done, we would hear the VFO signal on top of the signal we were copying. Since the VFO is left operating at all times (this eliminates short-term drift), the offset circuit is necessary. The circuit is closed at J1 during transmit. This turns off the switch. When the circuit at J1 is open (receive), the 12-volt line reaches D2 and "saturates" it (turns it on). This places C9 in the circuit (Q1 source to ground), thereby shifting the oscillator frequency. J1 can be connected to the station transmit-receive control switch or relay to provide automatic offset actuation. The offset amount on 20 meters is 100 kHz, during 40-meter operation it is 44 kHz and on 80 meters the shift is 67 kHz.

[1]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.

C8 serves as the main tuning control. The shaft of C8 is coupled to a Radio Shack or Calrad vernier drive to provide smooth VFO tuning.

Output is taken from the oscillator at the source of Q1. It is routed by means of light capacitive coupling to the gate of source-follower Q2. The rf energy is next routed from the source of Q2 to the base of broadband amplifier Q3. R1 has been added as a convenience to those who wish to reduce the VFO output power. This is useful if the VFO is to be used as a signal generator, or to excite a circuit which requires less rf voltage than is available when R1 is set for maximum output. If this VFO is to be used only with the December 1979 *QST* transmitter, then R1 can be eliminated. If that is done, the 100-pF coupling capacitor should be connected directly to J4.

Output from this circuit is 5 volts peak-to-peak across R1, as measured with a 50-MHz scope. If an rf probe and VTVM are used for measuring the rf circuit voltages, the rms reading with the probe will be 0.3535 × the listed peak-to-peak voltages. Dc voltages are indicated on the diagram at significant points. The values rf and dc voltage given were obtained with the VFO operating on 80 meters. Fig. 4 shows the inside of the assembled VFO chain.

Construction Notes

We need not follow the layout in Fig. 4. Almost any format and packaging technique will be suitable, provided the signal leads are kept as short and direct as possible. Those who are adept at laying out and etching their own pc boards can make this unit much more compact through that technique. Single-sided pc board should be used for the VFO circuit board if this is done — double-sided board creates unwanted capacitors between the foil elements and the ground-plane side of the board. This can cause poor performance and drift with the circuit of Fig. 3. Although the Universal board for this project *is* double-sided, no problems will result. This is because the critical components are not mounted on the pc-board pads. The VFO case is 4-1/2 × 3-3/4 × 2-1/2 inches (114 × 95 × 63 mm), wide, deep and high, respectively. The front panel measures 2-3/4 × 5 inches (70 × 127 mm). Installation of the Universal Breadboard chassis is accomplished by soldering it to the front panel and rear wall of the assembly. The panel and side walls of the box are joined in a like manner. Note: The bottom plate is the ground-plane side of The Universal Breadboard. Four adhesive-backed plastic feet are affixed to the bottom plate after it is soldered in position. The top cover is secured at each corner by means of 4-40 or 6-32 screws. Hex nuts of the appropriate size are soldered to each upper inside corner of the VFO case to accommodate the screws.

The main tuning capacitor is submounted on a U-shaped bracket which is made from pieces of double-sided pc board. It is 1-1/2 × 1 × 5/8 inches (38 × 25 × 16 mm) HWD. This bracket is soldered in place on the inner surface of the front panel.

A parts-placement guide is given in Fig. 5 for the main chassis. Parts which do not appear on the drawing are located on the front panel or rear wall of the VFO compartment, as shown in Fig. 4.

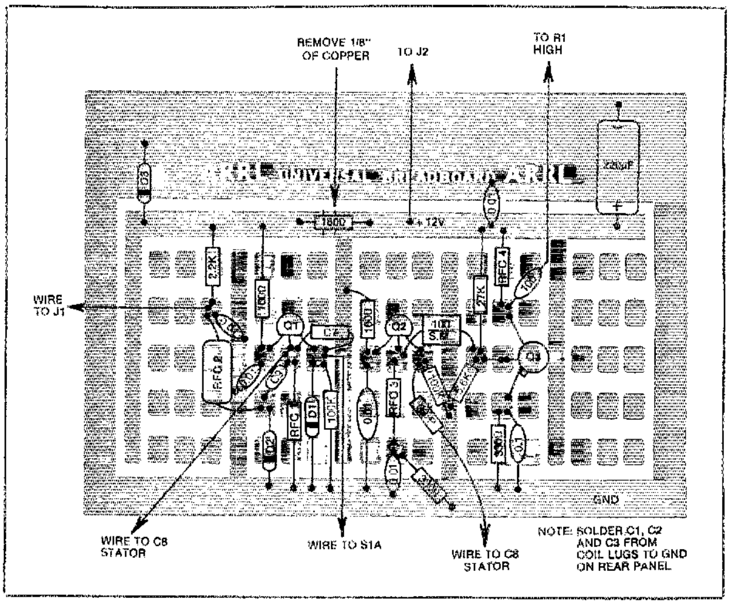


Fig. 5 — Scale layout and parts-placement guide. The scale black-and-white pattern for this board was presented in Basic Radio for September 1979 *QST*.

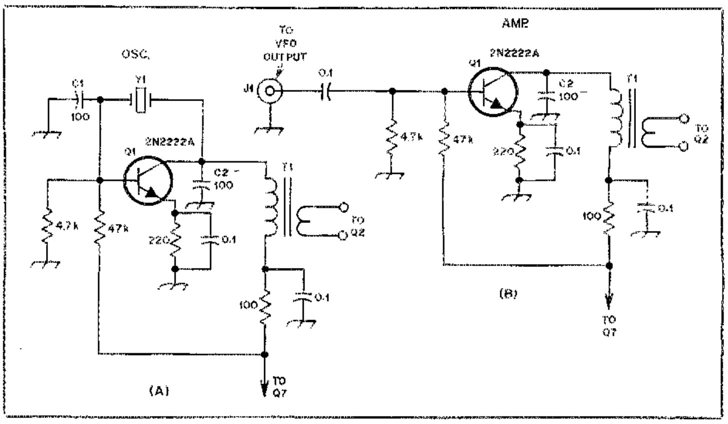


Fig. 6 — Original oscillator circuit (A) of the December 1979 *QST* Basic Radio transmitter. At B is the circuit modified for use with this VFO. Y1 and one 100-pF capacitor have been removed. A jack and 0.1-µF blocking capacitor have been added.

Concluding Comments

So that we will not have any unwanted "fireworks" or damaged components, we should examine the assembled VFO carefully before applying the operating voltage. Be sure the diodes are connected for the proper polarity in the circuit. Check also for unwanted solder blobs between adjacent circuit-board pads. Be certain that chips of metal or solder have not become lodged between the plates of the main-tuning capacitor. J2, since it carries +12 volts, must be insulated from the front panel. Check this and the +12-volt lines in the circuit to ensure that there is no short-circuit to ground. A VOM can be used for this part of the checkout. Finally, be very sure that the three transistors are connected to the circuit correctly. If the leads get mixed up, the transistors can be ruined quickly.

The major cause of malfunction in projects of this variety is inferior soldering. If the circuit fails to operate, but the wiring is correct, reheat the solder joints to be sure they are secure.

Calibration can be effected by connecting a length of wire (3 feet/0.9 m) to J4. Set R1 for maximum output. Place the far end of the wire near the antenna terminals of a calibrated receiver. Adjust C8 of Fig. 3 so that the plates are fully meshed. Set the receiver at 3.5 MHz and adjust the slug in L1 until the VFO signal is heard (zero beat). The same process is used for calibration on 40 and 20 meters.

If this VFO is to be used with the QRP transmitter from December 1979 *QST* it will be necessary to make some minor changes to the transmitter oscillator. These changes are shown in Fig. 6B. The original oscillator is depicted at A of Fig. 6.

We hope you have learned some of the fundamental considerations for VFO design and use from this article. The workshop project of this installment will permit you to move around in the amateur bands. Your QSO score should rise greatly after kicking the crystal-control habit!

All Solid-State QSK for the Heath SB-220

If you enjoy QSK cw and want the extra "sock" of an amplifier without pedaling a foot-switch, here's the answer. With prolonged tube life and reduced power consumption, you've got a deal that's hard to beat!

By Phil Clements,* K5PC

Spoiled by full break-in cw operation and being involved in long-haul traffic handling, I made a long search for a compatible "legal-limit" amplifier. It was immediately evident that the commercially available full-QSK type of units were out of reach of my pocketbook. An article by Dick Frey, K4XU, of Ten-Tec and a "crash" course on biasing in the ARRL *Handbook* helped the circuit evolve.[1,2]

To meet the "legal-limit" requirement an almost-new Heath SB-220 amplifier was purchased. The SB-220 is a real workhorse — very reliable and reasonably priced. It also lends itself nicely to modification, with ample room for additional parts. Along with the SB-220, an Ameco PLF-2 receiver preamplifier was purchased to serve as the T-R switch.

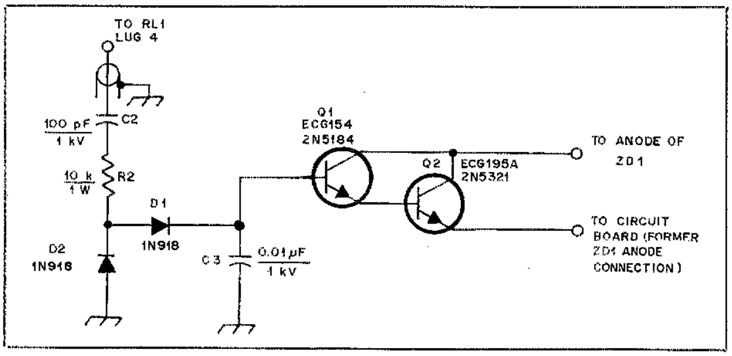
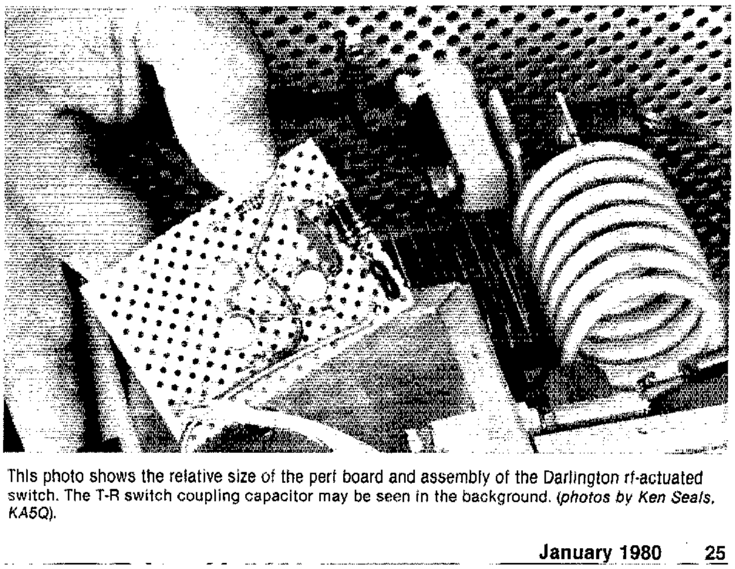


Fig. 1 — Diagram of the rf-actuated Darlington bias switch. All components are mounted on a small perf board secured to the chassis wall.

Circuit Theory

The next requirement was to devise a fully solid-state switching system for both the biasing and antenna changeover functions. An rf-sensing circuit in a Darlington configuration is used to remove the cutoff bias from the amplifier. See Fig. 1. Under standby conditions, Q2 is an open circuit allowing the full 120 V dc of the bias supply to cut off the 3-500Z tubes. When excitation is applied, Q2 conducts and the operating bias becomes the sum of the Zener diode voltage of ZD1, the collector-to-emitter saturation voltage of Q2 and the voltage drop across the grid-meter shunt, R3, for a total of approximately −6 V dc at an input of 1 kW. The switching speed and reliability of the Darlington circuit far surpass those of a mechanical relay. When the amplifier is in use one might think it is operating Class C because



This photo shows the relative size of the perf board and assembly of the Darlington rf-actuated switch. The T-R switch coupling capacitor may be seen in the background. (*photos by Ken Seals, KA5Q*).

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[1]Notes appear on page 27.

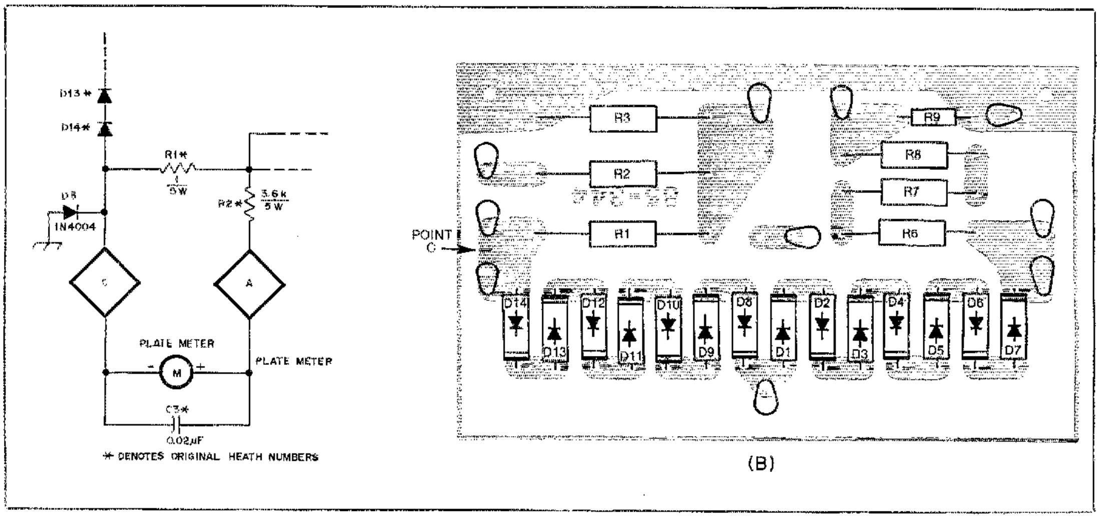


Fig. 2 — D3, the 1N4004 diode added at point C, acts as a protective clamp in case of bias-supply failure. The layout at B is viewed from the foil side.

the final amplifier plate current is zero with no rf excitation present. In reality, the mode of operation is still Class B. The added bonus (for both cw and ssb operation) is reduced quiescent plate dissipation — from an approximate 400 watts to almost nothing! This increases tube life and reliability while also lowering the operating temperature and consequent heat generation.

The switching circuit is operated by the rectification of a small amount (about 400 mW) of rf excitation which is fed to the base of Q1. This turns on Q2 which restores the original circuit configuration for proper Class B operation. This switching is done at very high speed in response to the applied excitation voltage.

Construction

All components (with the exception of the bias-current limiting resistor, R1,) are mounted on a small perf board which is secured to the vertical wall between the plate current meter and the input coil assembly.[3] A single hole is drilled from the plate tank side of the final-amplifier compartment. This is positioned just above the plate-loading capacitor, C57, to accommodate the metal standoff used to mount the perf board. The rf pickup cable is routed through the grommet below.[4]

The lead to the anode of Zener diode ZD1 from the circuit board is removed and discarded. The Darlington switch is inserted at this point by installing a lead from the Q1/Q2 collector junction to the anode of ZD1. Then a lead from the emitter of Q2 is attached to the point on the circuit from which the ZD1 anode lead was previously removed. This places the newly constructed switch assembly in series with ZD1 and the grid metering circuit.

A 1N4004 diode (D3) is connected between point C on the circuit-board assembly and a convenient ground point. See Fig. 2. The diode serves as a clamp to prevent that point from going negative with respect to ground should the bias supply fail. Should any of the added devices open, the amplifier will remain in a cutoff condition.

As shown in Fig. 3, R1 (5.6 kΩ, 5 W) is installed from lug 11 to lug 9 of relay RL1. This resistor limits the current drawn from the bias supply. R27 (100 kΩ, 1/2 W) is removed from lug 9 of the relay and discarded. Remove the black lead from lug 6 of RL1 and connect it to

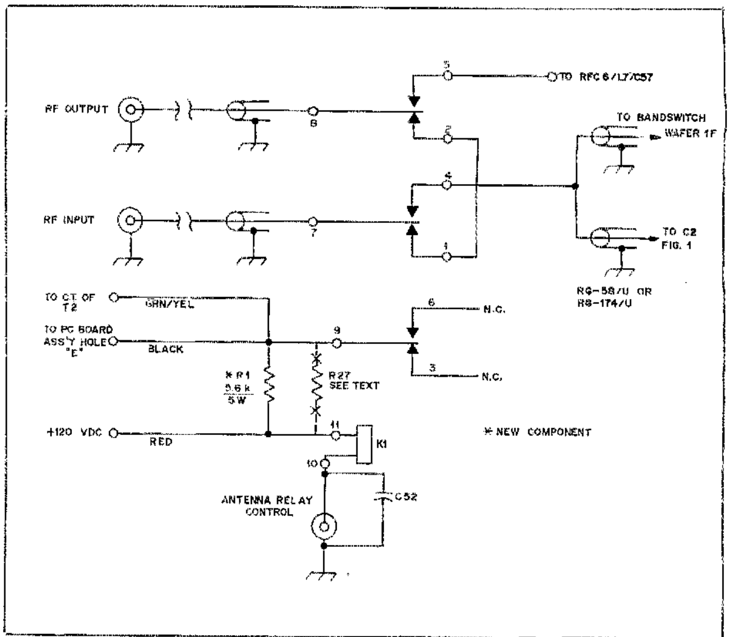


Fig. 3 — R1 is installed at the relay and acts as a bias-supply, current-limiting resistor. R27 is removed from the circuit.

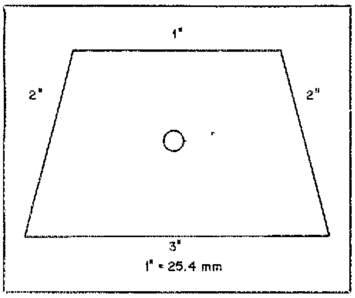


Fig. 4 — A single plate for the T-R switch coupling capacitor is fashioned from either scrap aluminum or a modified Heath bracket. See text.


The T-R switch coupling capacitor is shown here. It is mounted by means of a standoff insulator secured through one of the perforated holes on the side of the amplifier cage. This permits adjustment of the distance between the plates of the capacitor. The coaxial cable runs across the inside of the front panel, down the far side and through the cooling-fan cutout.

lug 9 of the same relay.

The center conductor of the rf pickup lead previously routed beneath the chassis is now soldered to lug 4 of RL1. The relay now functions simply as an amplifier in/out switch affecting only rf connections between the exciter, amplifier and antenna. RL1 may be operated remotely through the relay jack or from a front-panel switch. If desired, the relay can also be removed completely and all connections wired to a terminal strip mounted in its place. I chose to ground the blue lead from RL1 at the antenna relay control jack on the rear panel and use the jack for the receiver coaxial cable connection. Thus, when the amplifier is turned off, the transceiver is connected directly to the antenna.

T-R Switching

Now that the transmit functions have been taken care of, the remaining step is to couple the receiver to the station antenna electronically. Electronic T-R switches developed a bad reputation because they were usually placed at a low-impedance point — the output of the final amplifier tank circuit. This allowed the transmitter final tank circuit to act as a "suck out" trap, greatly reducing received signal strength. To eliminate this problem and obtain optimum operating conditions, one plate of a low-value capacitor (1 to 3 pF) is fabricated from some scrap aluminum having a thickness of 0.060-in. (1.5-mm). (The other plate of the capacitor is formed by the existing plate coil bracket.) The dimensions are shown in Fig. 4. As an alternative, another Heath plate coil bracket (P/N 204-2102) may be used. The lower one inch (25 mm) of the bracket is removed to provide the proper dimensions. The capacitor plate is installed at a high-impedance point which is available at the stator of C55, the plate-tuning capacitor. This placement may be seen in the accompanying photograph. The presence of high voltage on the tube side of the plate blocking capacitor, C29, and the high rf voltage present at this point mandate proper installation of the capacitor. A capacitor much larger than approximately 3 pF will affect amplifier tuning and could overload the FET in the receiver preamplifier. The Ameco PLF-2 preamplifier is connected via coaxial cable from the fabricated capacitor to the receiver and operated as directed in the PLF-2 instruction manual. For added protection, a pair of parallel, reverse-connected 1N914 diodes was installed across the rf input jack of the PLF-2 as shown in Fig. 5. The 20-dB gain of the preamplifier more than makes up for the losses in the coupling method used.

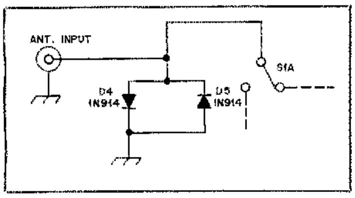


Fig. 5 — Protective diodes are added to the Ameco PLF-2 preamplifier to prevent damage to the input FET.

Summary

For a very modest investment, I have achieved the goal of a legal-limit, full-QSK station with no relays or mechanical parts. There are also added bonuses of longer tube life, better reliability and a cooler ham shack!

Notes

[1]Frey, "How to Modify Linear Amplifiers for Full Break-In Operation," *Ham Radio*, April 1978.
[2]Bryant, "Electronic Bias Switching for RF Power Amplifiers," *QST*, May 1974. [This presentation included oscilloscope waveforms of the bias switching action and may be of interest to some readers. — Ed.]
[3]SB-220 instruction manual, pictorial 4-4, above point CZ.
[4]See note 3, pictorial 4-4, position T.

Strays

ON PROGRESS AND PROGNOSTICATION

☐ Nostalgia-oriented old-timers may get a chuckle or two from the following excerpts from *The Marconigraph* for February 1913. Not only do we find an air of exuberance concerning what was then considered (and rightfully so) a scientific breakthrough in communications (via mobile radio), but we learn what fools mortals can really be when it comes to forecasting the future of progress. Perhaps there is still a lesson to be learned from all of this.

"Demonstrations which have been given in practically all of the countries of Europe caused a general revision of ideas in transmitters and receivers, until today the apparatus proves an unqualified success when subjected to the most rigorous tests. The automobile stations, the largest for which any great demand for military use has been found, are of the 1-1/2 kilowatt power, with a range of 150 to 200 miles." This excerpt was taken from page 212.

On page 215 we find the following proclamation, "Trips to the Planets?" It says, "A Paris literary man predicts that trips to neighboring planets will be possible some day. It is *just* a prediction, however. There are no grounds for it. He thinks it is not more impossible than wireless telegraphy would have seemed 300 years ago. But, perhaps we are nearing the end of the scientific age, instead of being at the beginning. It has accomplished quite enough in the field of transportation, and mankind should be content if it turns its time to improving the quality of things that the world has now gained."

Interestingly, there are people today who subscribe to the foregoing doctrine. We are fortunate, indeed, that scientific endeavor did not come to a screeching halt in 1913! Anyone for spark transmission in and below the standard broadcast band? — *Doug DeMaw, W1FB*

DO YOU HAVE "MOVING UP?"

☐ If any members or clubs have permanent copies of *Moving Up to Amateur Radio* and would be willing to loan the film to people in their area, then we need your help. Hq. does not have enough copies to keep up with an ever-increasing demand. Members must now reserve the film two to three months in advance. If you're willing to help, contact Donna McManus, film librarian, at ARRL hq.

Multielement Twin-Loop Array Antennas for VHF/UHF

Want to stack two antennas on a single boom? Here's an effective array for experienced experimenters.

By Hiromu Okagaki,* JA4VWK

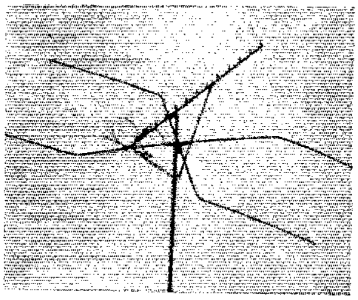
This article describes paired loop antennas for the 144- and 432-MHz bands. Each element is a figure-eight configuration of two one-wavelength loops. A figure eight has a gain of about 2 dB over a single loop. This antenna is inherently broadbanded.

A 15-element array for 432 MHz mounted atop a mast is pictured in the title photo. Table 1 lists the construction information. The dimensions are given first in millimeters because the original work was done in those units. The editor has inserted near-equivalent English dimensions.

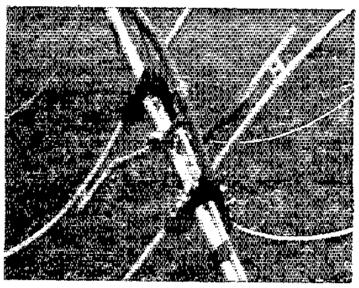
The radiation resistance of a one-wavelength circular loop is on the order of 150 ohms. As illustrated in Fig. 1, we have a choice of terminal impedances when we connect two loops in a figure eight. The proximity of the parasitic elements reduces the radiation resistance. Direct 50-ohm coaxial feed is used in the 432-MHz antenna pictured.

As mounted in the photo, the antenna radiates a vertically polarized wave. For horizontal polarization, the loops should be stacked vertically rather than horizontally. Avoid placing conductors (such as metallic masts) between the elements, because to do so will distort the radiation pattern.

Two reflectors are used in the 432-MHz array to improve the front-to-back ratio.



A 432-MHz twin-loop array, supported by vinyl tubing. Direct 50-ohm coaxial feed is used.



50-ohm matching section of the 144-MHz antenna. Note that the loops are cross-connected for end-fire phasing.

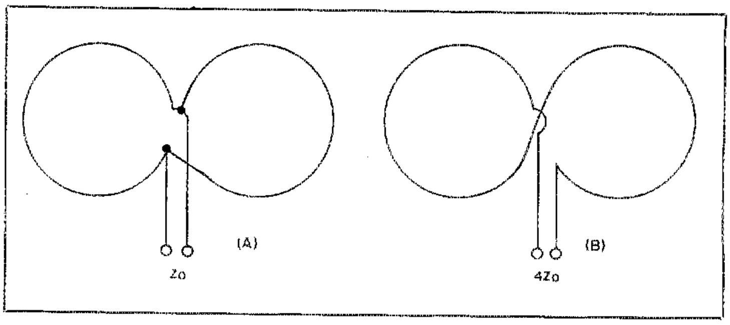


Fig. 1 — (A) Parallel-connected loops present an impedance of approximately 75 ohms (50 ohms in a parasitic array). (B) Series-connected loops present an impedance of approximately 300 ohms (200 ohms in a parasitic array).

*504 Sakae-machi, Tottori-shi, Japan

Table 1

15-element Twin-Loop Array for 432 MHz (Direct Feed)

Element	*Material*	*Element length, each side (mm)*	*(inches)*	*Spacing from the preceding element (mm)*	*(inches)*	*Notes*
Reflector II	3.9-mm (3/16-inch) dia aluminum rod	750	29-1/2			Lattice
Reflector I	10-mm (3/8-inch) dia aluminum tube, flattened	750	29-1/2	215	8-1/2	
Radiator	2.5-mm dia (no. 10 AWG) enam. coated copper wire	690	27-1/8	85	3-3/8	
Director I	3.9-mm (3/16-inch) dia aluminum rod	640	25-1/4	85	3-3/8	
Director II	"	630	24-3/4	63	2-1/2	
Directors III-XI	"	630	24-3/4	135	5-5/16	
Director XII	"	630	24-3/4	120	4-3/4	
Boom	22-mm (7/8-inch) dia polystyrene tube and 18-20-mm (3/4-inch) dia fiberglass tube					Length 1810 mm (71-1/4 inches)

Table 2

9-element Twin-Loop Array for 144 MHz, End-Fire Driven, Lambda-Matched

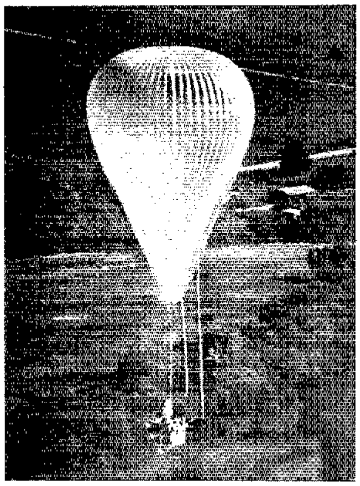
Element	*Material*	*Element length, each loop (mm)*	*(inches)*	*Spacing from the preceding element (mm)*	*(inches)*	*Notes*
Reflector	4.1-mm (3/16-inch) dia aluminum rod	2180	85-13/16			Twin-loop supported by a fiber-glass arm
Rear radiator	10-mm (3/8-inch) dia aluminum tube	2120	83-1/2	360	14-3/16	
Front radiator	"	2030	79-15/16	220	8-5/8	
(Matching rod)	"	440	17-5/16			"Lambda-match"
Director I	4.1-mm (3/16-inch) dia aluminum rod	1940	76-3/8	280	11	Supported by spacers to front radiator and director II
Director II	"	1910	75-3/16	180	7-1/8	Supported by a fiber-glass arm
Directors III-V	"	1880	74	410	16-1/8	"
Director VI	"	1880	74	390	15-1/4	"
Boom	26-mm (1-inch) dia aluminum tube and 22-mm (7/8-inch) dia aluminum tube					length 2700 mm (106-5/16 inches)

The rear reflector consists of a rod folded so that the long members are parallel to the polarization plane.

A different scheme is used in the 144-MHz design. Two driven elements in a log-periodic cell illuminate the array. The most convenient way to feed the antenna is by means of a quadruple lambda match. The feed system is shown in detail in the close-up photograph. The matching method can best be described as four half-delta/gamma sections fed from a common coaxial center conductor. The driven element loops are grounded to the boom, as is the coax braid. Construction information is given in Table 2. The dimensions for both antennas were determined empirically.

The parasitic elements of both antennas must be closed loops. They may be grounded to the boom at a common point, or left floating. The transmission line is secured to the boom and exits at the rear of each antenna.

Strays



Fred Hyde, KØLIS, Prairie Village, KS, was one of four crew members on the *DaVinci Trans America Balloon*, which set a long-distance flight record for balloonists in the continental U.S. before crash-landing in Ohio because of a severe storm. Amateur Radio kept the crew in touch with hams on the ground. This photo was taken near Topeka, KS, from a light plane piloted by John Shilder, WBØNEV. *(photo by Dale Monaghen, WØHSK)*

NEW ADDRESS FOR MICHIGAN AREA REPEATER COUNCIL

☐ Raleigh L. Wert, W8QOI, secretary of the Michigan Area Repeater Council, requests that all mail be directed to: Michigan Area Repeater Council, 309 E. Gordonville Rd., R 12, Midland, MI 48640.

I would like to get in touch with . . .

☐ anyone who has information on special radio aids for blind operators, to be included in a new manual. Please contact Byron Eguiguren, WD9IAN, WA9WHS A.R.S. Trustee, Hadley School for the Blind, 700 Elm St., Winnetka, IL 60093.

Hunt Turner, KØHT (left), and artist John Adams recently presented an art exhibit to hams in six call areas via SSTV. A comic strip series especially written for slow scanners is coming next. *(photo by Lynne Glaeske)*

Simple, Accurate Resistance Measurement

If you're looking for close-tolerance resistors, this little gem could save you time and money. You may have the creatures right in your junk box!

By William D. Koch,* WD9BFI

One of the frustrations that face most builders of equipment these days is the dwindling number of sources and quality of electronic components. It seems that building even relatively simple equipment requires shopping and scrounging from several sources before all the parts are located. But woe be unto the ham who tries to purchase precision components — he'd better have a rich aunt!

Not too long ago, I became interested in building a phasing type ssb transmitter and receiver.[1,2] As you might guess, the design called for some 1-percent resistors and 3-percent capacitors for the audio phase-shift network. After searching through several catalogs, I managed to locate only about half of the close-tolerance components required. I was ready to scrap the project when I wondered if there was an easy way to accurately measure resistors and capacitors obtained from my junk box. Assuming that reasonable accuracy could be expected, it seemed possible to use series and parallel combinations to fabricate the needed values. A dependable, yet inexpensive, measuring device resulted from this thoughtful moment. Other amateurs may find the approach and techniques I employed a practical solution for conducting similar measurements.

Circuit Theory and Description

A simplified circuit diagram is illustrated in Fig. 1. Most readers should immediately recognize this circuit as the classical Wheatstone resistance-bridge

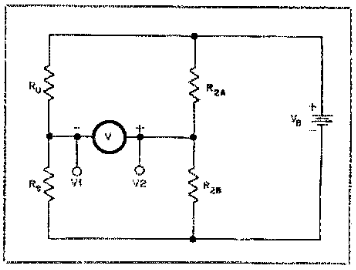


Fig. 1 — A basic Wheatstone resistance-bridge circuit

configuration. Current through M1 will be zero when the voltages V_1 and V_2 are equal. When $V_1 = V_2$, the following relationship holds:

$$\frac{R_U}{R_S} = \frac{R2_A}{R2_B}$$

$$\text{where } R_U = R_S \times \frac{R2_A}{R2_B}$$

It can be seen that, as $R2_A/R2_B$ is a dimensionless quantity, there is no need to actually *know* the values of $R2_A$ and $R2_B$. We only need to know accurately the ratio of $R2_A$ and $R2_B$.

One way to take advantage of this ratio property is to use a potentiometer for $R2_A$ and $R2_B$. The slider is connected to the point where $R2_A$ and $R2_B$ are wired to the meter. The ratio of the two end-to-slider resistances will vary according to the slider position. The problem is to accurately determine the actual slider position. Use of a very linear 0.25-percent 10-turn potentiometer neatly solves this matter. Such potentiometers are occasionally available for a nominal price as surplus items.

By coupling a 10-turn counter to the potentiometer, you can easily determine the position of the slider to better than 1/100th of a turn. As an example, let's presume we have a maximum counter-dial scale of 1000. The ratio of $R2_A/R2_B$ then is 1000 − X/1000, where X is the dial reading and can be read to a 3.5-place accuracy (e.g., 437.0, 437.5, 438.0). With a dial reading of 437.5, the ratio R_U/R_S is 1.286 or $R_U = 1.286 \times R_S$. If R_S equals 10,000 ohms, then R_U equals 12,860 ohms.

For best accuracy, strive to have readings close to 500 or mid scale to minimize effects of any dial backlash. Presume that we have a half-digit backlash (437.0 vs. 437.5). The error caused by this backlash at 100 and 900 is 0.6 percent while at 500 it is 0.2 percent.

The particular end-to-end resistance of the potentiometer is not too critical. However, with lower values, current draw could become high enough to dissipate excessive power in the potentiometer. On the other hand, with values higher than 20 to 50 kΩ, detection of the exact null becomes more difficult unless a more sensitive meter is used.

In Fig. 2, R1 is the sensitivity control. When a measurement is first started, the bridge can be unbalanced enough to cause excessive current to flow through the meter. R1 adds series resistance to prevent meter damage. As the null is approached, R1 can be rotated to reduce the resistance

*1138 Stockton St., Indianapolis, IN 46260
[1]References appear on page 31.

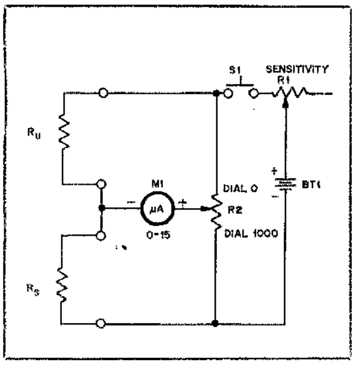


Fig. 2 — WD9BFI uses this circuit configuration for determining the values of unknown resistors where accuracy is desired.
BT1 — 6- to 18-V battery.
R_U — Unknown resistor.
R_S — Standard resistor.
R1 — 1-megohm potentiometer, audio taper.
R2 — 10-kilohm, 10-turn, wirewound linear potentiometer.
M1 — Surplus 0- to 15-µA zero-center meter.

thereby increasing circuit sensitivity.

Construction

The resistance bridge can be built on almost any junk chassis you happen to have. When I was testing the idea, I haywired the circuit in an old chassis scrounged from a 6V6 crystal-oscillator transmitter built when I was a Novice, some 17 years ago. Construction is not critical, although the 10-turn counter should be solidly mounted for minimum backlash and best accuracy. In my unit, R_S was mounted outboard between two five-way binding posts, although a rotary switch and multiple precision resistors could be used just as well. The battery supply in the original unit contained four penlight cells wired in series, although a 9-V radio battery is a satisfactory substitute. R_U is suspended between two five-way binding posts on the top of the chassis.

Only one adjustment needs to be made before the unit is operational. The counter must be set at 500.0 when the potentiometer is in the exact center of travel. This is easy to do. Find two 10-kΩ resistors, one to serve as the unknown and the other for the standard. Balance the bridge. Note the reading. Now, switch the two resistors. Balance the bridge again, and note the reading. The difference of 500 minus reading no. 1 should be the same as reading no. 2 minus 500. If not, adjust the counter-to-potentiometer coupling and redo the entire procedure. Keep adjusting the coupling until the two differences are the same.

Resistance Standards

There are at least two ways to acquire an accurate set of standard resistors. You may elect either to buy surplus 0.05- to 0.25-percent accuracy resistors or use certain characteristics of commercially available 5-percent resistors and mathematically calculate a given standard value. In effect, the second method relies on the manufacturing tolerances and statistical analysis of resistors in your junk box to measure the value of a standard candidate resistor.

The first technique is by far the preferable one, although the second can give acceptable results if enough patience is exercised. I picked up my "standards" at hamfests for next to nothing. Keep your eyes open. Many times you can bargain for a handful of precision resistors for a few dollars. Beware, however, of castoffs and damaged resistors! Before accepting the marked value as gospel, test it against several of the other values you acquired.

Testing the value of a prospective standard is not all that difficult, but it does take a little thought. Suppose the proposed standard R_U is marked 9380 ohms ± 1 percent. The value of the resistor could range between 9286.2 and 9473.8 ohms, assuming the resistor is within specifications. Suppose you are testing it against a 10,000-ohm 1-percent resistor, R_S, which can have an actual value from 9900 to 10,100 ohms. The maximum ratio these two resistors can have while remaining within the specified bounds is 10,100/9286.2 ohms or 1.0876 with a dial reading of 479.0. The minimum ratio is 1.0450 with a dial reading of 489.0. If a dial indication between these two limits is obtained, then your proposed standard resistor is likely within tolerance. This test should be performed several more times against other resistors to make certain that both the standard and original test resistors are not off by the same amount (2 percent) in the same direction. Using several other resistors to test the proposed standard reduces the probability of such an occurrence. After passing a number of such tests, it is probably safe to presume that your standard is within the marked tolerance. The procedure can be repeated for other standards, but keep in mind the backlash issue mentioned earlier.

The second procedure for testing a standard candidate involves an approach similar to the first, although it is more tedious. Basically, a number of like-tolerance, like-resistance values are compared against the proposed standard resistance with the potentiometer ratio being recorded for each comparison resistor. The results of the comparison resistor list is scanned for obvious "ringers" which are discarded from further analysis. A simple average of ratios is then taken. This ratio is then multiplied by the nominal value of the comparison resistors to determine the value of the standard.

Table 1 is an example showing a ratio comparison between a comparison resistor and a standard resistor. In this case both the standard and comparison resistors are rated at 10 kΩ and 5-percent tolerance. Reading number 2 is discarded because the ratio of two 5-percent resistors of the same nominal value must lie between 0.90476 and 1.1052 (0.95/1.05 and 1.05/0.95). Since only comparison no. 2 does not lie within this range, very likely it is the only one out of specification. Discarding this reading leaves us with five. The arithmetic total of readings is 5.1278, or an average of 1.0256 per reading. This means that R_T/R_S = 1.0256 or R_S = 9750 ohms.

I emphasize that the second approach to validating standards is more subject to error than the first. For best accuracy and minimum chance of error, a large number of comparisons should be made. Even more important, one should make certain that the comparison resistors are from different sources and not all from the same manufacturing lot. If this precaution is not taken, the standard resistor may be biased inasmuch as there could have been a production run in which the resistor values tended to be higher or lower, on average, than the nominal value. Amateurs who are ambitious enough to try this second technique should have a number of resistors acquired over the years. I do not mean to seem too negative on this approach. If you try it, use a little discretion. I have employed both procedures with equally acceptable results.

Table 1

A comparison between a standard resistor and a comparison resistor where both are rated at 10 kΩ with 5-percent tolerance.

Test	*Ratio of Comparison Resistor to Standard Resistor*
1	1.056
2	1.128 discard
3	0.9948
4	1.046
5	1.026
6	1.005
.	.
.	.
.	.
.	.

Conclusion

The technique described to measure resistors has proved quite satisfactory. First of all, when measuring 1-percent junk-box resistors, I consistently find that I can measure them accurately. Furthermore, the ssb phasing receiver has been completed and it works well. Sideband suppression, which is significantly affected by phase-shift network inaccuracies, appears adequate. [QST]

References

[1]Shubert, "Solid-State Phasing-type SSB Communications Receiver," *Ham Radio*, August 1973, p. 6.
[2]Shubert, "Phasing-type Single-Sideband Transmitter," *Ham Radio*, June 1975, p. 8.

A Remotely Controlled Antenna-Matching Network

Want to get rid of feed-line losses caused by antenna mismatches? Put the matching network right at the antenna feed point. Here's how!

By Herbert Drake, Jr.,* N6QE

You can't dispute the benefits of full-size, resonant antenna systems as part of a complete amateur station. But there are many amateurs who can only consider small, highly reactive random arrays or verticals because of real-estate limitations. Presented here is an approach that makes such types of antennas more acceptable in terms of overall station efficiency. This is accomplished by placing an antenna-matching network *right at the feed point* and controlling it remotely to provide convenient band-changing capabilities without compromise.

The basic theory applied is that any antenna, be it vertical, horizontal or a combination of both, can be a satisfactory radiator provided it is properly matched in a low-loss manner. In other words, all of the transmitted power must be radiated if there are no mismatched feed lines and other lossy elements to convert this power into heat. The energy may not go in the chosen direction, but at least it will be radiated!

The antenna-matching network may be placed anywhere between the transmitter and the antenna if the intention is simply to match the transmitter to the load. It is assumed that the transmitter output tank is capable of handling the impedance of the line connected between the matching network and the transmitter. In this vein, many older transmitter pi-network output tanks were sufficiently flexible in matching range to dispense with the need for external matching network. The reason for locating the network at the antenna feed point is to eliminate transmission-line losses while matching the wide range of impedances that result from the use of random-length antennas operated as multiband radiators. In such cases, the VSWR on a coaxial feed line becomes so severe that high losses are the result. Of course, it is possible to use open-wire feeders with a matching network at the operating position, but often the aesthetic appearance and inconveniences resulting from this approach are unsatisfactory. In industrial and military hf radio installations, remotely controlled matching networks are commonplace. Some of them contain servos and phase detectors that can automatically adjust the matching network within seconds.

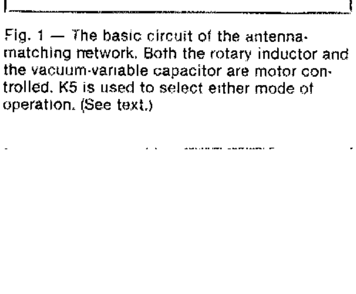


Fig. 1 — The basic circuit of the antenna-matching network. Both the rotary inductor and the vacuum-variable capacitor are motor controlled. K5 is used to select either mode of operation. (See text.)

The system presented here contains many features that are offered for consideration and not necessarily for exact duplication. This antenna-matching network has performed reliably since installation. A 60-foot (18.3-m) horizontal random-length antenna about five feet (1.5 m) above the surface of the roof was used at the time. The matching network components employed are capable of operation at a sustained 1-kW input level during RTTY operation. Only two motorized adjustments (L and C) are required and both of these are metered at the control point to permit coarse tuning from tabulated settings. The control switches are duplicated inside the remote unit so that maintenance may be accomplished without the need for assistance.

The Circuit

The circuit of the antenna-matching network is shown in Fig. 1. Successful operation depends upon the use of components displaying a wide tuning range, such as the 7- to 1000-pF vacuum-variable capacitor. Fig. 2 shows the range of complex impedances that may be matched at a frequency of 3.5 MHz to a source requiring a 50-ohm resistive load. The two modes are relay-selected. Fig. 2B shows the detail near the origin. Fig. 3A presents the same data for 29 MHz. It is assumed that almost all random-length antenna impedances will fall within the areas

*40 Pikes Peak Dr., San Rafael, CA 94903

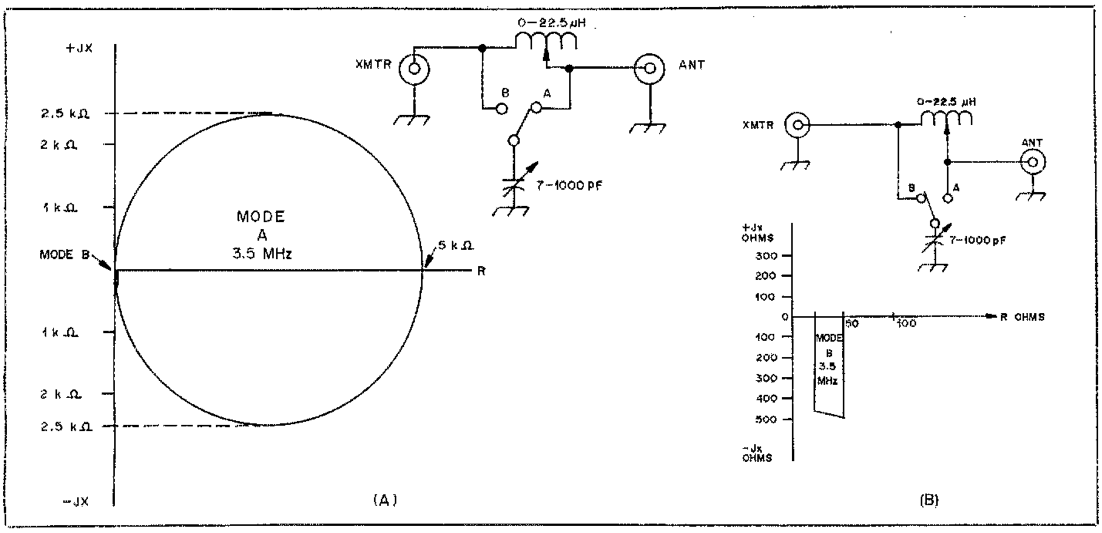


Fig. 2 — Diagram showing the 3.5-MHz complex impedance matching range. At A, the whole plot is shown, while at B, the area near the origin is shown in greater detail.

representative of one of the two modes of operation at any given frequency. However, should an "unmatchable" impedance be presented, a small amount of pruning of the antenna would no doubt bring the feed-point impedance into range of the matching network.

Fig. 4 shows the schematic for the remote box. A dual-field, series-wound 24-V dc motor with a built-in gear train was chosen to drive the rotary inductor at approximately 120 rpm. Its operation is controlled by K1, K2 and two limit switches (S1 and S2). A 27-V dc permanent-magnet field motor and associated limit switches were already mounted on the variable capacitor assembly and it was only necessary to add a potentiometer and suitable gearing for the logging-meter feature. Note that this motor is driven by a potential of only 10 V in order to slow it down. Both control relays are wired so that the accidental simultaneous operation of a clockwise and counter-clockwise relay will not result in a short circuit.

The logging potentiometer associated with the inductor is operated with a dial cord and pulley arrangement. A stand-off insulator is mounted on the sliding tap of

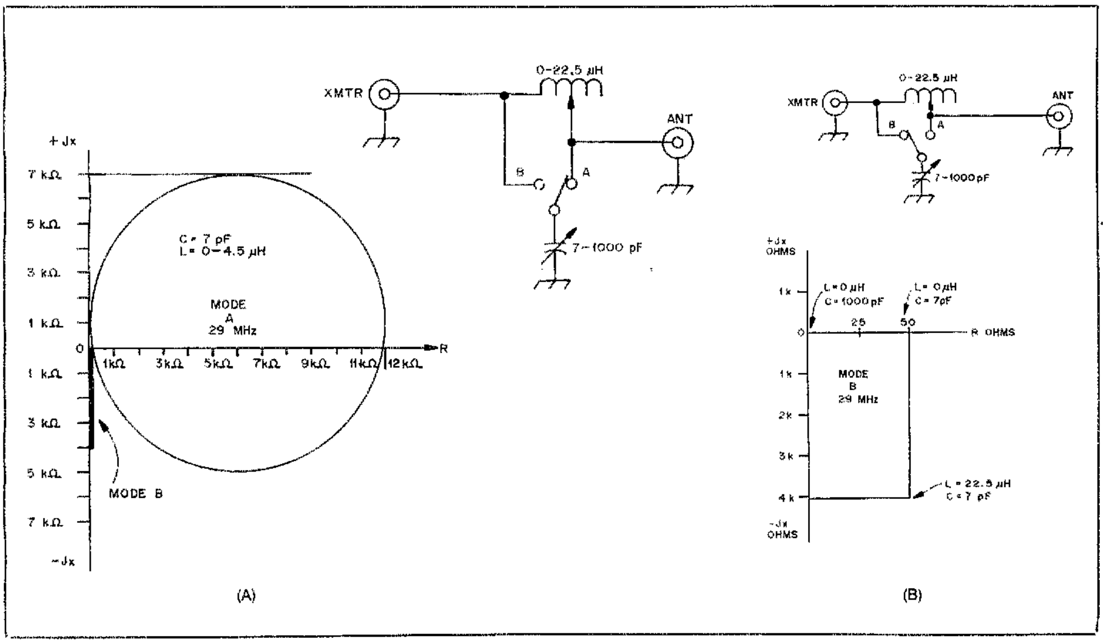


Fig. 3 — The 29-MHz complex impedance matching range diagram. The entire plot is at A, with detail near the origin shown at B.

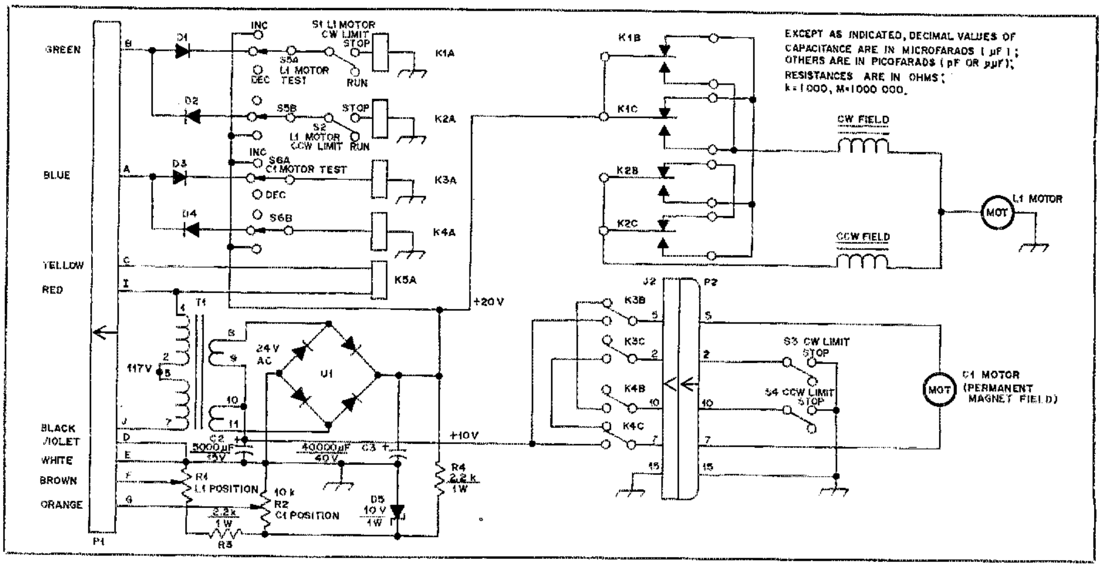


Fig. 4 — The circuitry for the remotely controlled antenna-matching network. The power supply is also located remotely to avoid losses in the control cable because of the heavy current requirements of the low-voltage motors. See separate parts list for component specifications.

Parts List

C1 — Jennings UCSL-1000 vacuum variable capacitor.
C2 — 5000-μF, 15-V electrolytic.
C3 — 40,000-μF, 40-V electrolytic.
C4, C5 — 1000-μF, 50-V electrolytic.
D1-D4 — 1N4001.
D5 — Zener diode, 10 V, 1 W.
D6-D9 — Motorola MR501, 100 PIV, 3 A.
J1 — TRW/Cinch S310AB.
J2 — Part of P2 assembly.
K1-K4 — Knight KN105-2C-24D, dpdt, 24 V dc.
K5 — Hart-Advance AT/2C/115VA, dpdt, 115 V ac.
L1 — E. F. Johnson 226-1-4 rotary inductor.
M1, M2 — 0-1 mA.
P1 — Amphenol 3102A-18-1P, 3106A-18-S, and 3057-10A.
P2 — Cinch DB-15-S.
P3 — 3-wire ac plug.
R1 — 5-kΩ potentiometer.
R2 — 10-kΩ potentiometer.
R3, R4 — 2.2 kΩ, 1 W.
S1-S4 — Spst Microswitches.
S5, S6 — 2-pole, 3-position rotary.
S7, S8 — Spdt, Centralab 1455.
S9, S10 — Single pole, 3-position rotary.
T1 — Stancor RT-202.
T2 — Stancor TP-2.
U1 — Diode bridge, Motorola MDA 970-2, 100 PIV, 4 A.

the inductor and serves two purposes; it activates the limit switches and drives the dial cord and L potentiometer. The limit switches for the L motor were placed in the coil circuits of relays K1 and K2 rather than in the motor-field leads. This was done to protect the switch contacts from the high current present in the motor fields. Both the capacitor and inductor logging potentiometers are adjusted mechanically so that the wipers are at ground potential with either C or L at minimum. The wipers travel close to the end of their rotation with either of the units at their maximum positions.

The power supply for the motors, test switches and meter circuits are located in the remote box in order to minimize power losses in the control cable. Although the inductor motor draws several amperes, the primary current of the power transformer is considerably less, resulting in a lower control-cable voltage drop. The Zener diode in the meter supply and the separate ground return ensure that the meter readings do not fluctuate with line-voltage variations during the operation of either or both tuning motors.

Fig. 5 is a sketch of the component

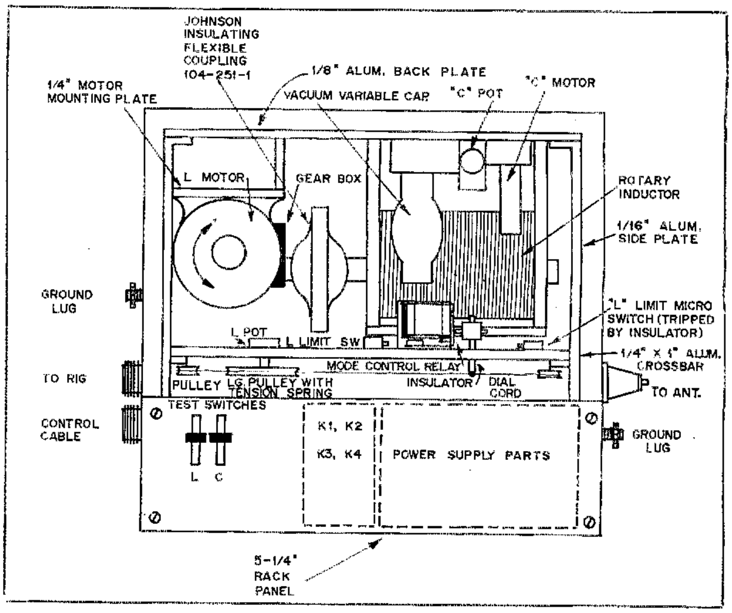


Fig. 5 — A sketch of the antenna-matching network box layout. The sketch is meant to be used as a guideline and not necessarily drawn for exact duplication.

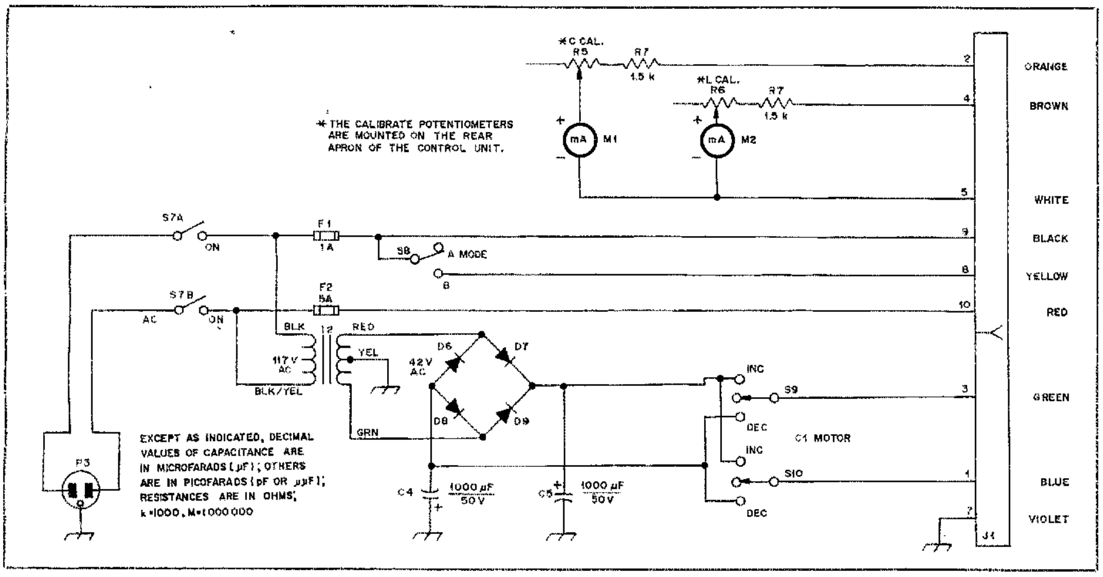


Fig. 6 — Schematic of the operating position control unit. The calibration controls are adjusted according to the text. The switches, S4 and S5, are mounted beneath their associated meters. See separate parts list for component specifications.

location within the remote box. More exact data are omitted since a builder would probably use different motors and alternative components, depending upon sources of supply.[1] Sheet aluminum and 1/4 × 1-inch (6 × 25-mm) aluminum bar stock were employed in construction. A surplus aluminum box with a well-sealed "suitcase" type of removable top was selected. Components were mounted to an independent frame rather than to the box itself in order to obtain good mechanical stability and to avoid drilling too many holes in the outer box. All holes that were drilled for screws or connectors were carefully waterproofed by means of rubber gasketing material, including the SO-239 chassis connector. The Cinch DB-15-S connector specified for P1 and J1 was the fitting required to mate with the surplus vacuum capacitor/motor assembly; it was not my choice. The Amphenol numbers listed for P1 represent one of those "military" connectors ordered by specifying the shell, clamp, insert, boot, etc. My concern was that the connector be waterproof. Finally, an ample supply of blue/pink indicating silica-gel desiccant was placed in the box. This gel must be renewed periodically in the oven because of the accumulation of moisture.

Table 1

Frequency (MHz)	*L*	*C*	*Mode*
3.525	46	91	A
3.600	42	86	A
3.700	37	83	A
3.800	30	76	A
3.900	11	73	A
4.000	22	100	A
7.025	68	39	B
7.300	61	40	B
14.025	54	50	A
14.350	57	49	A
21.025	16	40	B
21.450	17	39	B
28.000	17	42	A
29.700	5	42	A

Operation

The control circuitry mounted near the station equipment is shown in Fig. 6. The two control switches are mounted horizontally beneath their associated meters. Operating either switch left or right results in the meter indicating the same direction. The meter calibration potentiometers are set so that the meters read full scale when their motors operate the appropriate limit switch.

The operation of the matching network is simple once the tasks of "homing in" the L and C values, logging the meter readings and noting the mode settings are accomplished. I have found that a table (such as that shown in Table 1) posted near the rig is helpful. Additional columns can be provided to show the tune and load control settings of the transmitter. After setting the inductance and capacitance in accordance with the logging meters, a VSWR indicator can be used to aid in nulling the residual reflected reading by alternately operating the L and C switches. Happy matching! QST

[1]Possible sources of supply for components similar to those used by the author are Radiokit, Box 429, Hollis, NH 03049; Multronics, Inc., 9005 Red Branch Rd., Columbia, MD 21045; Fair Radio Sales, Box 1105, Lima, OH 45802, Herbach and Rademan, Inc., 401 East Erie Ave., Philadelphia, PA 19134; Newark Electronics, 112 Cottage Grove Rd., Bloomfield, CT 06002. (Newark has coast-to-coast dealerships.) For relays: Allied Electronics, 845 Woburn St., Wilmington, MA 01887 (Allied has coast-to-coast dealerships; the relays are listed in the *Engineering Manual and Purchasing Guide, No. 790*).

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The Microprocessor and Slow-Scan Television

Put your 6800, 8080, or whatever microprocessor you may own, to work. It can become the heart of a video processing system for reception and transmission of SSTV pictures.

By Paul M. Jessop,* G8KGV

Slow-scan television (SSTV) is one of the more interesting modes available to the radio amateur. But at present, much equipment is either a bit primitive, homemade using long-persistence phosphor tubes, or else very expensive commercial, using slow-to-fast conversion. These latter use dynamic shift registers which are now more expensive than the more modern equivalent, the random access memory (RAM). They are also more temperamental and require awkward high-level clock drives.

This article describes how the owner of a microprocessor with a reasonable amount of memory can decode, display and process SSTV signals received off the air or from tape and also send user-generated pictures. The term "reasonable" here means that 8-K bytes of memory are required for picture storage and there is an additional software overhead of perhaps 1-K on top of this. Another requirement is a display device capable of displaying a matrix of 128 × 128 dots in 16 tones. This must use direct memory access (DMA) and can derive many of the signals it requires from an existing video display. Such a device is not, to the author's knowledge, commercially available.

To survey quickly the SSTV technique, a picture is sent by frequency modulating an audio subcarrier according to the intensity at that point in the picture. This subcarrier is fed to the transmitter which is normally operated in the ssb mode, but fm is not unknown and has advantages for short-range work. Sync pulses are added at the end of each line (5 ms) and frame (30 ms). The lines are scanned at about 16 lines per second and there are about 128 lines in a frame. A complete frame thus takes about eight seconds. The frequencies used are shown in Table 1.

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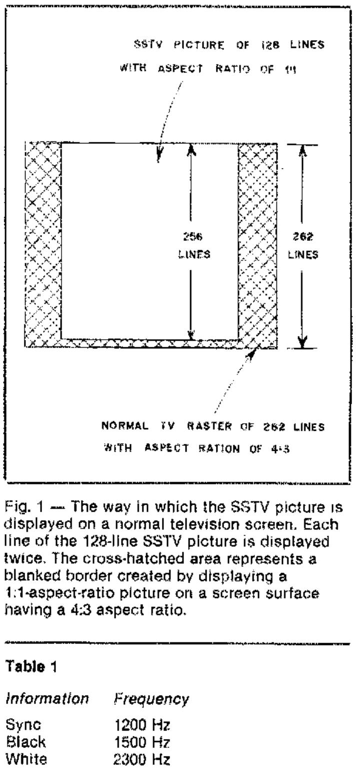


Fig. 1 — The way in which the SSTV picture is displayed on a normal television screen. Each line of the 128-line SSTV picture is displayed twice. The cross-hatched area represents a blanked border created by displaying a 1:1-aspect-ratio picture on a screen surface having a 4:3 aspect ratio.

Table 1

Information	*Frequency*
Sync	1200 Hz
Black	1500 Hz
White	2300 Hz

In the system described here, each line is divided into 128 dots (pixels), each of which can take one of 16 values of intensity, white through black. Each pixel thus occupies 4 bits of information (4 bits represent 16 discrete values) and there are 128 × 128 = 16,384 pixels. Thus 65,536 or 64 K (1 K = 1024) bits are required to represent the whole picture. Since most microprocessors work in terms of 8 bits (1 byte), the memory requirement is for 64 K ÷ 8 = 8-K bytes, a standard size of memory board.

To turn now to the hardware required, each of the dots must be displayed on a domestic television. A proposed scheme is shown in Fig. 1. A noninterlaced scan of 262 lines is produced, with each line of the SSTV picture duplicated. This leaves a small gap at the bottom and a rather larger gap at either side. The latter occurs because the SSTV picture is square whereas the television screen is rectangular. The scan rate of the domestic television is 15.75 kHz and therefore the time for one scan is 64 μs. Some of this time is used by the line sync and blanking periods and only 75 percent of the image width is used by the SSTV picture. Therefore, the time in which the 128 pixels making up the SSTV line are shown is about 42 μs. Hence the time between consecutive pixels is 330 ns, but this does *not* mean that the memory must have an access time of less than 330 ns. This is because of a trick in the way the information is stored; more on this later. The actual required memory access time is 600 ns or less. This is a normal speed since a microprocesor running at 1 MHz (e.g., 6800, 8080) needs an access time of 575 ns.

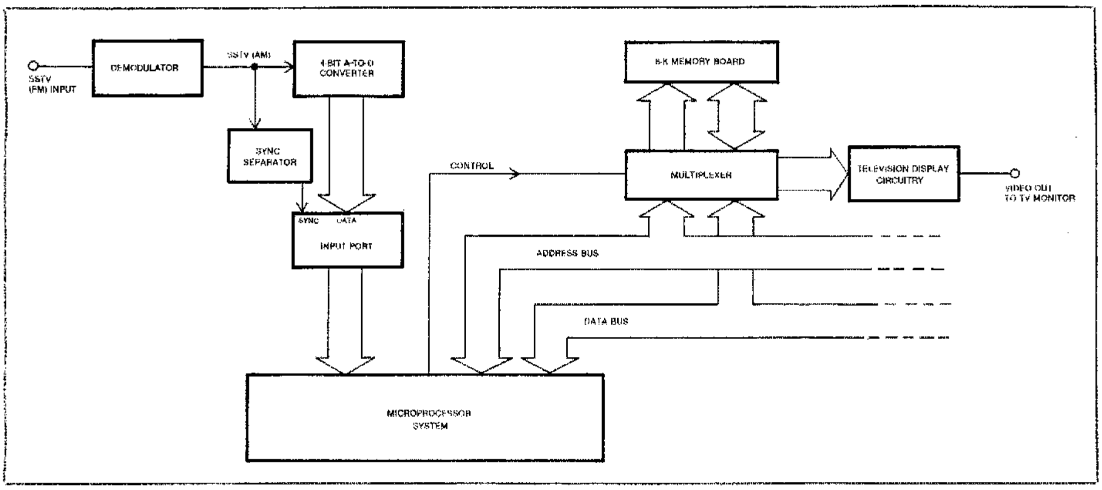
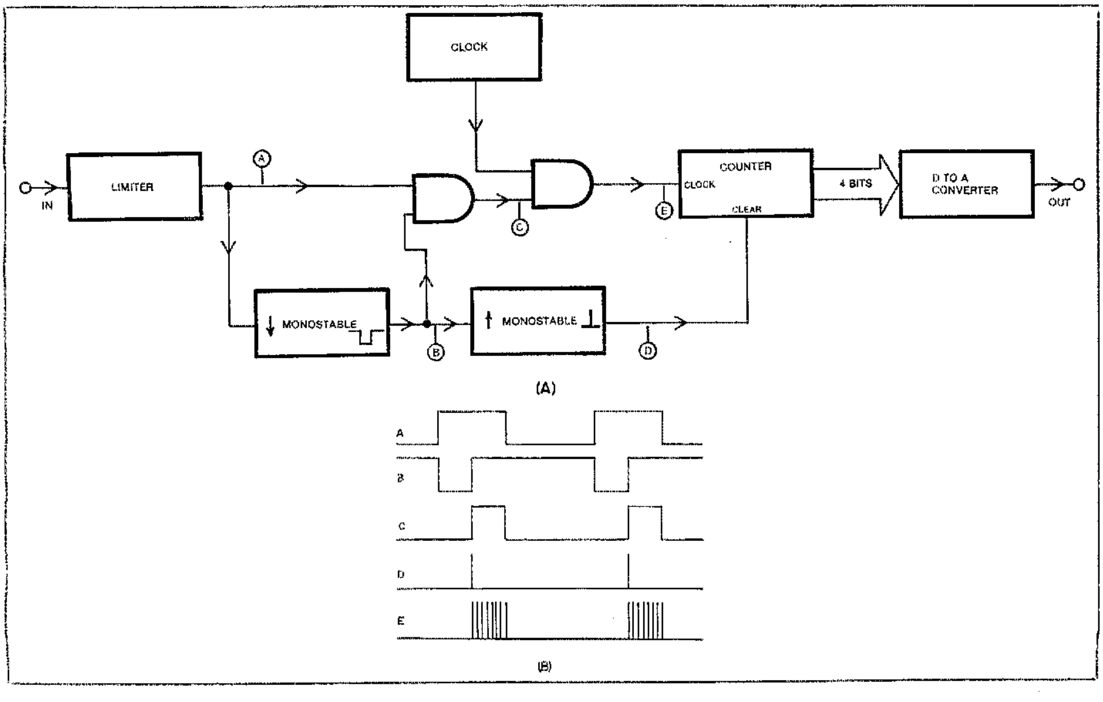


Fig. 2 — Block diagram of the complete microprocessor-based SSTV slow- to fast-scan converter.

Thus standard memory parts can be used, a major factor since the assembly of the memory could be a headache unless a ready-made unit or at least an etched circuit board is available.

The overall system block diagram is shown in Fig. 2. The large block labeled "microprocessor system" covers a multitude of sins. Any microprocessor will do and the choice is governed largely by availability, since it is unlikely that anyone should consider buying a microprocessor solely for use on SSTV and its suitability for other tasks would be a primary consideration. There are many circuits for the SSTV demodulator and this choice is clearly with the builder, who may well already have a unit available. It is possible to perform the demodulating function in software but this is not as simple as it might at first seem. A hardware system which in essence is very similar is shown in Fig. 3. The principle is to count how much longer the pulse length is than a pulse representing white picture information (1/2300 Hz or approximately 435 ms). While the output of the counter could be fed to the microprocessor or the hardware could be emulated in software, there is a major difficulty. The system

Fig. 3 — Block diagram of a circuit to demodulate incoming SSTV audio signals for the microprocessor. At B waveforms for corresponding points indicated at A are shown. The duration of the incoming-waveform pulse (A) is greater than that for white picture information (B). The principle is to count how much longer, represented by the number of spikes in waveform E.



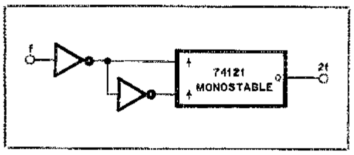


Fig. 4 — A technique for frequency doubling with a 74121 monostable multivibrator. (See text.)

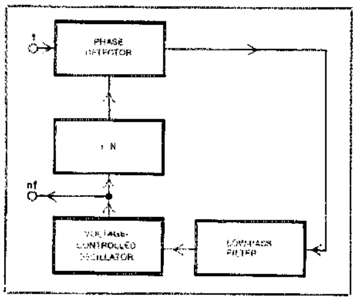


Fig. 5 — Frequency multiplication "by division," using a phase-locked loop. (See text.)

requires 128 samples per line but in a line of black, there are less than 100 cycles (1500-Hz tone for approximately 1/16 second). Thus to utilize this scheme, either some complicated software or modification to the hardware is required. One way around this is to multiply the frequency of the signal either directly (Fig. 4) or "by division" (Fig. 5). Frequency doubling still gives less than 200 cycles per line so some fairly sophisticated software is yet called for. If this method of demodulation really must be used, the easiest way is to time the pulse in hardware, convert to an analog signal and smooth this. The signal can then be converted into a digital form and sampled by the microprocessor as required.

The multiplexer of Fig. 2 serves to share the 8-K RAM between the microprocessor and the TV display generator (TVDG). The memory is normally connected to the TVDG but when the microprocessor attempts a read or write on the memory block, the multiplexers switch the control to the main buses. Thus the microprocessor has priority in accessing the memory; this could cause glitches on the screen unless the software were so written that all transfers take place during the frame blanking period. It is generally found, though, that with this type of circuitry, the glitches are not objectionable, and of course only occur when a signal is actually being received.

By far the most complicated part of the circuitry is the TVDG. However, no new boundaries are being broken as it bears much resemblance to a normal video display teminal. If one of these is already in use, many of the signals required by the TVDG can be derived from it (sync and blanking pulses). A more detailed block diagram of this part of the circuit appears in Fig. 6. Its operation is perhaps best understood if the actions taken immediately after a frame-sync pulse are examined. This pulse clears the row and column counters which keep track of which cell is being accessed. The next line-sync (LS) pulse triggers a delay circuit which defines where the left edge of the picture falls on the screen (see Fig. 1). The delayed pulse gates the master clock which controls the rate at which the pixels occur across the screen, i.e., the width of the picture. This is about 3 MHz. This pulse train feeds the column counter which is a 7-bit binary divider. The most significant 6 bits act to address the 6 least significant bits of the RAM. And the least significant bit of the counter is fed to a data selector which effectively multiplexes the 8-bit memory word onto 4 lines. As mentioned earlier, a trick in addressing the memory allows the use of slower (and therefore cheaper) RAM. This is that trick, but it has another advantage up its sleeve. Since the data are stored in 8-bit-wide bytes, standard memory boards can be used. Two consecutive pixels are stored in the same byte so when they are accessed sequentially, the memory need only be referenced once. The access time requirement of the memory is therefore halved. The data selector has the function of separating the two pixels.

A carry or overflow from the column counter has three effects. First, it disables the clock gate so that no further counting takes place until it is cleared by the next LS pulse. Second, it blanks the video

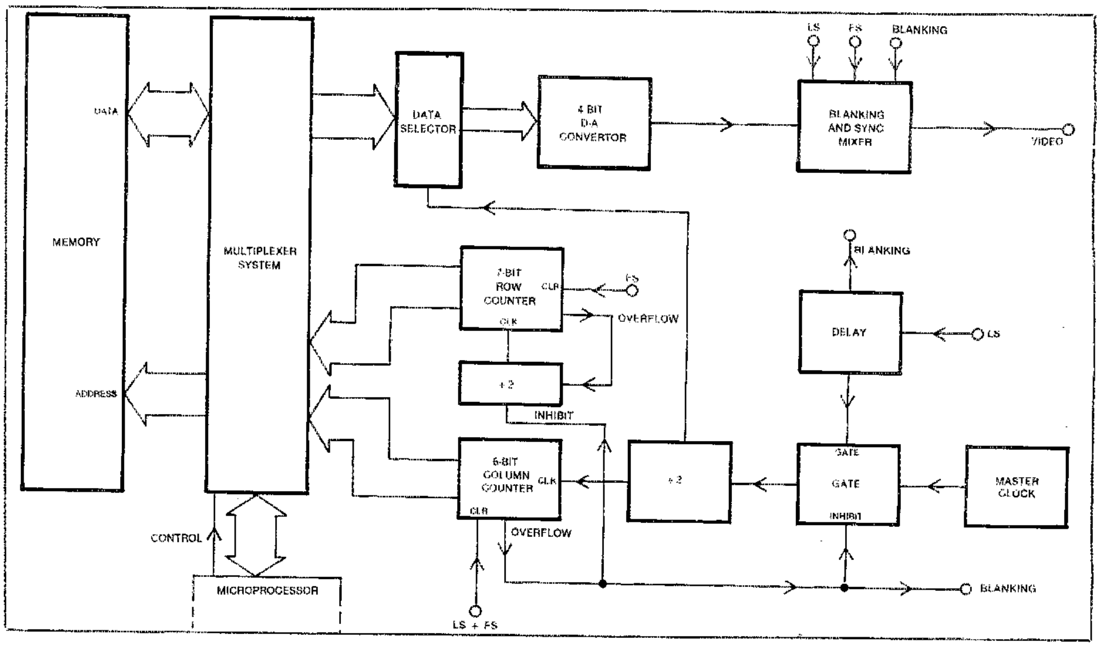


Fig. 6 — Detailed block diagram of the television display generator (TVDG). Operation of the circuit is discussed in the text. The 6-bit column counter and its preceding binary divider form a 7-bit counter.

output so that spurious picture information is suppressed. And third, it clocks the row counter. Since each row of the SSTV picture is to be displayed on two consecutive lines of the video output, a divide-by-2 flip-flop is inserted between the column and row counters, together with a gate which prevents further counting.

The output of the data selector feeds a D-A converter which generates 16 discrete analog levels. This, in turn, feeds a blanking/sync mixer, for which many designs exist. This concludes the details of the main features, at least of the hardware side. We now turn to the software required to use the hardware to the best advantage.

Software Techniques

The objective of the software controlling the system is to receive the signal, store it in the memory of the display generator and also to process the data to make the picture more intelligible. A basic routine for reading the SSTV information from the input port and writing it to the picture memory is shown in Fig. 7. If followed through, the process is self-explanatory but one thing should be noted, namely the difference between the two types of rectangular (process) boxes. The boxes with single sides represent basic operations such as can be performed by the microprocessor in one or two instructions but the double-sided boxes represent more complicated processes typically represented in the program by a subroutine. It should be noted that this is by no means an optimum algorithm but was designed merely to illustrate the basic principles involved in transferring the data from input port to memory. Other "bells and whistles" are within the grasp of the user merely by modifying the program. Some additions will be examined here, namely buffered read, 9-cell averaging and frame averaging.

Buffered Read

It was mentioned earlier that if the TVDG and the microprocessor attempt to access the 8-K memory block at the same time, the microprocessor will win, possibly causing a spurious response on the screen. This can be avoided if, instead of writing received data direct to the TVDG memory, it is stored in a buffer and transferred to the TVDG memory when the TV display is blanked. There are four FSTV half-frames during each SSTV line and thus there are four vertical blanking periods during which the transfer may be made. These last rather more than 1 millisecond so at least 4 ms is available to transfer 128 four-bit data items which can in fact be treated as 64 eight-bit bytes.

In order to carry out this task, the microprocessor must clearly know when the display is blanked and another input line would be required, carrying the FSTV frame blanking signal. However, the pro-

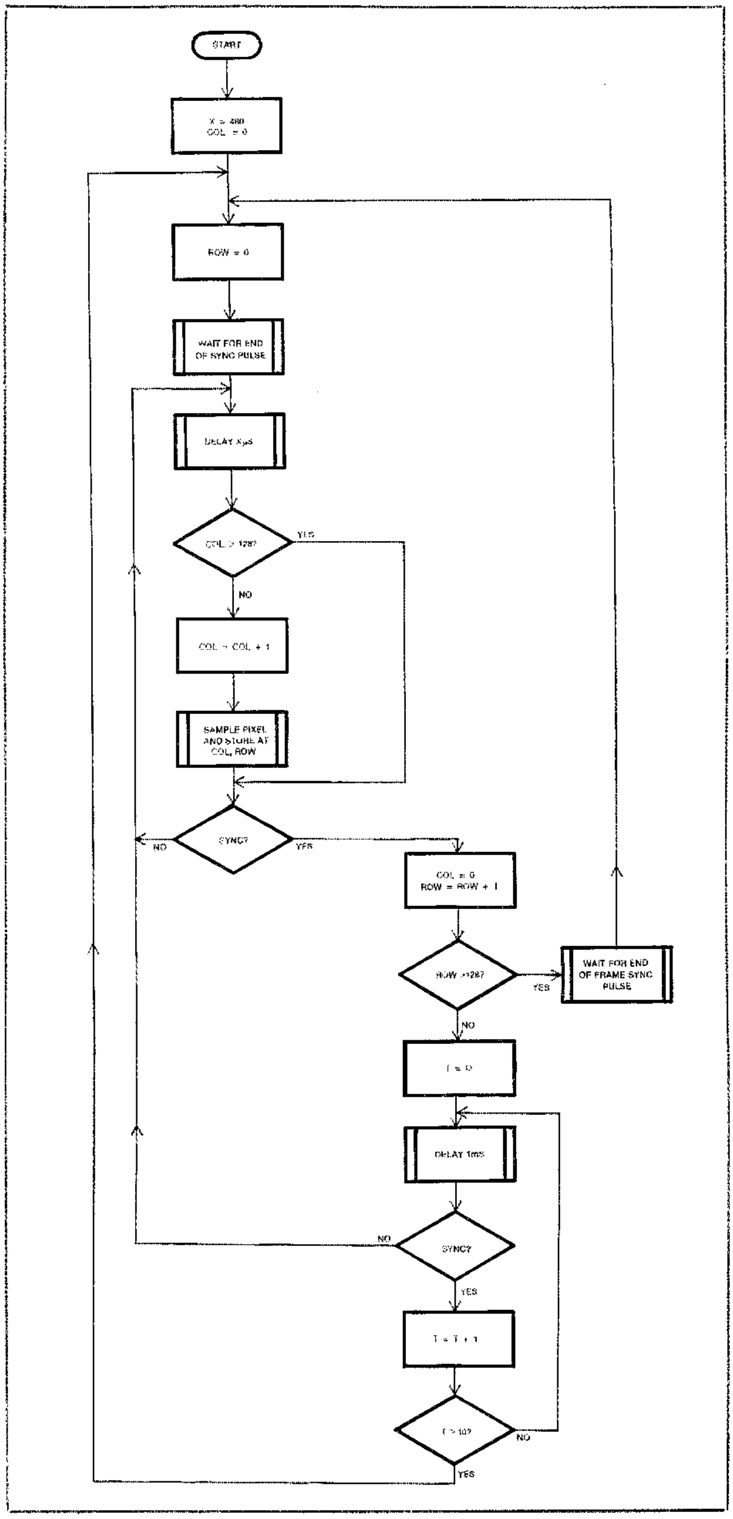


Fig. 7 — A routine for copying SSTV video input into the TVDG memory.

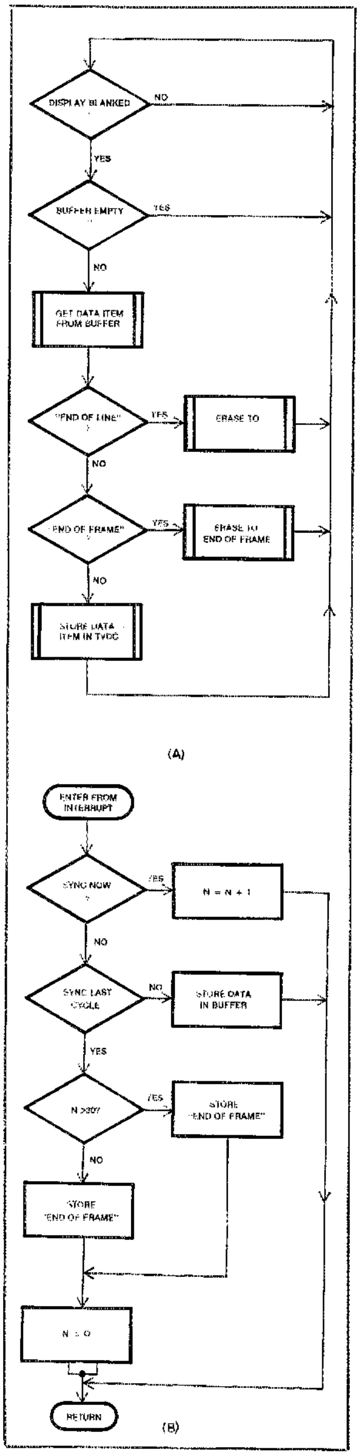


Fig. 8 — Flow charts for a buffered read technique. At A, the main routine for an interrupt-driven system. At B, the interrupt-handling routine.

cess of unloading the buffer must not be allowed to interfere with the timing of the input sampling or the timing of the SSTV sync pulses. These difficulties mean that there is a strong argument for an interrupt-driven system. This is a system where the microprocessor has a "foreground" task of unloading a buffer into the TVDG memory and a "background" task of sampling the incoming data and writing it to the buffer when an interrupt occurs, i.e., every 480 µs (the duration of each pixel). This interrupting signal can be derived from a crystal-controlled clock. Flow charts for performing these functions are shown in Fig. 8. The effect of this process is to have two tasks for the microprocessor which appear to be happening at the same time, but in truth, they happen sequentially but very quickly. The buffer requires some comment since the normal type of last-in-first-out device is inadequate. This is because the buffer is required to access both ends of data. The type of buffer needed is a circular buffer, such as is shown in Fig. 9. This sort of buffer occupies a finite area of memory, and both ends are in fact accessible. These are addressed by pointers which are incremented after each read or write operation and reset to the beginning of the buffer when they exceed the highest address of buffer area. Thus, although the buffer is implemented in linear memory, it appears to the program to be circular. The length of the buffer is clearly a matter for some thought and is dependent on several factors, for instance the processor speed and the time taken in responding to an interrupt request in reading the data on the input port and writing it to the buffer. Under any circumstances, 64 bytes should suffice and this can probably be significantly reduced.

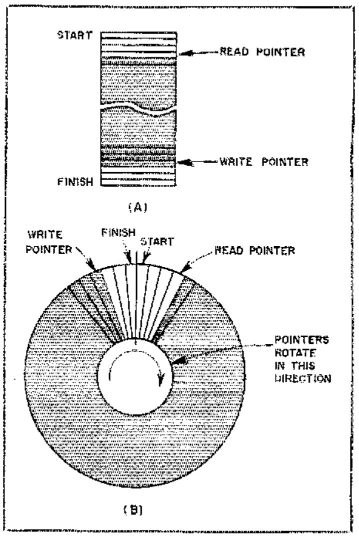


Fig. 9 — The circular buffer as it physically exists in memory (A) and as it appears to the program (B). The shaded areas represent the amount of buffer actually in use. This can contract until the two pointers are adjacent or expand until the same situation occurs, but they must not pass.

Nine-Cell Averaging

When noise is present on an audio signal, it is possible to reduce this by passing the signal through a low-pass filter. The same is true of the SSTV video signal; unwanted high-frequency components appear as snow on the picture and reduce its readability. These unwanted components can be removed by a normal RC or active filter but they can also be reduced by the use of a technique best known to statisticians, the moving average. In statistics, the fluctuations in a set of results can be reduced by replacing each data item by the average of those on either side of it and the item itself. The result is that the new data show the trend of the results without being obscured by individual variations. The same technique can be applied to SSTV processing and is very easy to operate under the control of a microprocessor.

Because an SSTV picture is a two-dimensional medium, the averaging is extended from three data items to nine cells, that under consideration and the eight surrounding it. However, despite the apparent simplicity of the scheme, there are two problems which arise. The first is that when the cell in question is received, that following it and those on the next line have not yet been received and are forward references. The other is that unless two separate blocks of memory are available, it is imperative to carry out the averaging process within one block, with the result that it is inevitable that already-processed data will be used to influence the new value of another cell. This means that the averaging process is being extended beyond the 9-cell block and while this may not be detrimental, it is not what was wanted. The only real answer to the second problem is to install another memory block but the first may be readily overcome by a software technique. This is as follows: When the bottom right cell of the 9-cell square is received, the square is complete and the averaging process may take place. The values of the intensity in all nine cells are added together and the sum is divided by nine (this is not easy, but there are alternatives; these will be discussed in due course) and the result is written back into the center cell. This is quite easy to achieve since it is the value in the list, 129 cells back from the current cell. The division by nine still remains as a major stumbling block, however, since it cannot be performed quickly by the microprocessor. The only numbers which are easy to divide by are powers of two so here 16 is suitable. The division can now take place by shifting the result in binary

1	2	1
2	4	2
1	2	1

Fig. 10 — Weightings for 9-cell averaging for convenient division by 16.

by four places to the right. As it happens, the necessity to divide by 16 provides another advantage, that is that the average value can be weighted toward the center cell. This means that instead of merely adding all the cells together, some are added in more than once and the result is divided by the total number of additions. Now the weightings must add to 16 and be larger toward the center of the square so the result is biased toward the center cell. A suggested plan is shown in Fig. 10. In practice the numbers would not be individually added a number of times but a process akin to Fig. 11 would be carried out. This achieves the same result but uses far less memory space to do it. Clearly, there are many possible weightings; each experimenter can easily determine the best arrangement.

Frame Averaging

This technique is very similar in essence to the averaging method described above. The averaging is not carried out within the same frame, however, but between successive frames. When a pixel is received, instead of storing it at its memory location, it is added to the previous value and the sum is divided by two. This is then returned to the previous location. The result is that the display shows the average of the frame just received and the previous frame. The previous frame was made up of that frame and the one previous to that, however, which was in turn made up of two frames. Thus each new frame is dependent upon all the previous frames, with the contribution made by each successive frame halving. Thus the contribution soon becomes so small that it cannot be resolved by the grey-scale of the TVDG. This means that when the received picture changes, the old picture is soon swamped by the new picture. The effect of individual noise pulses is much reduced, however.

Transmission

To turn now to the generation for transmission of SSTV signals, it turns out that the microprocessor is very versatile in the functions it is able to perform. Keyboards which allow the user to type to an internal memory have been available for a considerable time. The stored information is then sent in an SSTV picture by use of a dot-matrix character generator. This generator was originally made from a diode matrix but dedicated ICs are now available to perform the same function more efficiently and with much less inconvenience to the constructor. Although a microprocessor can easily perform the function of an SSTV typewriter, the designer has a few decisions to make about the way this works.

The first decision is in the way in which the character generator is implemented. The obvious way is to include the data for the generator in the software which runs the SSTV system, but this is wasteful of memory space and there is an easier solution. This is to "hang" a character-generator IC on the microprocessor bus. This IC is much cheaper than the equivalent amount of RAM because it is mass produced and it need not be loaded from paper tape each time the system is initialized. The older type of character-generator ICs is easiest to interface since it does not contain the shift registers which make the new ones so easy to use in a television typewriter. The second design decision is whether the transmitted picture is generated directly from alphanumeric data stored in the computer memory or is first translated into the actual intensities for each point in the frame, stored in the TVDG memory and then transmitted straight from the memory. The second method has the advantage that any transmitted data are automatically displayed but if it is desired only to transmit alphanumeric information,

(1)	V = 0	Clear V
(2)	V = V + Center	—
(3)	V = V × 2	Shift left
(4)	V = V + Edges	—
(5)	V = V × 2	Shift left
(6)	V = V + Corners	—
(7)	V = V ÷ 16	Shift right four times

Fig. 11 — A procedure to generate the weightings shown in Fig. 10. At the end of this procedure, the variable V contains the averaged value.

either method is quite suitable. If, however, it is also desired to transmit pictorial or diagramatic information, the second method is mandatory, and, of course, some method of creating the picture in the first place is required. This can be based on a cursor, moved about the screen depositing bright cells as it goes. This is slow but very accurate results are obtained. A much quicker alternative is a light pen, but this can produce rather ragged results and use very complicated hardware.

Other Applications

One clear candidate for microprocessor use in SSTV is in the generation of animated sequences. Here, memory space can be saved by storing only changes to the frame. Or the microprocessor can be used to produce tapes which can be transmitted later. This latter is possibly more practical and shows that high technology is not necessarily the best way to solve a problem. An area where some research is required in the amateur field is in the use of random sampling to reduce the bandwidth of a signal. The principle is that instead of sending a row of a picture at a time, one dot from each row, chosen by a pseudo-random algorithm, is sent and the receiving equipment, by the use of the same algorithm, can reconstruct the picture and display. Clearly, the use of microprocessors makes this much easier; it may even be possible to transmit actual animated sequences within the confines of a voice band by the use of this technique.

The experimenter with a microprocessor at his command can contribute much in development work. Complexity is not an economic factor because all the work is done in software. If the individual has almost unlimited time at his disposal, he can perform feats which would not be considered economical in industry. QST

Strays

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☐ The evaluation forms that we have been sending out with film, slides and tapes are considered first class mail when filled in. As a result of this, we will not be using this form any longer. The return label has been changed to include an area to comment on needed repairs. The Post Office may require extra postage on the return labels. — *Donna McManus, Film Librarian, Club and Training Dept.*

WELDING? WATCH IT

☐ There is the same amount of force in an exploding butane lighter as in three sticks of dynamite. Two Union Pacific Railroad employees experienced tragic accidents when butane lighters exploded as the result of welding accidents. A welding spark can come in contact with the lighter and burn through, exposing the fluid, resulting in an explosion. Remember, safety is everybody's business. — *Dial Radio Club, Middletown, OH, Newsletter*

Hints and Kinks from Abroad

Edited by Doug DeMaw,* W1FB

Pat Hawker's monthly column in Radio Communications, *"Technical Topics," contains some really great data. Here are a few of the gems from past issues of the Radio Society of Great Britain (RSGB) journal.*

MOSFET SSB Adaptor

The March 1978 "Technical Topics" column included an item from Lionel Sear, G3PPT, about a combined product detector/oscillator arrangement that he had found suitable for use in a direct-conversion receiver. He explained that this had stemmed from an item in *Elektor* (combined July/August 1977 issue, page 72) where a 455-kHz version formed the basis of a MOSFET ssb adaptor intended for use with any hf receivers not already fitted with a product detector or BFO. The original circuit is shown in Fig. 1 although, of course, it could be adapted for use at other intermediate frequencies.

It is noted in *Elektor* that self-oscillating product detectors tend to force the oscillator into resonance with the incoming signal, but that the dual-gate MOSFET appears to be reasonably free of this vice. However, by increasing the signal applied to the adaptor, this forced resonance effect can be used deliberately to achieve synchronous demodulation of a-m signals over about a ± 1-kHz range. The oscillator arrangement is based on the Clapp configuration.

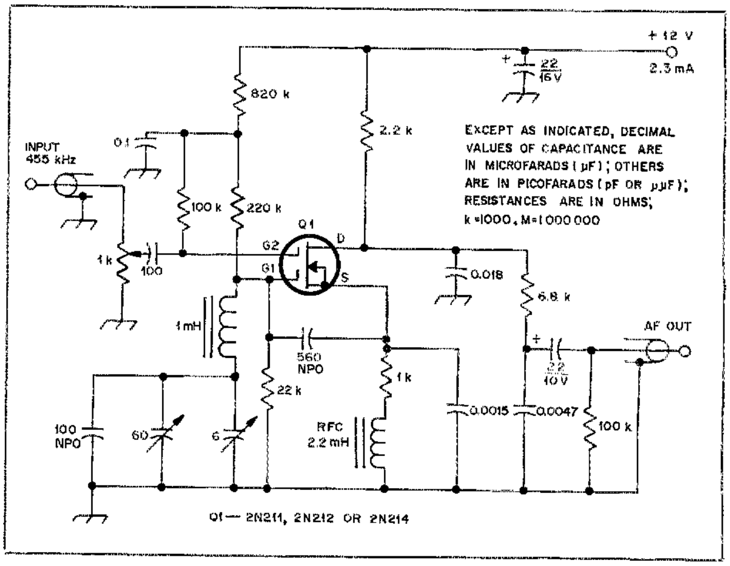


Fig. 1 — MOSFET ssb adaptor featuring combined product detector/oscillator circuit described in *Elektor.*

Matching Coaxial Cables

Wyn Mainwaring, G8AWT, has made effective use of a novel technique for matching different coaxial cables or curing socket-to-cable problems. Although as indicated later, I am not sure whether this is as easy to implement as an alternative idea that was drawn to the attention of readers by G3KYH in "Technical Topics," October 1971, and subsequently has been included in several editions of *ART.* But first let G8AWT explain his technique. He writes:

"Much radio equipment is built to professional standards, including 50-Ω impedance coaxial feeds, of which there are many (and an expensive range of inter-series connectors). The well-established BNC devices are ample for the power levels found in amateur radio and they are usable to 10 GHz; it is small and positive in a quick connection with no threads to cross or bind.

"However, older gear is more likely to have 75-Ω outlets or feed impedance, via a B-L connector. The nickel-plated versions of B-L are a better long-term proposition than the more common aluminum-bodied plug, mating with a nickel or cadmium-plated socket. It depends on a firm push "home" to minimize dielectric air-gap and to ensure reflection-free connection at very high frequencies.

"How can we join the two systems? A $\lambda/4$ coaxial matching transformer (taking into account the velocity factor of the cable) can provide the answer if this can be made by using a solid polyethylene cable of an impedance that is the geometric mean of 75/50-Ω systems, i.e., 61 Ω, or in terms of solid polyethylene cables, 67 pF, 100 pF and 82 pF per meter-length of cable. But how can we make a 61-Ω length of cable?

"This can be done without disturbing the inner part or cutting the outer conductor of a piece of single-cored UR43 (or the flex-cored UR76) as follows: Start with the cable correctly terminated at one end with a 50-Ω BNC connector. Then, carefully strip the black PVC sheath from a good $\lambda/4$ length at the other end (68 in. [1.7 m] for 28 MHz, 28 in. [0.7 m] for 70 MHz, 13-1/2-in. [343 mm] for 144 MHz; etc.); the outer shield can then be pushed back like a sausage skin to reveal the solid polyethylene dielectric. Next, some readily available plumbers' PTFE pipe-thread tape (0.06 mm thick seems a common type) is lap-wound over the length of polyethylene, forming two layers from the braid toward the free end, then returning toward the braid, forming a three-layer lap, totalling five layers over the polyethylene. It is this taped length that forms the new-impedance cable, an overall diameter of 3.5 mm being needed for this mixed dielectric length of cable.

"The braid now needs to be eased back over the taped section resulting in a shrinkage of about four percent. As much care as possible should be exercised in replacing the braid smoothly and keeping it in place with adhesive PVC tape, which can be multilayered to bring the diameter up to a convenient size for the B-L plug at the 75-Ω matching end, or for accepting a larger PVC tube (from some domestic fringe-type cable) which may be sealed from the weather with Bostick no. 1 or PVX adhesive."

*Senior Technical Editor, ARRL

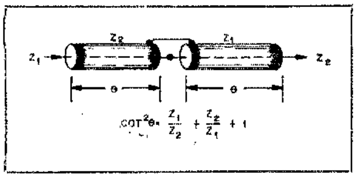


Fig. 2 — Transmission-line transformer used to provide a simple means of matching 50-Ω and 75-Ω coaxial cables.

G8AWT sent along a short length of modified cable showing that it makes up into a very neat arrangement with the λ/4 matching section built into the cable.

However, the alternative technique suggested in 1971 by G3KYH and based on an article in *Electronic Engineering* (April 1962) is shown in Fig. 2. This permits any two cables of different impedance to be matched together by using appropriate lengths of the cables as shown, thereby avoiding the need for a cable at the geometric mean impedance. G3KYH simplified the original formula to that shown and noted that "for a 50/75-Ω transformer this works out to an electrical length of 29.3° for each section of cable. The physical length must of course take into account the velocity factor of the cables (typically about 0.66-0.80)."

Versatile Calibrator

"Technical Topics," November 1976, showed how the 7490 IC decade divider can, by variation of connections, function as a divide-by-n device, where n is any integer from 2 to 10. An interesting example of how this facility can be put to very practical use is to be found in a handy crystal calibrator designed by G8JKL and G8ISY. This provides marker points for use up to vhf at intervals of 1 MHz, 100 kHz and then the option of either 10- or 12.5-kHz markers.

G8JKL writes: "Since operation on fixed channels has become the vogue on vhf and I use a tunable receiver, the need for something better, in the way of crystal calibrators, than the original band-edge marker soon became apparent. To this end the TTL calibrator shown in Fig. 3 was designed by G8ISY and me. The switching allows netting on to the fm channels which are 25 kHz apart by arranging the second 7490 to divide by either 8 or 10. The unit can be built on Veroboard and conveniently fits into a tobacco box together with three no. 8 cells making a 'jam' fit."

Frame Receiving Antenna

On several occasions we have mentioned briefly the use of simple frame antennas, with single-turn coupling coils, for DX reception of medium-wave broadcast or 1.8-MHz stations. Each time inquiries have been received seeking further constructional details, although these are not particularly critical. As such a design has recently appeared in *Electronics Australia* (October 1976), the opportunity is taken of reproducing it (Fig. 4).

About 100 feet (30.4 m) of plastic-covered wire (about no. 22) should be used for the main winding. This should be wound to a whole number of turns; if it will not tune to 1.8 MHz with seven turns, take one off and try again. Coaxial cable (75 Ω) can be used instead of 300-Ω balanced line to the receiver, but aim at making the windings and general construction as symmetrical as possible, since the depth of the rejection null depends on the electrical balance. Tune in signals on the receiver, peaking the antenna tuning control and adjusting direction of loop for maximum pickup or for maximum rejection of interference. QST

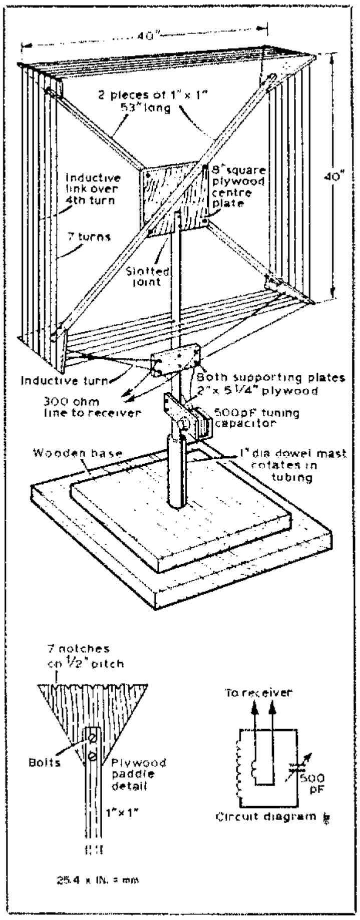


Fig. 4 — Constructional details of loop antenna for operation on medium waves and/or 1.8 MHz and capable of providing deep null on interfering signals *(Electronics Australia)*.

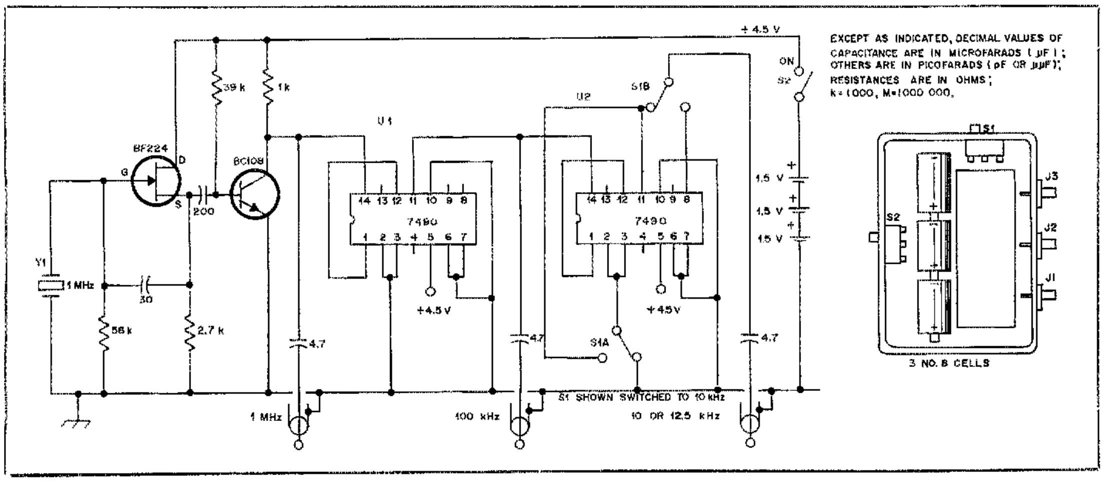


Fig. 3 — The versatile calibrator providing switchable 10- or 12.5-kHz markers.

A Static Morse Keyboard

Build this Morse keyboard for your cw station and send "perfect" code. Its static design will permit separation of the keyboard and code-generating circuitry — and no EMI problems!

By C. T. Isley,* W7KIM

A recent *QST* article by Al Helfrick, K2BLA, described an inexpensive Morse keyboard that utilized a *scanned* keyboard.[1] The design described in this article, on the other hand, utilizes a *static* keyboard. A static keyboard generates the appropriate digital code for the Morse-code character selected, as soon as the corresponding key is closed. The digital code is the same seven-bit binary "word" used by K2BLA in his design.

Why a static keyboard? In my case, a separate keyboard was preferred with the code-generating circuitry in another enclosure. Since I planned to add other functions in the near future, this approach appeared to offer greater flexibility over a unit where all functions are packaged inside the keyboard. Several feet of connecting cable would be required for this type of design and it was felt that a potential for EMI (*e*lectro*m*agnetic *i*nterference) problems might arise with a scanned keyboard. A static keyboard will not cause EMI. From the standpoint of externally induced EMI, it might be argued that a relatively long length of unshielded interconnecting cable would pick up enough rf in a strong field to cause spurious operation of the keyer. While this has not happened in my case, it would appear that such an occurrence could easily be suppressed by the installation of simple single-section LC or RC filters at the input of the keyboard circuitry. The "brute-force" approach using fully shielded cable could also be used (which might solve all EMI problems), however, using multi-conductor cable this approach becomes physically unattractive.

Table 1

Keyswitch Connections for the Morse Keyboard

Connect keyboard switches as indicated. "A" coordinates represent vertical matrix lines; "B" coordinates represent horizontal matrix lines.

	Connect			Connect	
Character	*From*	*To*	*Character*	*From*	*To*
A	A7	B7	W	A7	B15
B	A6	B2	X	A6	B10
C	A6	B6	Y	A6	B14
D	A7	B10	Z	A6	B4
E	A7	B3	1	A4	B15
F	A6	B5	2	A4	B13
G	A7	B12	3	A4	B9
H	A6	B1	4	A4	B1
I	A7	B5	5	A5	B1
J	A6	B15	6	A5	B2
K	A7	B14	7	A5	B4
L	A6	B3	8	A5	B8
M	A7	B8	9	A5	B16
N	A7	B6	Ø	A4	B16
O	A7	B16	$\overline{AS}$	A5	B3
P	A6	B7	$\overline{AR}$	A5	B11
Q	A6	B12	BT	A4	B2
R	A7	B11	$\overline{DN}$	A5	B10
S	A7	B9	$\overline{SK}$	A2	B9
T	A7	B4	Comma	A1	B4
U	A7	B13	Period	A2	B11
V	A6	B9	?	A3	B13

Design of the Matrix

The design of a static keyboard generally implies the use of a diode matrix. Using the direct approach to designing a diode matrix for this application would call for a large number of diodes — obviously onerous and undesirable in this instance. If the seven-bit binary "word" is partitioned so that the first four bits (in the sense of right to left) are used to specify the matrix column, then a relatively simple, tractable design approach results. Fig. 1 shows the matrix circuitry. Only 41 diodes, three transistors, and four ICs are needed for this matrix — hardly formidable or costly to fabricate. As can be seen in Fig. 1, depressing a particular key completes the circuit between the base(s) of the selected transistor(s) (Q1-Q3) and the terminating resistors corresponding to selected rows for the desired binary code. Table 1 shows the connections from the matrix to the keyboard switches. The steering diodes associated with each row and column (respectively) effect this selection process. The strobe signal needed to indicate the presence of a character code is developed by U4. Actually, the circuitry used to convert the seven-bit "word" into Morse code requires the complement of the strobe ($\overline{STR}$), so one of the inverters in U3 is used to implement this operation.

Circuit Operation

The method for generating the actual Morse-code character is the same as that described by K2BLA with only minor circuit modifications. The schematic diagram for the Morse-character generator and keying circuit is shown in Fig. 2. The operation of the shift register and character generator has been described in K2BLA's article, and will not be covered in detail here. Each of the parallel inputs to the shift registers (U6 and U10) has been labeled with the binary weight corresponding to the output line from the keyboard encoder. When $\overline{STR}$ is low, the output of U13C goes high. This positive step triggers dual multivibrator (U5B) causing the Q output to go high. After

*804 Cortez La., Foster City, CA 94404

[1]Helfrick, "An Inexpensive Morse Keyboard," *QST*, January 1978, p. 24.

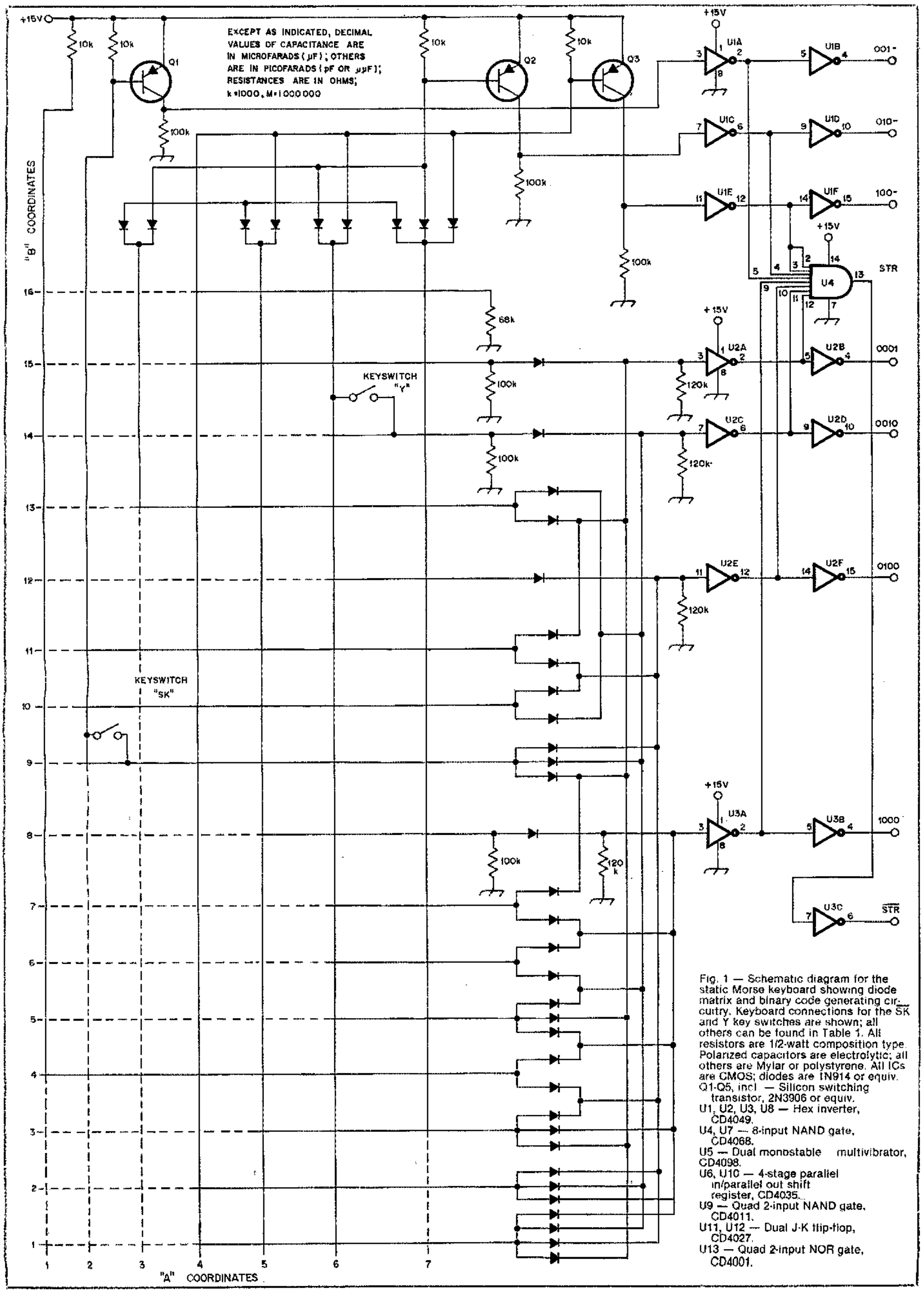


Fig. 1 — Schematic diagram for the static Morse keyboard showing diode matrix and binary code generating circuitry. Keyboard connections for the SK and Y key switches are shown; all others can be found in Table 1. All resistors are 1/2-watt composition type. Polarized capacitors are electrolytic; all others are Mylar or polystyrene. All ICs are CMOS; diodes are 1N914 or equiv.

Q1-Q5, incl — Silicon switching transistor, 2N3906 or equiv.
U1, U2, U3, U8 — Hex inverter, CD4049.
U4, U7 — 8-input NAND gate, CD4068.
U5 — Dual monostable multivibrator, CD4098.
U6, U10 — 4-stage parallel in/parallel out shift register, CD4035.
U9 — Quad 2-input NAND gate, CD4011.
U11, U12 — Dual J-K flip-flop, CD4027.
U13 — Quad 2-input NOR gate, CD4001.

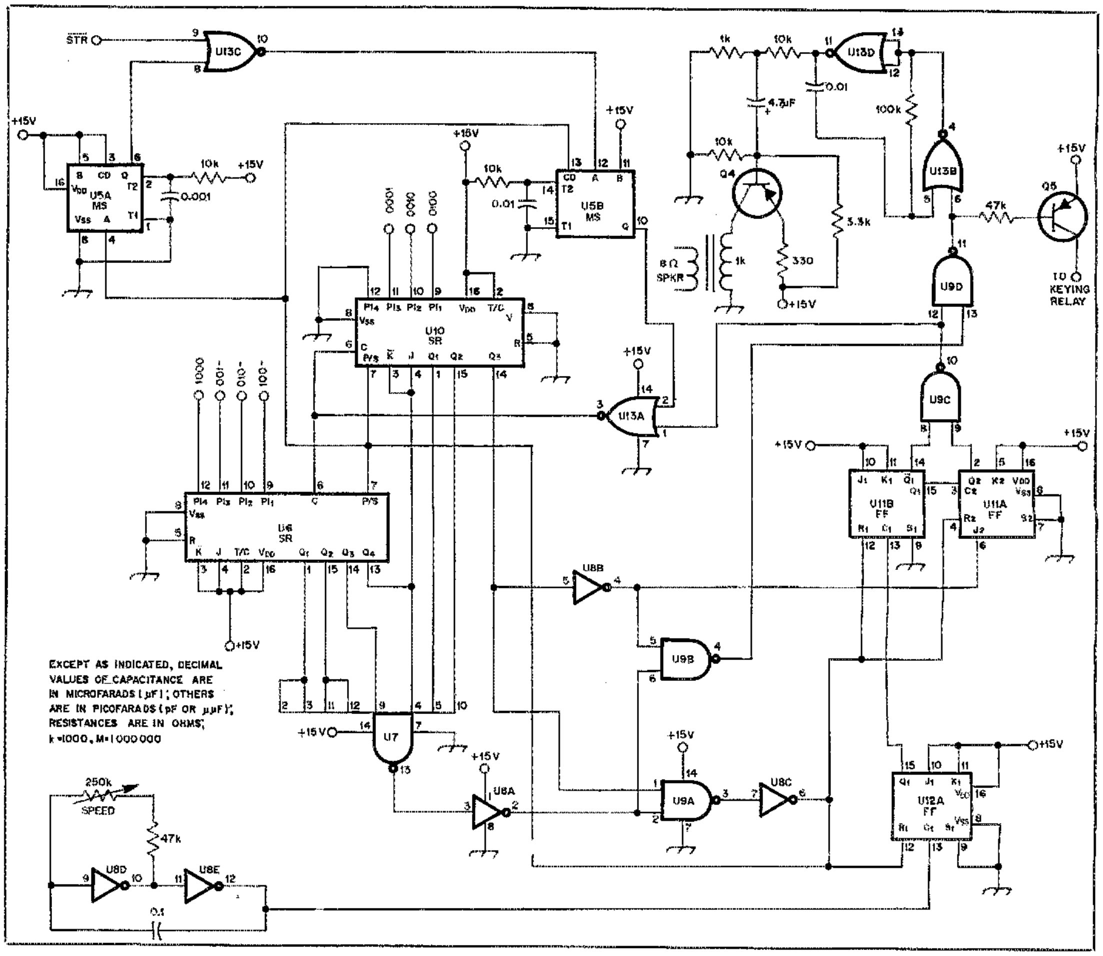


Fig. 2 — Schematic diagram showing Morse-character generator and keying circuitry of the static Morse keyboard. Parts list is given in Fig. 1 caption.

about 40 µs, U5B resets itself. A negative-going step will cause the output of U13A to go high. This positive transition, applied to the clock inputs of U6 and U10, effects transfer of the binary word present at the parallel inputs. When the shift registers are loaded, gate U7 senses that the binary word in the registers is no longer all ones. As a result, the reset lines to flip-flops U1B, U2A and U2B are caused to go low, allowing the dit-dah timing to start. This same level change is applied to the CD input of U5B. So long as CD is low, U5B cannot be triggered. Thus, during the generation of the Morse-code character, further entry of data from the keyboard is locked out. After readout of the encoded "word" plus one character space, the output of U8C goes high. This positive step resets flip-flops U1B, U2A and U2B and inhibits any further dit-dah keying action. The positive step also triggers U5B, resulting in the appearance of a positive pulse of about 2-µs duration. If the STR signal is present (low), the output of gate U13C will first go low, and then go high on the trailing edge of the pulse. This positive transition will trigger U5B and cause a repeat of the sequence just described. If STR is not present (high), further operation ceases until STR is again present.

Since the strobe and the data bits are developed by a single key closure (when the STR signal is at a level adequate to trigger U5B), the "high" data lines will also be at a level suitable for reading into the shift registers. This is true even if the key closure has not completely stabilized. As long as the delay in the dual multivibrator (U5B) is small enough, the keying action is effectively "debounced." No difficulty was encountered with the time constant used in the timing network for U5B. If difficulties are encountered the time constant should be decreased.

While *n*-key lockout is provided during the character generation, only the intended key should be closed at the time U5B is reset; otherwise, "garbage" may be transferred into the shift registers.

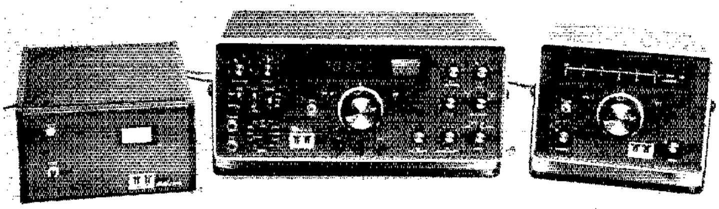
No evaluation has been made of operation at low supply voltages, since the 15-volt supply was already constructed. I suspect that unreliable keyboard operation might occur with supply voltages well below 15 volts, since there is approximately 1.5 volts total drop across the matrix diodes themselves. With respect to the transistors (Q1-Q3) there must be sufficient voltage developed across the respective 10-kΩ bias resistor to drive the transistor into saturation.

The keyboard is working fine in its breadboard form and I'm currently working on a more suitable layout. I hope all who build the keyboard will enjoy sending perfect code as much as I have. See you on the air!

Product Review

Conducted By Paul K. Pagel,* N1FB

The Ten-Tec OMNI D Transceiver



The OMNI D complete with the optional matching power supply and remote VFO. The bails on the transceiver and VFO may be used as support brackets as shown and double as carrying handles, or they may be removed entirely.

The Ten-Tec OMNI D Transceiver
Claimed Specifications
Frequency coverage: 160 to 10 meters, plus WWV receive at 10 MHz.
Modes: Ssb and cw.
Power output: 85 to 100 watts, typical.
Power requirements: 12 to 14 V dc, 850 mA receive, 18.5 A transmit.
Receiver sensitivity: Tailored from 2.0 μV on 1.8 MHz to 0.3 μV on 28 MHz for 10-dB S + N/N ratio.
Weight: 14-1/2 pounds (32 kg).
Dimensions: (HWD) 5-1/2 × 14-1/4 × 14 inches, less bail (140 × 362 × 356 mm).
Price class: OMNI D, $1120. 252 MO power supply, $140. 243 remote VFO, $140.

Once there was a valid argument that cw ops had to take a back seat when it came to equipment choice. That is to say, most transceivers appeared to be designed primarily for ssb use with cw "thrown in" as an afterthought. Then along came Ten-Tec. Anyone tuning the cw bands and listening to the descriptions of the equipment being used will attest to the fact that a great many cw ops have made a home for their favorite piece of Ten-Tec gear. Not only are they used in the house, but in the car, in campers, and while mountaintopping as well.

The latest offering from Sevierville is the B version of the OMNI. This updated model, complete with optional 1.8- and 0.5-kHz filters, noise blanker and model 243 VFO arrived at the Product Review desk one afternoon. That evening it was on the air.

General Description

The OMNI series transceivers are light in weight and ideally suited for mobile or portable use as well as fixed-station applications. A clam-shell aluminum cabinet houses the components and is finished with a black vinyl-covered top and bottom. A complementary-colored dark gray panel and satin-etched trim provide the finishing touches. The power supply may consist of any source capable of supplying 13.8 V dc at 18.5 A. The 252 MO supply was received with the review unit. This supply has over-current protection and is equipped with a front-panel-mounted meter. An optional over-voltage protection feature is available, too. This provides for instantaneous removal of the power supply output voltage should it rise above 15 volts for any reason.

The transceiver covers 160 through 10 meters with WWV reception at 10 MHz. There is also an AUX position for future band additions and the 10-MHz position may be converted for transmission should the need arise. The OMNI is fully transistorized. A total of 20 ICs, 44 transistors and 63 diodes is used along with 23 circuit boards. The only transmitter "tuning" necessary is the setting of the DRIVE and ALC controls for the desired power output. The receiver RESONATE control is peaked to optimize the preselector tuning when changing bands. There are no tuning or loading controls *per se*. The final amplifier transistors are warranted fully for the first year and prorated for 5 years. To check the "100-percent duty cycle" rating given the transceiver, we locked the key down at full power output (into a dummy load) for over an hour. During that interval, the output power decreased from 100 watts to 82 watts. No tuning touch-ups were made. The final-amplifier heat sink was warm to the touch after that episode, but not unduly so. A fan was used to cool the heat sink of the power supply, not that of the OMNI. (This procedural step is outlined in the power supply manual). Operation of the transceiver under conditions producing a VSWR of 3:1 (during antenna-matching-network adjustment) produced no failures.

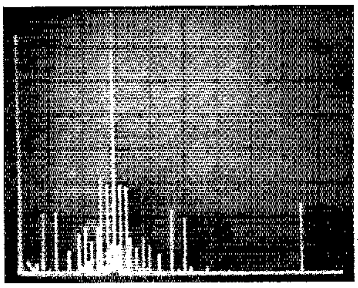


Fig. 1 — This photo shows a worst-case condition with the OMNI operating at rated input power on cw at 28 MHz. The vertical divisions are 10 dB each. Horizontal divisions are 10 MHz each. The spurious emissions close to the carrier frequency are 48 dB down with respect to the fundamental. Other spurs are at least 51 dB down. The OMNI D meets present FCC requirements for spectral purity.

The "B"(asic) Differences

There are a few differences between the earlier OMNI and the later OMNI B. The first units had a squelch control. This has been replaced by a notch filter which is quite effective in eliminating bothersome heterodynes . . . and there can be lots of those on 40 meters! A close look at the selectivity switch will disclose another change. The earlier OMNI had an audio active filter for use on cw which had three selectable skirt contours. The B model has both an optional 0.5-kHz cw crystal filter and a 1.8-kHz crystal filter for ssb. The audio filter is retained and used in conjunction with the crystal filters for providing additional selectivity. Both of these filters may be switched in cascade with the standard filter. The switching is arranged so the operator may simultaneously employ the audio filtering as well. Ten-Tec is offering factory conversion of the earlier OMNI series to the series B at a nominal cost.

The Receiver

The receiver employs an 8-pole ladder filter with a 2.4-kHz bandwidth and 1.7:1 shape fac-

*Assistant Technical Editor, ARRL

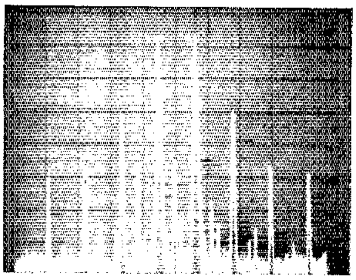


Fig. 2 — The output of the OMNI D during a full-power, 14-MHz, two-tone test. Each vertical division is 10 dB and each horizontal division is 1 kHz. The third-order products are approximately 30 dB down from the PEP level.

tor. The two optional filters available display a 1.8-kHz bandwidth, 1.8:1 shape factor for the narrow ssb filter and 500-Hz bandwidth, 1.9:1 shape factor for cw. A single-conversion system is used with a 9-MHz i-f. The rf amplifier stage is fixed-biased and has no agc applied to it. The rf-gain control is actually used to control the i-f gain. A quad diode, high-level, doubly balanced mixer circuit is used. This type of mixer circuit is characterized by its ability to handle high signal levels without being adversely affected. Receiver dynamic-range measurements were made in the ARRL lab. These are worst case figures developed at 80 meters: MDS (minimum discernible signal or noise floor) −128 dBm; blocking dynamic range 115 dB; IMD dynamic range 94 dB. This provides an input intercept figure of +13 dBm. At 20 meters, the following figures were obtained: MDS −139 dBm; blocking dynamic range 125 dB; IMD dynamic range 90 dB. The resulting input intercept figure is −4 dBm. The sensitivity of the receiver is tailored to produce a 10-dB S + N/N ratio with input signals of 2.0 μV on 160 meters and 0.3 μV on 10 meters.

There are a number of receiver "birdies" and the instruction manual points out a couple of strong responses that will be encountered. The strongest was that on 10 meters at 28.980 MHz (S9 + 20 dB). This response may be bypassed by switching to the next higher band segment and tuning appropriately below that segment edge. Other in-band responses were found at: 3.600 (S3), 7.181 (S3), 21.320 (S4), 29.234 (S4), and 29.984 (S4).

The tuning rate is a comfortable 18 kHz per revolution of the knob. A small amount of backlash was noted when tuning in one direction only. This is because of the action of the tension spring in the PTO. If present, backlash may be eliminated by simply loosening the setscrew on the knob and pushing the knob a bit further in toward the panel. Operators are cautioned that touching the metal insert or the knob skirt will shift the frequency of the PTO slightly. This is because the PTO shaft is above chassis potential. The actual frequency change is slight and during operation this never occurred unless a deliberate attempt was made to touch these areas. Frequency readout on the OMNI D is by means of six 0.43-inch LEDs. All are red in color with the exception of the 100-Hz unit which is green. The PTO stability is excellent. It took an awful lot of physical abuse to persuade the PTO to move a few hertz. The OFFSET control has two ranges: plus/minus 0.5 kHz and 5 kHz. This function is used for receiver offset tuning only and is disabled during transmit.

The RESONATE knob controls the preselector for the receiver. Care should be taken to ensure that the control is peaked correctly as it is possible to peak at an image frequency of the internal 9-MHz oscillator frequency on all but the two lower bands. One spurious response was noted while listening on 20 meters. An 80/40-meter inverted V was being used as a receiving antenna and the antenna-matching network hadn't been tuned for 20 meters. The response heard was that of a strong 16-MHz RTTY signal and resulted from mixing with the fifth harmonic of the VFO signal. The frequency of the signal was verified by means of a separate receiver. Even with the RESONATE control properly peaked, the signal was still audible. It wasn't until the matching network was tuned correctly for the band in use that the response was eliminated. This example underscored the usefulness of an antenna-matching network in rejecting unwanted signals. Use of a properly designed and matched-antenna system is also emphasized.

There is plenty of audio output both with the internal speakers (two bottom-mounted 2-1/2 inch [64 mm] types) and with headphones. In fact, Ten-Tec recommends a pad be used when employing low-impedance headphones. This consists simply of a couple of resistors which may be hidden within the body of the phone plug.

The Transmitter

The power output on all bands was in excess of 90 watts except on 160 meters. There, the power was measured at between 80 to 82 watts from one end of the band to the other using a Bird wattmeter and dummy load. On 10 meters, the output was a healthy 98 watts. QRP operation is readily accomplished by using the ALC and DRIVE controls to vary the level of output power.

The transmitter was subjected to spectrum analysis in the ARRL lab and the results are shown in the accompanying photos of Figs. 1 and 2. Audio quality reports received while operating ssb were complimentary. A high-impedance microphone is required and a standard 3-conductor plug is used for the microphone connector. A speech processor is not supplied with the OMNI, but since the reviewer is not an avid ssb DXer, it wasn't missed. VOX system sensitivity is excellent and it operates noiselessly. The VOX controls are readily accessible at the front panel and have no effect on the cw QSK operation of the transceiver.

QSK . . . now, there's where the cw enthusiast can really "do his thing"! Operating QSK allows you to hear what's happening on the frequency between dits and dahs. It can mean preventing the loss of a contact due to fading, QRM, etc., and gives the other operator(s) a chance to interject a comment now and then. This has the effect of lending a truly conversational air to a cw QSO. Two speeds are provided for QSK operation which should suit most any type of operating condition. The SLOW position has a smooth receive/transmit transition which "holds" between code elements. The FAST position allows the operator to hear between the code elements but is somewhat "noisier" to the uninitiated.

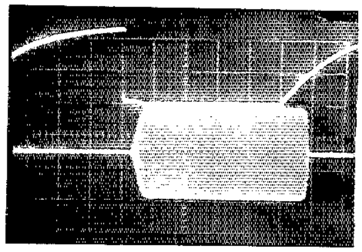


Fig. 3 — Two waveforms are shown: The upper waveform depicts the actual key-down time, while the lower is the cw output signal of the Ten-Tec OMNI D, series B, on 10 meters. Each horizontal division is 5 ms. The "make" of the wave differs slightly between bands (only 1-1/4 ms). Here, the wave is shown starting approximately 1-1/4 ms after key down. On 40 meters, this point shifts to approximately 2-1/2 ms after key down. "Make" and "break" time constants of approximately 5 ms will produce absolutely clickless keying. (An excellent treatise, "Some Thoughts on Keying," was presented by Goodman in April 1941 *QST*).

Unlike some VOX keying systems (commonly called "semi-break-in" keying), no part of the initial code element is lost in going from receive to transmit . . . it's instantaneous. A presentation of the keyed cw waveform is shown in Fig. 3. The cw monitor note is internally generated and both volume and pitch are controlled by two thumbwheel potentiometers located beneath the OMNI. These are accessible through a hole in the bottom plate and may be adjusted during operation.

A ZERO BEAT switch on the front panel allows the operator of the OMNI to adjust his transmit frequency exactly to that of the received signal frequency. When this button is depressed, the receiver carrier oscillator frequency is shifted a nominal 750 Hz to match the transmit frequency offset. The OFFSET control is automatically disabled. The operator then tunes the OMNI for an exact zero beat (or null) of the received signal. When the button is released, the receive and transmit frequencies will be the same and the beat note will again be heard.

The Remote VFO

The 243 remote VFO (optional) supplies more flexibility to the OMNI. In addition to the normal splitting of receive/transmit functions with the transceiver, there are two other positions available which allow *simultaneous* dual-frequency reception. The digital readout of the transceiver is not to be trusted during this mode as it will lock onto whichever VFO signal is the strongest or display random digits. To check the frequencies properly, the operator must switch to a single receive frequency position. The remote VFO readout is an analog readout and proved to be quite accurate.

The Ten-Tec OMNI appears to be ideally suited for the cw and ssb DXer. The rapid QSK and band-change features should appeal to many. RTTY enthusiasts will welcome the long-term power-handling capabilities of the final amplifiers, too. — *Paul K. Pagel, N1FB*

Presenting the Drake R-7 receiver. A synthesized, general coverage receiver, it offers a wide range of features. Covering the frequency range of 0 to 30 MHz, this receiver is at home in both the ham shack and the laboratory.

R. L. DRAKE R-7 RECEIVER

The beholder of this fine new product may regard it initially as just another "super-duper signal scooper," but it is, in fact, anything *but* just another fancy receiver. The Drake R-7 (model 1240) is a synthesized general-coverage (0- to 30-MHz) unit with no gaps in the frequency coverage.

The utility of this new product can be used to advantage in the ham shack or laboratory, with or without the many available options. Among them are the MS-7 speaker, i-f filters for 300, 500 and 1800 Hz. One can also purchase filters for 4.0- or 6.0-kHz bandwidths. Other accessories are the NB-7A noise blanker and Aux-7 range program/fixed-frequency board. The latter permits programming eight additional 500-kHz range segments in the 0- to 30-MHz range, irrespective of the existing eleven 500-kHz range increments.

Specific Circuit Features

The receiver front end employs a high-level doubly balanced mixer. As an enhancement to image rejection, the first i-f is derived at 48 MHz by means of "up-converting." Front-end bandpass filters are used from vlf through hf. A broadband preamplifier can be switched in from the front panel at all frequencies above 1.5 MHz. This adds 10 dB of front-end gain when it is needed.

A multiposition antenna selector switch is located on the front panel. It enables the operator to receive simultaneously with the R-7 and a TR-7 for split-frequency reception. Other positions can be used to select alternate antennas and outboard vhf and uhf converters. This receiver can be used for transceiving when utilized with the TR-7.

A tunable i-f notch filter is included in the circuit. It is used for reducing unwanted heterodynes from interfering strong signals. Electronic passband tuning is still another feature of the R-7. It can be adjusted for use with any of the filter bandwidths listed earlier.

There are three selectable agc time constants in addition to an "off" position. Also, the receiver is equipped for digital and analog frequency readout. A front-panel switch enables the operator to use the internal counter as a 150-MHz external frequency counter, if desired. A 25-kHz calibrator is included for alignment of the analog dial.

A low-distortion "synchro-phase" a-m detector is included in the receiver. This circuit permits a 3-kHz a-m sideband response when using a 4-kHz filter. The technique provides better interference rejection than is possible with conventional systems. The principal application for amateurs would be in the monitoring of international shortwave broadcasts, but amateur a-m diehards might appreciate the feature also!

Performance

As one might conclude from reading the specifications for the R-7, the receiver dynamic range is excellent. The worst-case numbers were obtained on 80 meters with and without the preamp switched in. They are, with the preamp actuated:

Noise Floor	Blocking	IMD
−139 dBm	112 dB	91 dB

Without the preamp turned on:

Noise Floor	Blocking	IMD
−133 dBm	>120 dB	100 dB

The tests were based on the W7ZOI measurement techniques described in July 1975 *QST*. These numbers equate to a third-order input intercept of −2.5 dBm on 80 meters with the preamp turned off and +17 dBm with the preamp turned on. The League's product-analysis engineer reported difficulty in identifying the IMD responses, as they were among other responses within the receiver, presumably caused by the frequency synthesizer. Our present measurement capability prevents us from making definitive LO noise-floor measurements.

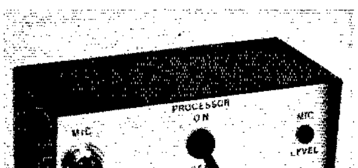
In actual amateur service at W1FB (two short blocks from W1AW), the receiver performed extremely well in the presence of very strong signals. There was no evidence of overloading when W1AW was operating. Image rejection appears to be excellent: Drake rates it at greater than 80 dB (48.05 MHz first i-f, 5.645 MHz second i-f and 50 kHz third i-f).

The antenna input impedance is 50 Ω. The audio output is rated at 2.5 watts with less than 10 percent total harmonic distortion (THD) into a 4-Ω load. The frequency drift checked out at 85 Hz after a 30-minute warm-up period. This is quite good, considering the power supply is built in and the heat from the many active devices contained in the circuit. — *Doug DeMaw, W1FB*

Drake R-7 VLF/HF Receiver
Claimed specifications
Sensitivity: 1.8-30 MHz less than 0.2 μV for 10 dB S + N/N with preamp on; less than 0.5 μV with preamp off. From 0.01 to 1.5 MHz, less than 1.0 μV.
Dimensions (HWD): 4.6 × 13.6 × 13 inches (116 × 346 × 330 mm).
Weight: 18.4 lbs (8.34 kg).
Power requirements: 100 to 240 V ac, 50/60 Hz. 60 watts, or 11 to 16 V dc at 3 A (13.8 V dc nom.).
Price class: $1300.
Manufacturer: R. L. Drake Company, Miamisburg, OH 45342. Tel. 513-866-2421.

THE SOUNDPOWER SP100 AUDIO SPEECH PROCESSOR

Many of the new transceivers and transmitters being sold today include either an rf or audio type of speech processor. Processors are designed to provide that extra "punch" on occasions when received signals at the other end are weak or the QRM makes the going tough. Rf speech processors employ clipping circuits and utilize expensive filters to "clean up" the signal. Most of these types of processors are



If you're looking to add a little more "punch" to your ssb signal, here's an accessory that may prove to be the answer. The Soundpower SP100 is simply installed in the mic line and provides a unique method of audio processing.

designed to be installed in the transmitter i-f circuit.[1] Audio processors, on the other hand, are plugged directly into the microphone jack and perform their function at audio frequencies.

The Soundpower SP100 audio processor is housed in a compact 5-3/16 × 2-1/2 × 2-7/16 inch (132 × 64 × 62 mm) cabinet. It is supplied with a female 4-conductor jack similar to Radio Shack 274-001. The review unit came with a mating power supply, the PS9, although any power source capable of providing 6 to 15 V dc at 30 mA may be used. A manufacturer's one-year guarantee accompanies the SP100.

During the review period, the SP100 was used with a Kenwood T-599D transmitter which does not have a built-in speech processor. Previous on-the-air reports indicated that the audio quality and "punch" of the transmitter alone were very good. In fact, many stations contacted had indicated that the "processor was working well" when none was in use! Under such circumstances, it appeared this would be a good proving ground.

Hooking up the SP100 proved to be no problem, though the instructions could have been made a little clearer. Two adjustments had to be made from the back of the unit — the gain and output level settings. My initial attempt at using the processor was not successful. Reports indicated too much gain or output and a correspondingly distorted signal. The instructions suggested the gain should be adjusted until the LED on the front panel was on almost continuously. With my Astatic 10-D microphone (a high-impedance microphone is to be used with the SP100), I found output quality to be better when the light was on only intermittently. In any case, the adjustment requires a fine touch, but once set, can be left alone.

As with any such piece of equipment, the proof of its worth is in the on-the-air reports. The station wattmeter indicated a significant increase in average output power with the SP100 in use. My on-the-air voice was definitely "different" as the processor is intended to utilize only those speech components that contribute to high articulation and intelligibility. In other words, concentrate the audio power at those frequencies most needed for communication. Operators who could already hear me well said the processor didn't help and most preferred that it not be used. But, when my signal was weak, the processor made a definite improvement in getting through. During a contest, a DX pile-up or even attempting a ragchew when QRM is rough, the SP100 will give you that added "edge" in intelligibility. — *Tom Frenaye, K1KI*

[1]Some rf speech processors, such as the Daiwa RF 440, are connected in the mic line. (See "Product Review," *QST*, April 1979.)

Soundpower SP100 Audio Speech Processor
Specifications
Input level: 0.5 to 500 mV.
Output level: Constant amplitude, adjustable 0 to 0.3 V.
Power requirements: 6 to 15 V dc, 0.01 to 0.03 A.
Weight: 1 pound (0.5 kg).
Case: Aluminum.
Color: Two-tone, gray and black.
Price class: Processor, $80; power supply, $6.
Manufacturer: Soundpower, P. O. Box 426, Bergenfield, NJ 07621.

APOLLO PRODUCTS CABINETS

Whether we like to believe it or not, eye appeal has a lot to do with our choice and appraisal of anything we buy, be it a car, house or a piece of electronic equipment. And no matter how good the design, how painstaking the circuit assembly, the finished product of any homemade piece of amateur equipment can be made or broken by the enclosure chosen to house the assembly. If your eyes haven't been captured already, a glance at Figs. 4 and 5 should get your mental "gears" in motion if you're contemplating another construction project.

Apollo Products has a cabinet, enclosure, box, housing or reliquary for virtually *any* item you may have that's looking for a home. The panels are made of 20-gauge brushed-chrome steel and may be finished with a touch of wood-grained adhesive-backed vinyl or baked enamel. Covers have a baked-on wrinkle finish of different colors. Certain chassis are nickel-plated copper to exhibit good rf conductivity. All cabinets are fully assembled and supplied with rubber feet.

Some of the units shown in Fig. 5 are supplied with red dpdt rocker switches. There's even a ready-made housing for an antenna-matching network. That's not all — there are more items available than meet the eye in the two photos. For instance, Apollo also manufactures small aluminum chassis which may be used to fabricate a coaxial switch — complete with prepunched holes for the SO-239 connectors and the switch. A catalog and price list are available from: Apollo Products, Box 245, Vaughnsville, OH 45893. — *Paul K. Pagel, N1FB*

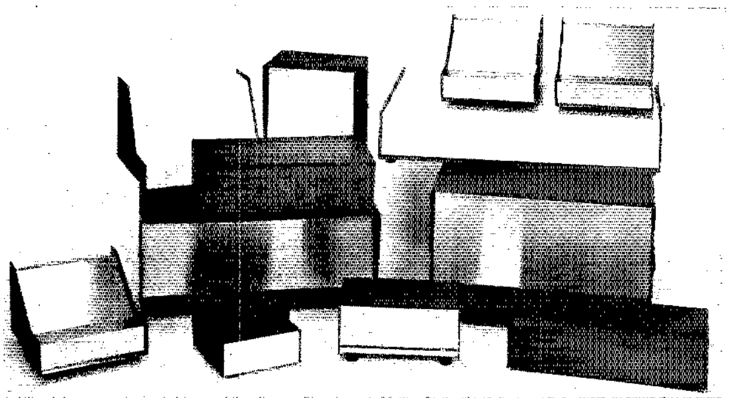


Fig. 4 — Here's a sampling of the offering from Apollo Products. The smaller, sloping-front cabinets are ideal for mounting meters and make perfect housings for smaller pieces of test equipment.

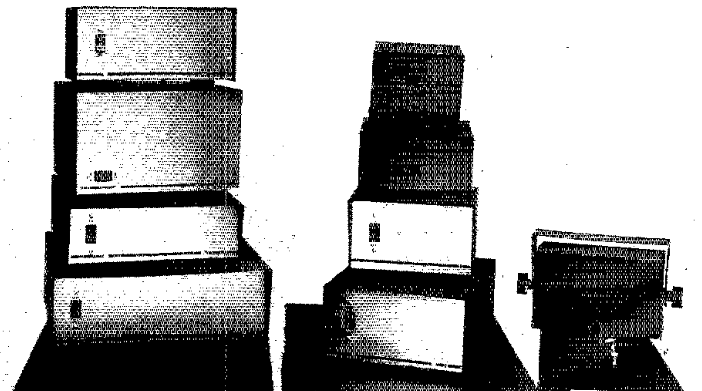


Fig. 5 — Power supplies, antenna-matching network, amplifier or oscilloscope — one of these cabinets should fit the bill for your next project.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

A TUNING AID AND PROTECTIVE CIRCUIT FOR THE HEATH SB-230

The following information, which is intended particularly for the SB-230, is applicable to other amplifiers, provided appropriate changes are made. Excessive plate and grid current in an rf amplifier can easily result from improper tuning, loading, drive or switch positioning. With a single meter which is switched from circuit to circuit for metering, excessive current in an unattended circuit could go unnoticed for an extended period of time. In order to protect my amplifier from such a situation, I've installed the circuit illustrated in the accompanying diagram. It is designed to limit plate and grid current to a desired level and provide a measure of protection in the event of an arc within the tube.

Components illustrated in solid lines have been added to my Heath SB-230. Q1, Q2 and D3 provide an alc voltage. If the plate current exceeds a value which causes the voltage across RP and the 0.5-ohm resistor in series to be slightly in excess of that specified for D3, these components provide a clamping action. Q3 and Q4 also furnish an alc voltage if the grid current through RG causes Q3 to turn on.

*Assistant Technical Editor, *QST*

All added components fit easily in space that is available in the amplifier. They can be supported by their leads. Additional wafer-style terminal strips may be mounted, using hardware that is already in the SB-230.

This modification requires that the original alc circuit in the SB-230 be removed. Addition of alc feedback from the SB-230 to the exciter may slightly disturb the exciter alc circuit.

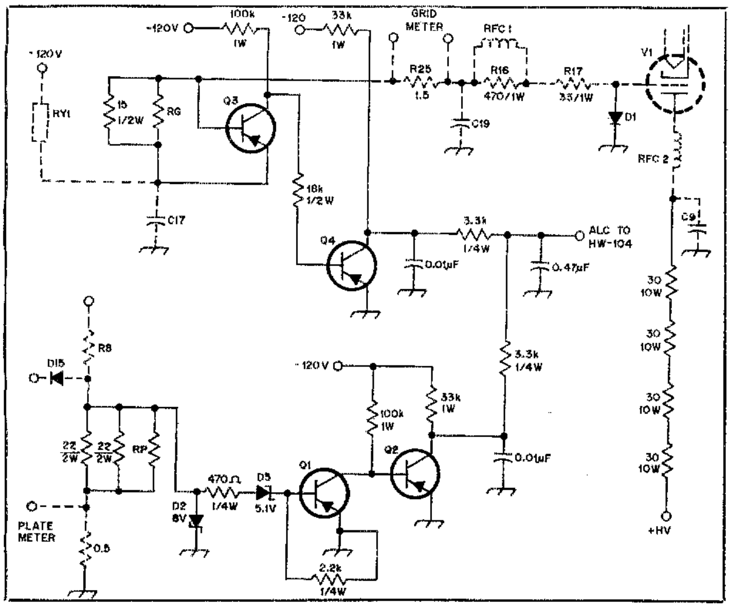
A 120-ohm, 40-watt resistance composed of four 30-ohm, 10-watt resistors was added in series with the plate voltage. In the event of an arc, this resistance will limit the plate currents. D1 will help protect the grid during an arc and also the metering in the grid circuit. D2 protects the plate metering and current limiting circuits.

The circuit, as shown, has been in use for some time and has proven satisfactory. While it prevents excessive currents, it will not prevent excessive dissipation if the tube is operated unloaded or mistuned for too long a time. The grid-current level of the SB-230 tends to become excessive if the load control is not adjusted properly (this is true of many grounded-grid linear amplifiers). As a result, the amplifier with the above grid-current limit cannot be driven to rated plate current if the load adjustment is not correct. Inability to drive the SB-230 to rated plate current with improper load adjustment is an indication that the grid-current limiting is working. The plate current will be driven to the limit if the load control is adjusted improperly. This happens when the drive is set too far beyond the point where the grid-current limiting is in effect because of improper loading. The circuit is fast-acting and will function as an rf compressor if the microphone gain is set too high.

Installing the foregoing modifications in the SB-230 should be attempted only by persons who are knowledgeable about high-voltage operation and semiconductor circuits. The plate-current limiting resistors can be mounted, preferably with the aid of at least one high-voltage standoff insulator, in the shielded cage containing the tube and tuning components. — *Wray U. Shipley, N4YC, Owensboro, KY*

A HARDLINE COAXIAL ANTENNA FOR 2 METERS

I ran across Phil Rand's antenna article in November 1951 *QST* while searching for data on coaxial antennas that could be made from obtainable materials and fabricated without the benefit of a machine shop. A similar antenna could be made from CATV Hardline cable. Often, odd length pieces of such cable are available from CATV companies.



This transistorized modification of the Heath SB-230 offers protection against excessive plate or grid current. Resistances are in ohms.

D1 — Silicon rectifier, 1000 PRV, 3 A, GE512 or ECG156, or equiv.

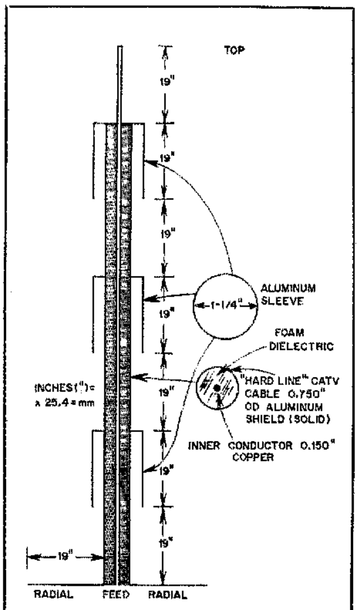
D2 — Zener diode, 8 V, 5 W, GE5ZD8 or ECG5122A or equiv.

D3 — Zener diode, 5.1 V, 5 W, GE5ZD-5.1, or ECG135A or equiv.

Q1-Q4, incl. — GE228 or 2N5415.

RG — Chosen to set grid current limit ≈ 56 Ω, 1/4 W.

RP — Chosen to set plate current limit ≈ 82 Ω, 1/2 W.



W9KPG suggests this antenna design for 2-meter operation. It is constructed from Hardline CATV coaxial cable. Measurements shown are for the 144-MHz end of the band. The measurements should be shortened to 18 inches for the fm segment.

I have corresponded with Phil about my idea (as shown in the accompanying diagram). He advises that there is no need to consider the velocity factor, inasmuch as the coaxial cable feeds only the top element. He also suggests that I keep the same ratio of mast-to-skirt diameters, stating that the skirt diameter should be 1-1/4 inches. Additionally he advises that the 19-inch dimensions are for the 144-MHz end of the 2-meter band. These measurements should be changed to 18 inches for the fm segment. — *Harry H. Heinrich, W9KPG, Green Bay, WI*

WRINKLE FINISH

I read with interest Doug DeMaw's explanation in September 1979 *QST* about using a drying oven in paint finishing of radio projects. I thought some readers might be interested in my method of getting a rather nice wrinkle finish on a panel.

A bare panel can be primed with standard zinc-chromate spray primer. Allow it to dry naturally. What I do next is to wait until my wife has gone for the day so that I can heat the panel for about 20 minutes in the oven at a 300°F temperature. After I'm sure the panel is completely heat-soaked, I remove it from the oven, place it on a piece of wood and spray it with the finish paint. The finish coat dries instantly. But rather than settling flatly, it provides an attractive wrinkle. Anyone trying this method should not let the paint can get too close to the project, lest runs appear.

Two other tips — aluminum should always be primed *before* painting. Zinc-chromate is the better choice for this purpose. For finish paint I prefer the type used on machinery. It is known as "machine gray." Most industrial supply houses carry it in spray cans. The price is about the same as one would pay at ordinary outlets, but the paint seems to be tougher. It is available in several tones and brands. I find that I can match S-Line colors fairly well and the finished work takes transfer letters nicely. — *R. C. Locher, Jr., W9KNI, Deerfield, IL*

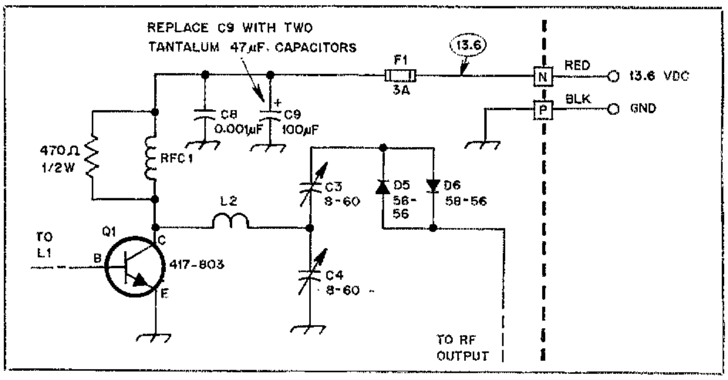
[Editor's Note: Readers who plan to have a wrinkle finish on panels and cabinets may also like to know that the Illinois Bronze Paint Co., of Lake Zurich, IL, produces wrinkle finish paint in several colors. Their Celestial Blue no. 338 closely matches Heath coloring.]

ELIMINATING 2-METER AMPLIFIER SPURIOUS EMISSIONS

After carefully constructing and adjusting my HA-201 2-meter amplifier according to the instructions, I was dismayed to discover that it was emitting spurious signals. Repeated adjustments failed to solve the difficulty. My Drake TR-22C was used to drive the amplifier. The antenna system operated with a low VSWR. Neither of these appeared to be at fault.

Consultations with other engineers regarding the amplifier design and circuit-board layout indicated two likely trouble spots. The first, C9, an aluminum electrolytic capacitor, could have been sufficiently inductive to form a low-frequency oscillatory circuit in conjunction with other components. I replaced C9, therefore, with two low-inductance 47-µF tantalum capacitors in parallel.

A second component that seemed questionable was RFC1. A high-Q choke in this position could also contribute to unwanted oscillations. The remedy I chose was to place a 470-ohm, 1/2-watt resistor in parallel with this rf choke. These modifications, which are indicated in the accompanying diagram, eliminated the spurious emissions. Another amateur, two blocks away, who checked my transmissions carefully, confirmed my observations. — *Ron Baxley, N4GB, Huntsville, AL*



N4GB suggests this modification of the Heath-201 2-meter amplifier to eliminate unwanted emissions. Two 47-µF tantalum capacitors replace C9 (100 µF) and a 470-ohm resistor is bridged across RFC1.

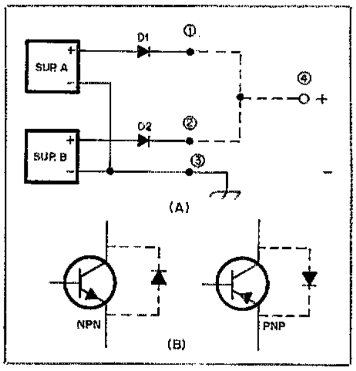
COUPLING TWO LOW-VOLTAGE POWER SUPPLIES

In order to provide an adequate power system for my UV-3 or Midland 510 transceiver, I paralleled two 4-ampere regulated power supplies. They were purchased previously for about $15 each. The arrangement for combining the two supplies provides equalized current drain and voltage. The design credits go to Richard Frankenfield, WA2QAF, of Trenton, NJ, who provided the schematic diagram and adjustment information.

Diodes for the parallel configuration must be able to handle the maximum supply current. Both power supplies (A and B) must be initially independent of each other. There should be separate supplies (as shown) or at least separate secondary windings. In either case, both sources must have equal current capabilities.

With the aid of a voltmeter connected between terminals 1 and 3, adjust supply A for the desired output voltage. Next adjust supply B for the same voltage. This measurement is taken between terminals 2 and 3. The balancing adjustment is made with the voltmeter connected to terminals 1 and 2. *Adjust only one supply to obtain zero voltage between the supplies.* Use the more sensitive meter scales as zero is approached. After reaching a balance, terminals 1 and 2 are jumpered to form a common + supply line to terminal 4.

For inductive-kick protection for the pass transistors, add the diodes shown in drawing B. These are rectifier types of silicon diodes, such as 1N5054 or 1N4005s. Protection is provided by keeping the reverse emitter-collector voltage from exceeding the breakdown specifications. Caution: Observe polarity — check with a VM first! — *Louis H. Roth, W2DKH, Jamesburg, NJ*



Two low-voltage power supplies may be paralleled in the manner shown at A above. D1 and D2 must be capable of handling the maximum supply current. Part B indicates the methods of providing inductive-kick protection for an npn or pnp pass stage. W2DKH, who submitted this idea, indicates that design credits properly go to WA2QAF.

TOO MUCH GAIN FOR THE "ACT" CAUSES PROBLEM

Jim Bartlett's May 1978 *QST* article concerning an audio continuity tester (ACT) impressed me as a mighty handy device to have around the workbench or for use as a code monitor. I constructed a copy of his instrument but failed to get it to perform properly. Completely rebuilding it from scratch did not correct the difficulty.

I suspected the choice of transistors I had used might be at the cause of my problem. This turned out to be the case. The parts list had not specifically indicated the transistors Jim had used.

At the Morgantown, WV, hamfest, where Jim gave a technical talk, he told me that the transistors he used were a Radio Shack RS-2010 for Q1 and a 2N3904 for Q2. I was able to purchase the RS-2010 but unable to acquire a 2N3904 for which I substituted an RS-2023. With these transistors installed, the ACT performed like a charm. Apparently I had provided too much gain by using a Darlington pair for Q1. — *Alvin L. Leedham, WD8NVG, Zanesville, OH*

FOR A SLOW-TURNING CDE HAM-III ROTATOR

If your CDE Ham-III rotator is slow-turning, try replacing the filter capacitor in the control box. Doing so should restore it to normal operation. — *Murray Lampert, VE3MDL, Downsview, ON*

CURING HIGH-POWER TVI

I completely eliminated a very serious TVI overload problem that affected my XL-100 TV set whenever I operated my 2-kW PEP rig in the 20-meter band. There has been no problem, however, with low power. My method may help other amateurs faced with a similar situation.

With a dip oscillator meter set in the absorption mode and tuned to the band causing the greatest TVI, turn the transmitter on and "sniff" along the TV antenna with the dipper. Start near the TV set. No doubt you will find a very noticeable indication on your meter as a result of the standing wave developed on the TV lead.

Add approximately 1/4 wavelength (based on the band you have chosen) of Twin Lead to your TV line and reconnect it to the TV set. Now sniff along the line until you find a minimum reading on the meter. This will indicate a low-voltage point of the standing wave. Cut the line at this point and reconnect the TV set. You should find the overloading minimized or eliminated. Be sure the antenna is connected to the TV set whenever you sniff with the dip meter. — *Sam Peck, W6CQR, Oxnard, CA*

A CURE FOR UNWANTED OSCILLATION IN THE FT-101E

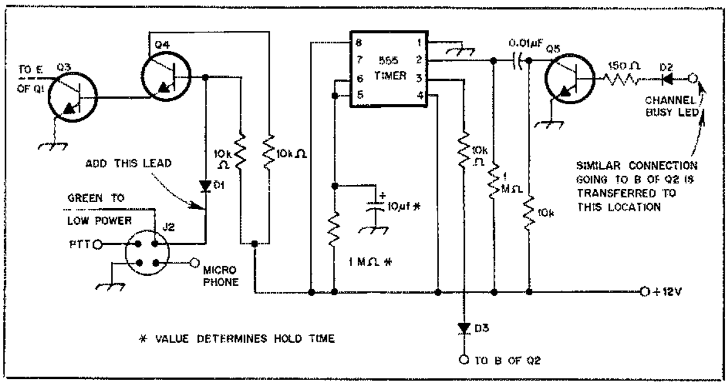
A tip found in the "Fox-Tango Newsletter" provided the cure for unwanted oscillation in my FT-101E. The oscillation would occur after the set had warmed up and when the rig was in the receiving mode. The interfering signal was evident across whatever band was in use, at times nearly blocking the receiver.

It turned out, as the tip suggested, that the problem was an open resistor in the bias section of the circuit board. The open resistor affected the bias of the driver tube, causing it to go into oscillation and making the final amplifier overheat. After a quick fix, the trouble ceased. It's great to be back on the air free of the difficulty. — *Jim Hoffer, WA8OVC, Marshall, MI*

TAPE-RECORDER-DRIVEN SOLID-STATE KEYER MODIFICATION

After constructing the circuit described by K7NVH/8 as presented in the October 1971 *QST* and on page 93 of *Hints and Kinks*, Vol. IX, I found the transmitter keying to be quite heavy in weighting. The tape-recorder volume adjustment was also critical. By removing the 5-µF electrolytic capacitor connected between the base of Q1 and ground, the desired weighting of the transmitted signal was achieved and adjustment of the recorder output level became less critical.

The only change to the circuitry, other than removal of the capacitor, was the use of a 2N2907 general-purpose transistor. This replacement for the 2N4126 in the original diagram is available at Radio Shack stores. The transmitter in use at my station (a much-modified 32S-1) uses only −27 volts at the key jack terminal. For simplicity, the circuit cannot be beaten: A straight key has *more* parts! — *Paul Pagel, N1FB*



This diagram is a circuit change suggested for use with the scanner designed for the KDK 2-meter transceiver and described in the October 1978 "Hints and Kinks." See text for details.
D1-D3, incl. — Small signal diodes, Radio Shack no. 1123 or equiv.
Q3-Q5, incl. — Npn transistor, type 2N3692 or equiv. Resistances are shown in ohms.

ADDITIONAL SCANNER MODIFICATION FOR THE KDK-144

KDK-144 owners who made the scanner modification described in the October 1978 "Hints and Kinks," should be interested in this refinement which provides further operating benefits. With this new modification the scanner will lock on a signal for about five seconds and then resume scanning. The scanner will run only when the power switch on the microphone is in the LO position. Switching to high power locks the KDK on frequency for both receive and transmit. The accompanying diagram, illustrating the new modification, was prepared with the assistance of W9EEL.

Q3 and Q4 can be mounted in the PLL compartment of the KDK. Q5 and the 555 timer must be mounted elsewhere. I suggest a position behind the front panel and above the main tuning switch. As with the 1978 KDK modification, no additional external switches are needed. — *Robert Shoemaker, W9MTU, Anderson, IN*

OIL WHERE YOU WANT IT

When the blower motor on my TS-820 seemed sluggish, I pulled the fan, cleaned the blades and attempted to lubricate the motor. Because the pin holes for oiling are so small I was not able to insert the tip of a sewing machine oil can. The dilemma was solved by my XYL who works at a local pharmacy. She suggested the use of a no. 3CC25G5/8 hypodermic needle. With this 18-cent plasticized syringe filled with oil, I can now inoculate my motor when necessary, with no spills, no drips and every drop of oil going where it belongs. With all the blowers in rigs today, I'm sure many amateurs will find this kink of immense help. — *Harry J. Drummond, W8WX, Fairmont, WV*

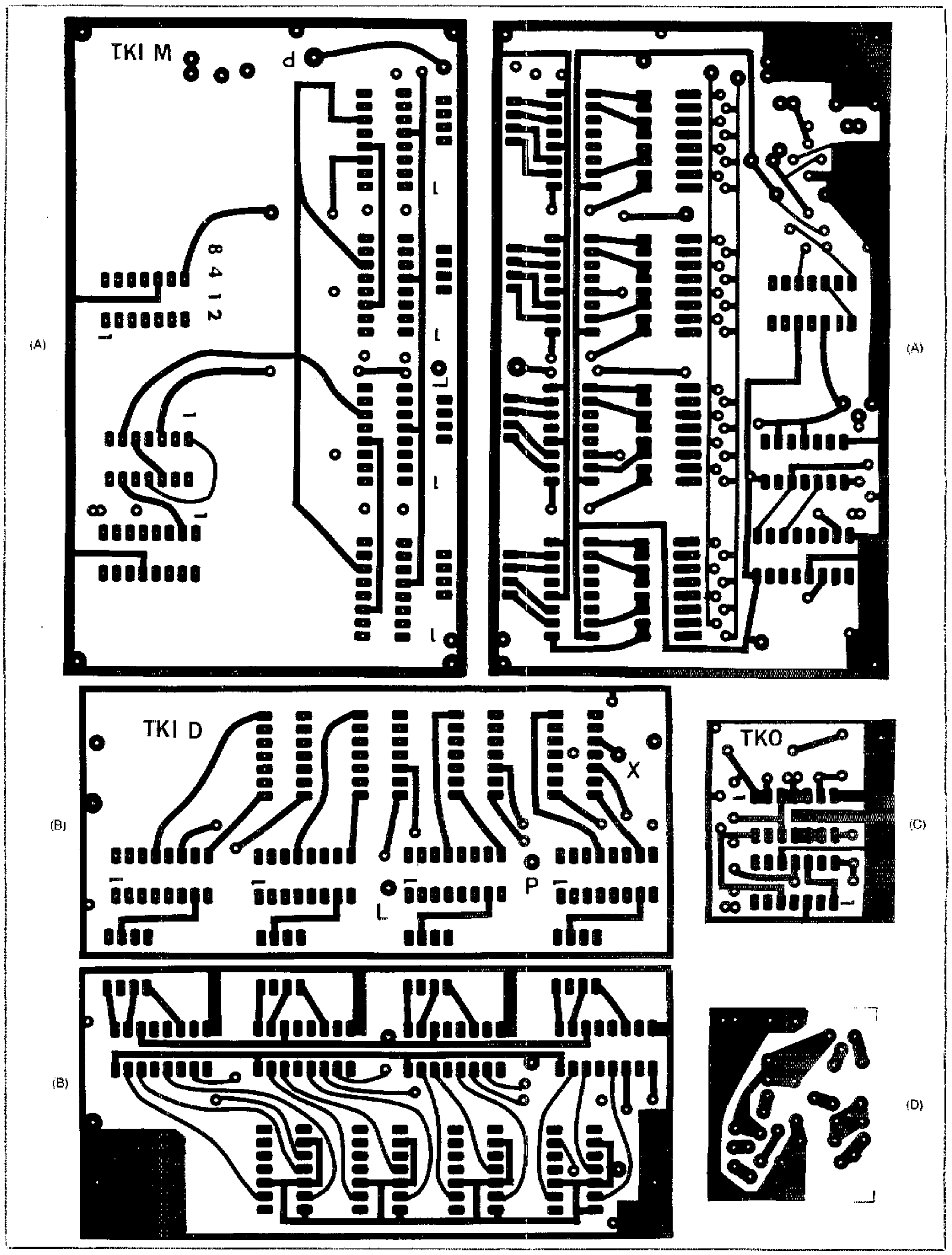
SOLDERING TARNISHED COPPER WIRE

To solve the problem of cleaning aged copper or copper-clad wire prior to soldering, heat the wire to a dull pink and then dip it in alcohol keeping it there until the bubbling stops. Then remove it from the fluid and the wire should be very clean. In order not to use an excess amount of alcohol, I use a 1-inch (25-mm) diameter piece of pipe with a plug in one end for the container. — *Glenn Markley, W8VLB, Mansfield, OH*

ACCU HINTS

☐ I have found that the Accu-Keyer and Accu-Memory work very well with type 74LS00 logic devices. This low-power Schottky series is pin compatible with the standard 7400 series, has the same general speed characteristics, but consumes only 1/3 to 1/4 the power of the standard series. However, it *is* important that if you use the low-power Schottky series, all chips should be of this same series. Otherwise, you could run into problems with regard to output loading. Thus, just substitute a 74LS00 for the 7400, 74LS02 for the 7402, 74LS74 for the 7474 and so on. This reduction in power has enabled me to get by with a very simple power supply, using a 7805 three-terminal regulator.

In the original Accu-Memory article (August 1975 *QST*) and supplemental notes (July 1976 *QST*), the decimal point in the display is shown as connected to the run-switch return. This has the decimal point on *any* time the unit is used as a keyer, when loading the memory or when sending memory. If you move the decimal-point return wire to pin 13 of U4 in the memory, it will function as a memory operating signal going on only when loading or sending memory and will not light when just keying. — *Harlan Bercovici, WØMYN (Life Member), Littleton, CO*



Circuit-board etching patterns for projects in this issue of *QST*. Patterns are shown at actual size from the etched side of the board, with black representing copper. The boards represented at A-A and B-B are double sided with plated-through holes (or appropriate through-board connections). Those at C and D have foil on one side only. The patterns at A through C are for the digital frequency readout (see Fig. 3, p. 14). At A is the pattern for the main board, at B for the display board, and at C for the oscillator board. As shown here the left edge of the left-hand pattern at A aligns with the right edge of the right-hand pattern, and the top edge of the upper pattern at B aligns with the bottom edge of the lower pattern. The pattern at D is for the Heath HW-104 RIT modification (see Fig. 2, p. 18).

Technical Correspondence

Conducted By
Doug DeMaw,* W1FB

The publishers of QST assume no responsibility for statements made herein by correspondents.

ONLY AN EMBER REMAINS!

☐ I thought you would be interested in the picture of my QRO mobile loading-coil form (Fig. 1). The rig is an FT-301-D and a Metron MA-1000 linear amplifier. The coil was wound with no. 10 wire. The coil form shown in the photograph is the outer cover for the loading inductor. It is made of PVC pipe. The end plates are made of aluminum. The inner coil form was also made of PVC tubing (grooved). When the damage occurred there was a high VSWR which was caused by a camping trailer being close to the van on which the antenna was mounted.

QST seems to be neglecting the subject of mobiles and related projects. I'm speaking about hf-band mobile, that is. We need to see such things as solid-state or tube-type amplifiers, multiband antennas — the works. — *Dwight McSmith, 500 Chapel St., Hampton, VA 23669*

[Editor's Note: The charred outer sleeve shown in Fig. 1 is fair warning that PVC materials are not well suited to high levels of rf voltage. Nylon insulating material is very poor under similar conditions. This was observed some years ago when the column editor attempted top loading on a 50-foot Rohn tower for operation on 160 meters. A PVC coil form was used. It lasted only a few moments after power was applied to the antenna. The result was a coil form which closely resembled the one in Fig. 1!

Concerning the *QST* articles on hf-band mobiling . . . well, the popularity of vhf and uhf fm-repeater operation has depleted the number of hf-mobile operators in recent years. As a consequence the editors of *QST* are not receiving articles on the general subject. We would welcome contributions concerning hf-band mobile hardware and techniques. If some of you are developing equipment for that style of operating, please send the details to us for possible publication in the journal.]

*Senior Technical Editor, ARRL

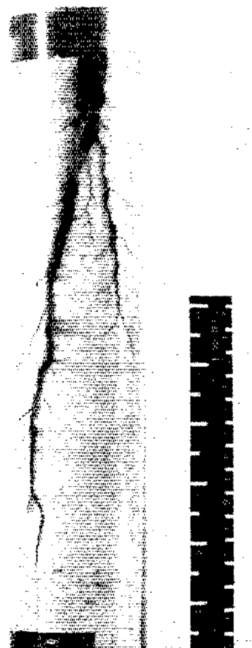


Fig. 1 — This charred PVC tube was the outer covering for the loading coil of a QRO-mobile setup. The dielectric broke down under conditions of high rf voltage.

MORE ON SOLID-STATE PA MATCHING NETWORKS

☐ When I experimented with Class C tuned transistor PAs about a decade ago I noticed the same phenomenon that W7EL reported in October 1978 *QST*. I also had the impression that the matching sections derived from vhf/uhf circuits are insufficient for hf power amplifiers.

The solution I adopted to cure this is somewhat different, however. I also place a capacitor (Cp) from collector to ground, but, as a starting value, the reactance (X_{Cp}) of this capacitor is about the same as the collector load resistance ($X_{Cp} = Vcc^2/2P_o$), giving a loaded Q of 1.

In multiband transmitters, therefore, the collector choke remains the same and is chosen for the requirements of the lowest band in use (typically 80 µH for an 18-volt, 2-watt output PA). The capacitor, Cp, is being switched from band to band together with the other tank-circuit components.

The loaded Q = 1 will stop the "ringing" phenomenon, but will also decrease the efficiency to 50 to 60 percent. On the other hand, the PA becomes very insensitive to mismatch, even at full drive. For better efficiency and slightly reduced mismatch safety the loaded Q may be reduced to about 0.7. In higher power PAs where transistors with high internal capacitances are used, the Q may be reduced even further, depending on the efficiency obtainable.

I purposely place this capacitor (Cp) from collector to ground, not to the emitter. As an additional measure for mismatch protection I recommend a small, unbypassed emitter resistor, which causes a dc drop of about 0.5 volt when the stage is tuned correctly. Placing Cp to the emitter in this case would form a *regenerative* circuit.

When using vhf/uhf transistors for hf PAs I further recommend reducing Vcc to 0.5 $Vceo_{(sus.)}$ or less for fail-safe operation, because the breakdown voltages are lower at dc and lower frequencies than at vhf/uhf.

Another trouble which may show up in tuned Class C transistor PAs is *frequency dividing*. The tank circuit, therefore, must have a configuration without any resonance at one half, one third, etc., of the operating frequency. This is especially important if multisection pi networks are to be used for high harmonic suppression, or if a low-pass L section is to be added for antenna tuning.

Subharmonic resonances may be avoided by incorporating a parallel-resonant circuit (Fig. 2) or a series-resonant circuit (Fig. 3). The components marked * are selected by means of the band switch. I have been using the circuit of Fig. 2 in my portable 5-band QRP transmitter (2N3553 PA) since 1969. It will match all random-length wires as well as coax-fed antennas.

The circuit of Fig. 3 will have somewhat better harmonic suppression, but the antenna must be safety-grounded by means of a separate choke. Therefore, this scheme will be

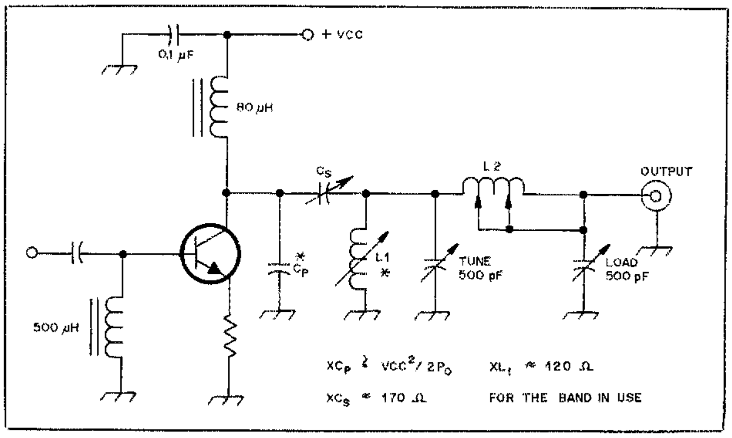


Fig. 2 — Details of the parallel-resonant circuit.

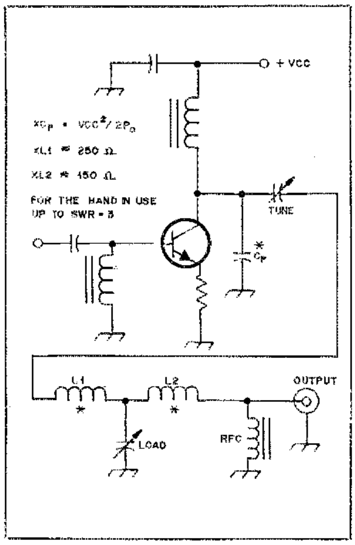


Fig. 3 — Circuit for the series-resonant condition.

good for coax-fed antennas and may take a rather high SWR, up to 3:1. — *Hans-Joachim Brandt, DJ1ZB, Lohensteinstrasse 7/b, 8000 Munich 60, Federal Republic of Germany*

TOWARD SAFER ANTENNA INSTALLATIONS

□ The article describing installation techniques for medium and large Yagis (June 1979 *QST*) was read with considerable interest. Much of the material will be quite helpful to our colleagues who have no previous experience installing such antennas. There are, however, potentially fatal hazards in one or more of the suggestions. The following comments are offered:

1) Two pulleys, or blocks, should be used instead of one. Professional tower and antenna erectors never hoist in the manner K7NR suggests. Rather, they rig a second block, usually a snatch block for ease in rigging the hoist line, at the base of the tower. Thus, the pulling tension is applied horizontally along the ground to this pulley, thence vertically and parallel to the tower to the top pulley. This results in only thrust being imposed upon the tower, rather than a possibly significant lateral strain. The method shown in K7NR's sketch is particularly dangerous, in that the pulling strain is over the tower and against the restraint of the temporarily relocated guys. This could possibly result in pulling the tower over — even onto the people pulling on the hoist line.

2) It is safer to use mechanical power, rather than human power, to hoist an antenna, gin pole and the like. With the rigging described above, assuming fortunate lawn or driveway space, one can use the family automobile to pull on the hoist line. Lacking adequate space for such, a husky lawn or garden tractor can be used anywhere there is room enough to put up a large antenna. My then-11-year-old son operated my tractor some years ago in helping to install one of my Yagis. In any case, even with people furnishing the motive forces, horizontal pulling is to be preferred.

3) The temporary relocation of guys is not unusual in these kinds of installation jobs. However, a guying angle of 170 degrees is potentially hazardous to people on and near the tower. With such an arrangement it is difficult if not impossible to properly tension such guys. An improperly guyed tower is no place for someone to work, especially with a large antenna swinging from a hoisting line and gin pole. It it is necessary to relocate one or more guys temporarily, a much smaller angle should be used. It is generally possible to rotate the elements in a vertical plane as they pass the guys to obtain the necessary clearance. If not, elements can be actually attached at the top of the tower as the boom moves up. This latter method is inconvenient, to say the least. — *W. R. Gary, K8CSG/5, 14834 Falling Creek Dr., Houston, TX 77068*

MORE WOODPECKER THOUGHTS

□ Regarding the Siberian "woodpecker" which was reported in October 19, 1979, *Ham Radio Report*, no. 273, I too have noticed this buzz-saw phenomenon for the last several years. At first, I likewise thought it was deliberate jamming from some unwanted source.

However, since I have been checking WWV every night for the last seven or eight years, I've heard this jamming at times (even on CHU). I am an amateur meteorologist and am studying the weather. I noted this "woodpecker" effect occurred whenever there was a deep storm (intense low pressure) over the Midwestern states: The woodpecker would buzz away, making reception intolerable. When the storm center moved along, reception would clear!

Back in 1929 we thought the weather occurred in only the troposhere. During WWII the jet stream was discovered above this lower level. To this day no one has a good explanation for the cause of this effect. Anyway, this means the weather extends into the stratosphere.

Now, noting the propagation from WWV and correlating it with the progression of weather storms, the effect of these deep lows must extend into the ionosphere, affecting the Heaviside layers. The waves or ripples of these layers will seriously distort the reflection of radio propagation, thus causing the so-called woodpecker buzzing. If this is the case, don't we owe the U.S.S.R. an apology? — *Keith Rhodes, WB2AOT, 448 Plymouth Dr., Syracuse, NY 13206*

[Editor's Note: It is entirely possible that other phenomena cause buzzing types of radio interference, but it is well established that Russian over-the-horizon, high-power radar is the primary source of that woodpecker sound that has disrupted communications in many parts of the world. Apologize? The government thus far has been unable to get cooperation from the U.S.S.R. concerning the protests it has filed!]

BROADBAND BALUN BENEFITS

□ This is a comment on W1FB's "Antenna Accessories for the Beginnner" (February 1979 *QST*) and KA4GMG's letter in "Technical Correspondence" (November 1979).

In *QST*, baluns are offered for sale at prices from less than $10 to almost $50. It is to be expected that there will be differences in quality and performance among them, and no balun is perfect. Nevertheless, it is possible to build transmission-line baluns that are essentially flat over a 100:1 frequency range, particularly if a ferrite toroid core is used. See W2FMI's article (January 1976 *QST*).

It is not the purpose of a 1:1 balun to improve SWR or to increase radiated power. The purpose is to transfer power to a balanced antenna from an unbalanced coaxial line. Thus the name "balun" from *bal*anced-to-*un*balanced.

If the balun is terminated properly it can prevent radiation from the coaxial line by currents that otherwise may flow on the outside surface of the coaxial shield. On transmit this probably is of little consequence, although it may cause TVI. But on receive it is a different story. Most manmade noise is vertically polarized. A horizontal dipole discriminates against this noise. But if there is pickup from the vertical coaxial cable the discrimination is reduced. I have observed improvements in signal-to-noise of 2 or 3 "S" units by use of a balun in a noisy location. — *Jack Althouse, K6NY, P. O. Box 455, Escondido, CA 92025*

VARIABLE MEMORY FOR THE "TO MSG. KEYER"

□ This unit is made for the keyer described by Chet Opal in February 1978 *QST*. The unit is connected so that it counts bits after a character has been sent. If space exceeds a number of bits selected on this unit, the binary counter (CD4040BE) will be reset. The circuit diagram of Fig. 4 is shown wired for 12 bits. It will vary, however, between 12 and 13 bits. Theoretically, distance between words is 5 bits, and if space exceeds this it means there is no more message to be sent. But, only the well-trained operator can hope to keep this figure strictly, and a higher number of bits should be selected. If 12 is used, that will sound like a suitable space between the end of one message and the repeated one.

In order to make the keyer automatic (repeating messages) an spdt switch should be wired in parallel with S2. A switch should be connected (as shown) to determine whether the unit shall be *out* or *in* use. The original circuit board must be modified by inserting a 33-kΩ resistor between Q11 (CD4040) and S (CD4013) as shown. — *Jan Martin Noeding, LA8AK/G5BFV, A/STT Televerket, N-4801, Arendal, Norway*

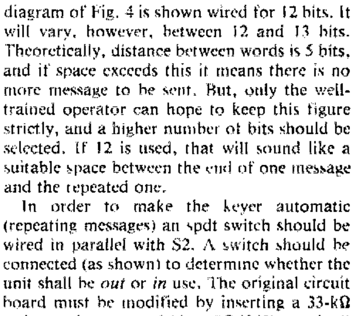
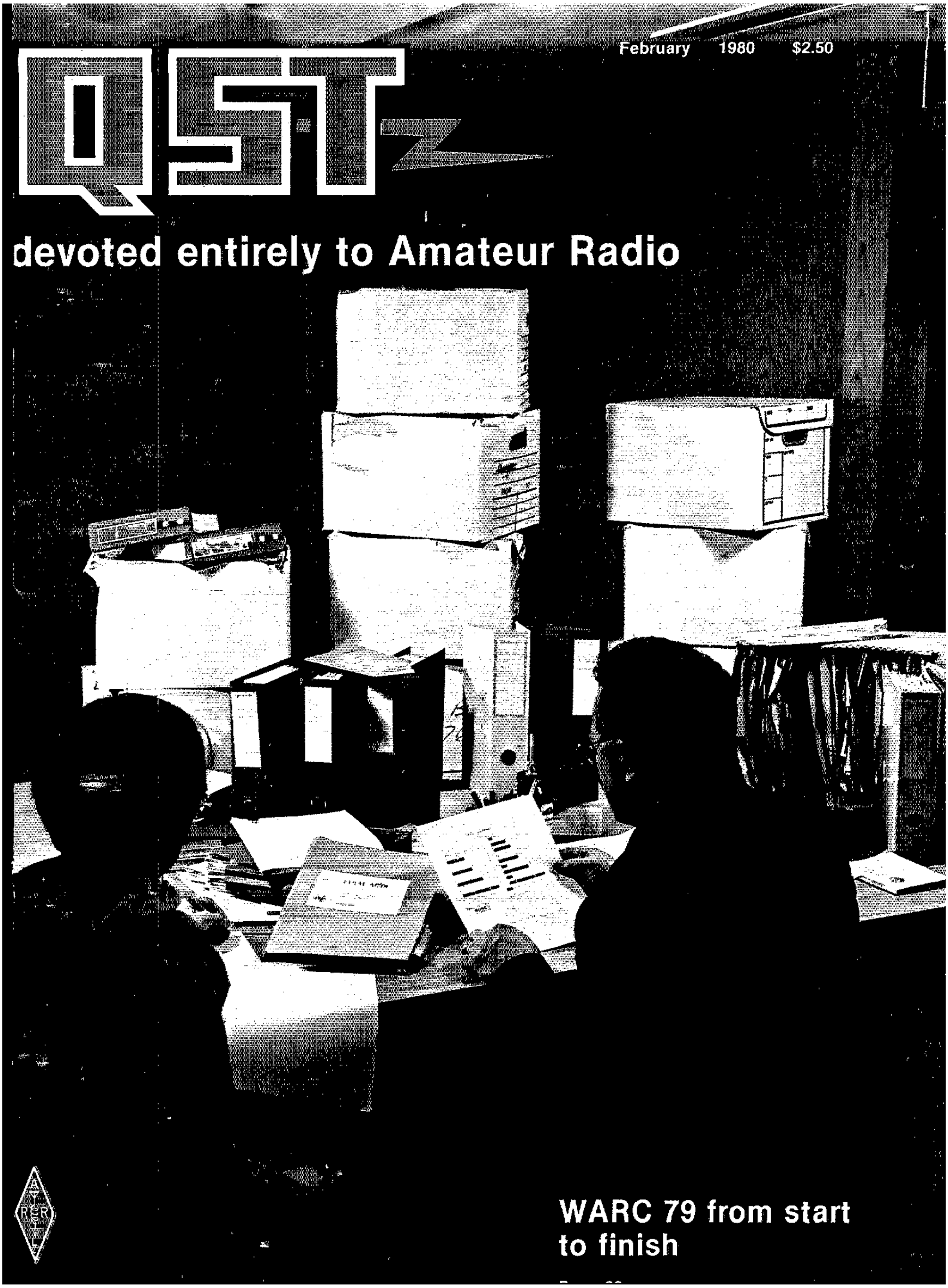


Fig. 4 — Circuit for the variable memory.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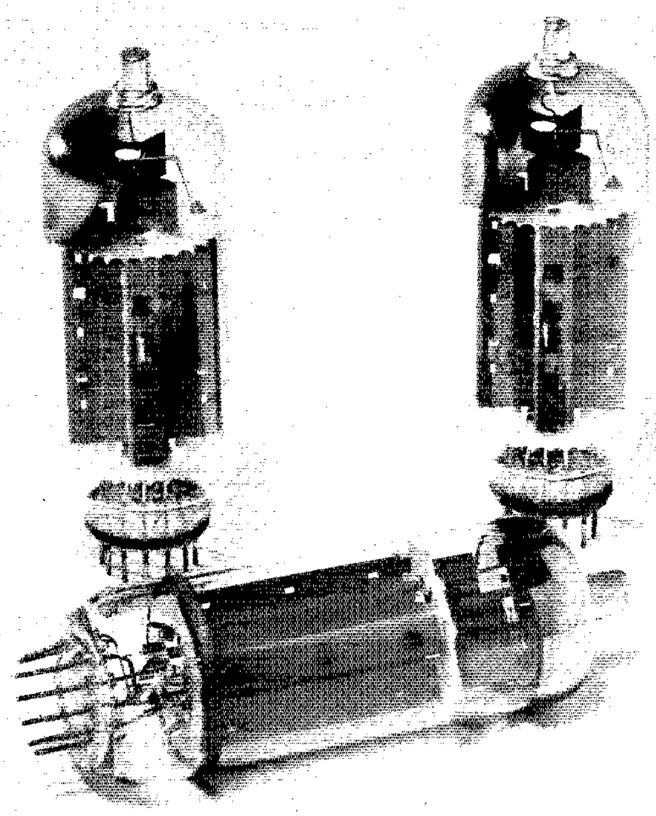
THE COVER

WARC-79, from start to finish, was a mountain of paper work, all finally condensed into the "final acts." See pages 52-71.

Contents

Some Thoughts About TV Sweep Tubes



There's nothing wrong with using TV sweep tubes as rf power amplifiers. Here are some observations.

By Doug DeMaw,* W1FB

A stigma seems to have developed concerning the use of horizontal-output tubes (sweep tubes) in amateur transmitters. Some operators fear them because of their thermal fragility and others claim they're no good as linear amplifiers for ssb operation. Sure, there's a bit of truth connected with both concerns, but there are some good features too!

In many parts of the world it is easier to purchase TV sweep tubes locally than it is to find a 6146B. Surely this is a plus feature. Also, a number of sweep tubes cost less than 6146s do.

In simple terms, the thermal-fragility problem can be explained by stating that the key-down (continuous-carrier mode) is limited to short periods compared to that of 6146s. Too long a period (generally in excess of 30 to 45 seconds) will cause excessive tube heating and subsequent damage or failure. The reason for this limitation is that sweep tubes are designed for high peak currents of short duration (pulse service), but not for high levels of

*Senior Technical Editor, ARRL

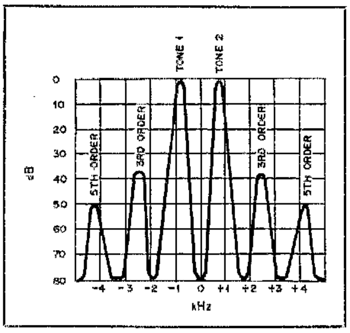


Fig. 1 — A classic spectrum display of what would be seen at the transmitter output during a two-tone IMD test. The maximum power output is represented by the peaks labeled tone 1 and tone 2. The 3rd- and 5th-order distortion products are displayed to the left and right of the desired signal. The 3rd-order products are 39 dB below full power and the 5th-order products are 50 dB below full output. Ideally, there would be no IMD products showing, and there would be some noise appearing as "grass" near the baseline of the spectral display. The higher the level of the 3rd- and 5th-order products, the lower the quality of the ssb signal.

Table 1

Some Sweep-Tube Parameters

Type	*C (Input) (pF)*	*Input Resonant Frequency (MHz)*	*C (Output) (pF)*	*Output Resonant Frequency (MHz)*	*Probable*** Upper Frequency Limit of Operation (MHz)*
6GJ5	19.1	190	10.0	190	150
6HF5*	25.5	86	16.3	141	60
6HF5**	26.7	100	16.3	141	75
6JB6	19.1	190	10.5	200	145
6JE6	24.3	82	14.5	152	60
6JM6	17.2	200	10.3	194	150
6JG6	22.9	187	14.7	226	150

*One grid connection.
**Two grid connections.
***75 percent of self-resonant frequency.
Data courtesy of Sylvania

continuous current. They are entirely suitable, however, for ICAS (intermittent commercial and amateur service) operation.

In linear-mode service, they do not yield the IMD (intermodulation distortion) quality which is typical of 6146 tubes at full rated power, respectively. In a properly designed and operated amplifier, however, it is possible to obtain sweep-tube linearity which nearly approaches that of the 6146 tube. For example, the Yaesu FT-101E which was reviewed in September 1976 *QST* exhibited 3rd-order distortion products which were 34 dB down from full output. The '101 uses sweep tubes in the PA. The Kenwood TS-820, which contains 6146Bs in the PA, was reviewed in the same issue. The 3rd-order products from the '820 were 39 dB below full power.

The worst-case IMD observed in the ARRL lab from a rig which utilized sweep tubes was −27 dB. The ARRL technical staff feels that an acceptable level for 3rd- and 5th-order distortion products (see Fig. 1) is 30 dB or greater below full power. Therefore, the FT-101E and TS-820 units are considered above average in terms of IMD.

The now-defunct Galaxy Company once marketed a 2-kW PEP linear amplifier (model 2000+) which contained 10 sweep tubes in parallel. The amplifier operated Class AB1 and was grid-driven across a 50-ohm noninductive power resistor. The measured 3rd- and 5th-order distortion products were 31 dB below full amplifier power output.

Another example of acceptable performance was seen when a linear amplifier built by the author was tested by means of a spectrum analyzer. The circuit contained four 6KD6 sweep tubes in parallel, cathode driven and in Class AB1. The IMD products were observed at −30 dB or better. Peak output power was 800 W.[1]

Operating Frequency

Generally speaking, TV sweep tubes are able to give acceptable performance up to 30 MHz. The 6146B, on the other hand, is good well into the vhf region.

The useful upper frequency limits of sweep tubes are determined by the internal lead lengths, the input capacitance and the output capacitance. Since these tubes were designed for low-frequency TV service (15.750 kHz), the manufacturers are not concerned with the aforementioned "problem causers." The high terminal capacitances of the tubes tend to shunt the rf currents to ground. This malady becomes more pronounced as the operating frequency is increased. The high-input C makes the tube hard to drive and presents impedance-matching problems. The high-output C can cause excessive currents inside the tube, causing gradual performance degradation or complete failure. Therefore, it is prudent to choose sweep tubes with short internal leads and minimum terminal capacitance. The effect of long internal leads is one of the lead inductance resonating with the internal capacitance at some specified high frequency. This condition can cause stray rf currents to be high, ultimately harming the tube. Vhf parasitic oscillation is enhanced greatly if the tube chosen has input and output self-resonant frequencies which are close in frequency. Table 1 shows how various popular sweep tubes compare in this respect. Parasitic chokes of the type shown in Fig. 2 (Z1) can be installed to prevent parasitics.

The writer made but one attempt to use a sweep tube at vhf. A 6JB6 was hooked up for grounded-grid operation and driven from a 5-W exciter. An output of 25 watts was obtained, but the tube efficiency was rather dismal — roughly 30 percent after considerable optimizing. The tank circuit was designed to absorb the tube output capacitance (Fig. 3). The 19 pF of input C presented no special problems.

[1]Notes appear on page 15.

The Problems of Parallel Use

No matter what tube a builder may choose for the amplifier, paralleling two or more such tubes creates design problems. A matter of special concern is the current drawn by each tube in the string. Dynamic balance is essential to ensure that no single tube in the combination "hogs" the plate current. If, for example, six 6HF5s were connected in parallel, and the g_m (transconductance) of one was substantially higher than the rest, the one with the high g_m would probably be driven well beyond its safe dissipation rating. The result would be disastrous as you sat and watched the anode turn red, just before the glass envelope melted or cracked! Sweep tubes are especially prone to this ailment because of their high g_m ratings: The 6KD6, for one, has a transconductance of 14,000 micromhos!

A not-so-practical solution to the problem of current sharing is to install a matched set of tubes. For the amateur this is not good news, as *many* tubes would be necessary in order to grade them out for the matched set required in the amplifier.

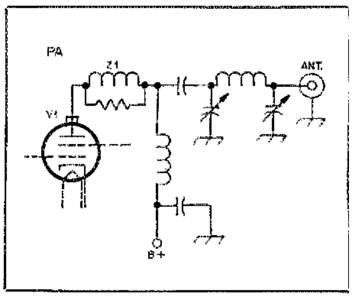


Fig. 2 — Schematic illustration of an amplifier which contains a parasitic suppressor (Z1). This component can be fashioned from a 100-Ω, 2-watt composition resistor. The coil is wound over the resistor body and made common to the resistor pigtails. Eight turns of no. 20 enameled wire are suitable for the coil.

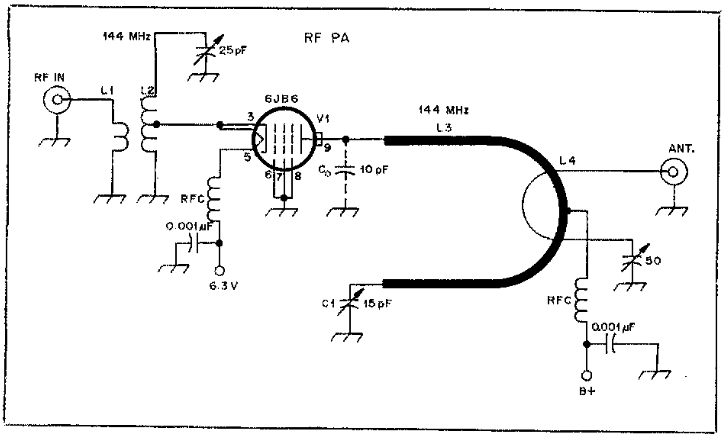


Fig. 3 — Circuit of an experimental 144-MHz grounded-grid amplifier which used a 6JB6 sweep tube (see text). C_0 is the tube output C. L3 is dimensioned so that resonance occurs when C1 is set at 10 pF.

A simple method for balancing the tubes was worked out by the author (note 1). The scheme is shown in Fig. 4. With full drive to the amplifier, the bias-adjust control for each tube is tweaked for equal plate currents. The resting plate currents may be unequal as a result, but they will not be too low to affect linearity of the amplifier. Although separate meters are shown for each tube in Fig. 4, they aren't necessary. A single 0-1 ampere meter can be employed to meter all four tubes at one time. Tube balance can be measured by installing a 10-ohm, 1-watt resistor in series with each cathode lead. R1 through R4 are then adjusted to obtain equal voltages across the 10-ohm resistors at peak drive. When choosing sweep tubes for grounded-grid service (Fig. 4), it is mandatory to select the types which have the beam-forming plates brought out to a separate base pin. This connection should be returned to rf ground along with the

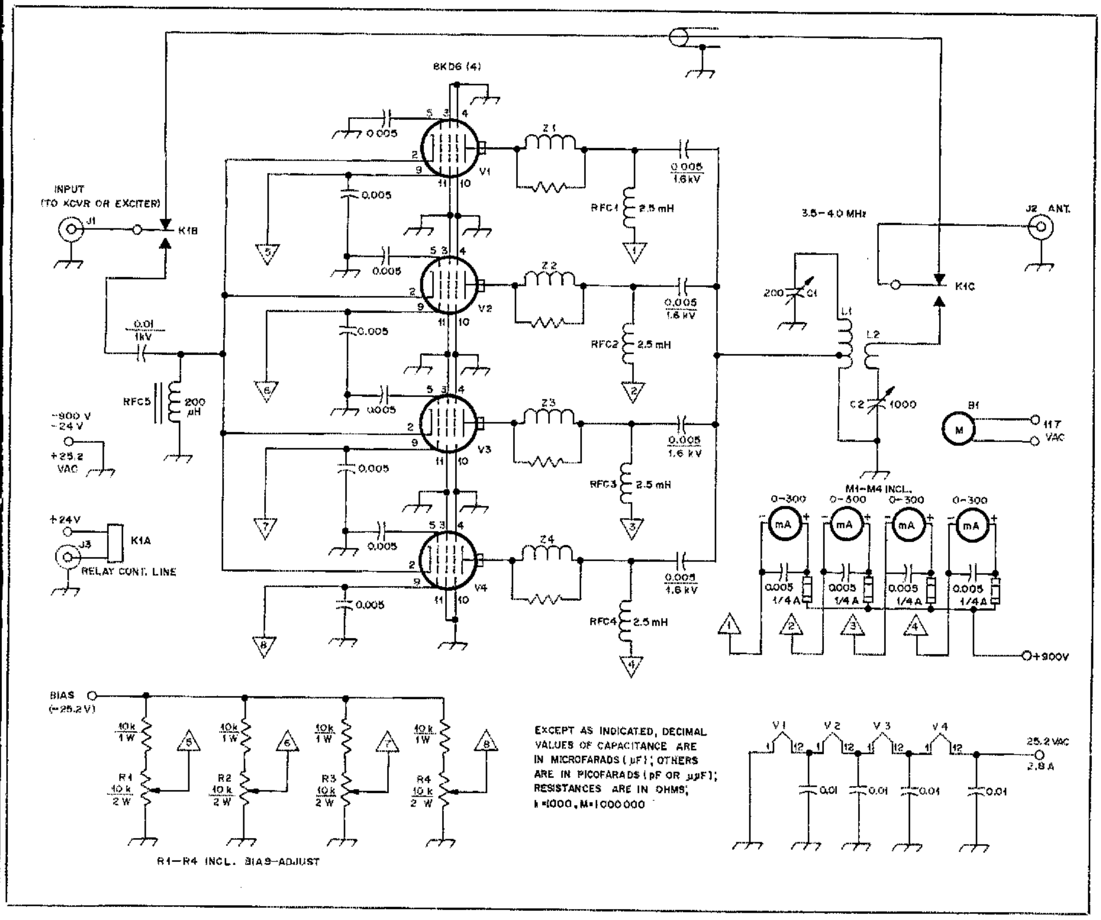


Fig. 4 — A grounded-grid sweep-tube linear amplifier which contains four 6KD6 tubes. Dynamic balance is ensured by means of R1 through R4. These controls are set to provide equal plate currents for the four tubes at peak drive periods (see text and note 1). This circuit originally appeared in July 1968 *QST*, page 31.

control and screen grids. Some sweep tubes have their beam-forming plates connected to the cathode *inside* the tube. In grounded-grid service, this will lead to amplifier self-oscillation, especially as the operating frequency is increased.

Another complication which results from paralleling several tubes is a marked increase in the combined input and output capacitance. Needless to say, as either of these values become elevated, the greater the unwanted rf-shunting effect discussed earlier. Severe limitations can be imposed on the upper frequency range of the amplifier. For example, the 6KD6 tube has a rated input C of 40 pF and an output C of 16 pF. Six of these tubes in parallel would yield 240 and 64 pF, respectively. The output capacitance could be absorbed in the plate-tank circuit, but the input capacitance would have to be dealt with by means of matching networks similar to those used with rf power transistors. In fact, the plate impedance of several sweep tubes in parallel becomes pretty low, causing the designer to move in the direction of transistor matching networks. A six-tube Class B amplifier (sweep tube) might develop 1 ampere of plate current at peak drive. If the plate voltage were 900 — a typical value for amateur service — the plate impedance would be approximately 572 ohms, as derived from

$$R_L = \frac{E_p}{1.57 \times A}$$

where

E_p is the plate voltage,

R_L is the plate impedance in ohms and

A is the plate current in amperes.

In basic terms, the low-impedance and high-output C makes conventional tank circuits impractical at frequencies above 40 meters. If a pi network with a loaded Q of, say, 12 were desired, the resultant values of C and L would become quite impractical at the upper end of the hf spectrum. For this reason, transistor types of networks become more desirable.[4]

Operating Parameters

In 1964, Sylvania Electric Products Inc. took the trouble to test their sweep tubes for rf service up to 30 MHz. Data were compiled for Class C and Class AB1 operation for six popular tubes. Tables 2 and 3 contain the information as it was presented in *Sylvania Industrial News* for November and December 1964. Table 1 was published by Sylvania at the same time. These are probably the only meaningful rf data developed for deflection tubes.

It was mentioned earlier that a plate voltage of 900 was typical for sweep tubes in amateur service.[3] That statement should be clarified by saying that 900 is more typical in homemade linear amplifiers than it is in commercial equipment. Tables 2 and 3 specify 500 volts as

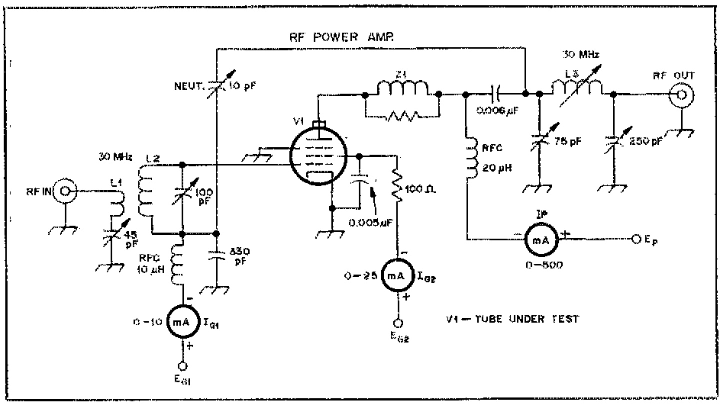


Fig. 5 — Schematic diagram of the 30-MHz test circuit used by Sylvania to collect rf operating data for six common TV sweep tubes. Z1 is similar to that of Fig. 2. L2 and L3 are chosen to provide a high operating tank Q.

Table 2

Class C Operation ICAS — 30 MHz

Type	(1) E_{G1} V dc	(1) E_{G2} V dc	(1) E_p V dc	Peak E_{G1} V rf	(1) I_{G1} mA dc	I_{G2} mA dc	I_p mA dc	Grid 1 Driving Power (Approx.) Watts	Grid 2 Dissipation Watts	Plate Input Power Watts	RF Power Output Watts	Efficiency (%)	Plate Dissipation Watts	(2) Circuit Loss Watts
6GJ5	−75	200	500	61	5.0	14.9	180	0.43	2.99	90.0	62.7	69.5	22.0	5.3
6HF5	−85	140	500	67	8.0	12.5	232	0.76	1.75	116.0	77.0	66.0	35.0	4.0
6JB6	−75	200	500	61	5.0	13.3	180	0.43	2.66	90.0	62.7	69.5	22.0	5.3
6JE6	−85	125	500	72	8.0	17.2	222	0.82	2.15	111.0	76.3	69.0	30.0	4.7
6JM6	−75	200	500	57	4.0	13.7	180	0.32	2.72	90.0	61.1	67.9	22.0	6.9
6JG6	−80	150	450	67	8.0	20.0	202	0.75	3.0	91.0	63.0	69.3	21.0	7.0

(1) Selected as optimum operating conditions.
(2) Calculated power lost in tank circuit.
Courtesy of Sylvania

Table 3

Class AB1 Operation ICAS — 30 MHz

Type	(1) E_{G1} V dc	(2) E_{G2} V dc	(2) E_p V dc	(1) I_p 0 Signal mA dc	I_{G2} mA dc	I_p mA dc	Plate Power 0 Signal Watts	Grid 2 Dissipation Watts	Plate Input Power Watts	RF Power Output Watts	Peak Envelope Power (PEP) Watts	Efficiency (%)	Plate Dissipation Watts	(3) Circuit Loss Watts
6GJ5	−43	200	500	30	3.8	85	15	0.76	42.5	17.5	35.0	41.5	22.0	3.0
6HF5	−46	140	500	40	4.5	133	20	0.63	66.5	28.8	57.6	43.0	35.0	2.7
6JB6	−42	200	500	30	4.2	85	15	0.84	42.5	17.5	35.0	41.5	22.0	3.0
6JE6	−44	125	500	40	3.9	110	20	0.49	55.0	23.4	46.8	42.6	30.0	2.6
6JM6	−42	200	500	30	4.4	85	15	0.88	42.5	18.3	36.6	43.1	22.0	2.2
6JG6	−35	150	450	30	4.5	98	13.5	0.67	44.0	18.9	37.8	43.0	21.0	4.1

(1) E_{G1} adjusted to indicated I_p (zero signal).
(2) Optimum conditions for providing best linearity and efficiency.
(3) Calculated power loss in tank circuit.
Courtesy of Sylvania

the upper limit, but some transceiver manufacturers use up to 650 volts. Most sweep tubes have sufficient internal-element spacings and insulation to take up to 1000 volts. The test circuit used by Sylvania is given in Fig. 5.

Closing Comments

Are sweep tubes suitable for amateur service? Tables 1, 2 and 3 offer hard proof that they can be used advantageously. They seem to be especially suited to Class C service in terms of efficiency. The cw operator should find them excellent for the purpose.

Practical experience has proved that these tubes can be pushed in excess of their ratings at low duty cycles. Remember the days when some of us ran our Class C 807s or 1625s with 1000 plate volts and higher-than-rated plate current? Rule number 1 was "don't hold the key down for more than a few seconds." If this rule were observed, many hours of operation at elevated power output could be had, but the longevity of the tubes was shortened as a tradeoff. If the reader wishes to "push" some sweep tubes (although it is not recommended), he or she should be prepared to replace them more frequently than if they are held within the prescribed ratings. QST

Notes

[1]DeMaw, "Some Ground Rules for Sweep-Tube Linear-Amplifier Design," *QST*, July 1968, p. 30.
[2]DeMaw and Hayward, *Solid State Design for the Radio Amateur*, chapter 4, ARRL, 1977.
[3]DeMaw, "A Husky Power Supply for Sweep Tube Amplifiers," *QST*, December 1969.

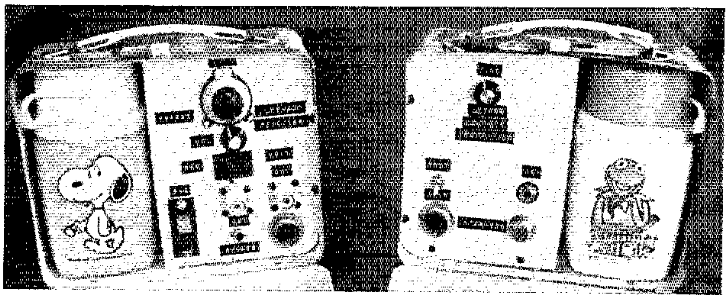
Strays

ABOUT PROJECT GOODWILL . . .

☐ No, it's *not* dead! The project was put on ice while the staff was at WARC-79, but it is now back in full swing, and we're slowly but surely matching a backlog of generous donors to recipients in developing countries. We apologize for this inevitable delay, but want to assure those clubs and individuals who have been patiently awaiting some word from Hq. that your money is safe, and you will soon be matched.

The success of the project was evident in Geneva during WARC, with favorable remarks being received from a number of developing countries' administrations. In addition, several kits were distributed on site in Geneva to delegates who expressed a genuine interest in promoting the Amateur Service in their countries.

Watch *QST* for periodic updates on the project. And thanks!



This novel job of packaging the Herring-Aid Five receiver (July 1976 *QST*) in the Charlie Brown lunchbox and the Tuna-Tin 2 transmitter (May 1976 *QST*), CB Slider (March 1977 *QST*) and Codzila 1 (February 1977 *QST*) in the Muppet Show lunchbox was done by Bill Barfield, WB5PRR, Satartia, MS. Bill built the panels with sheet metal. Since the thermos bottles still fit in the units, carrying liquid refreshment is easy.

DO YOU SEND QSL CARDS TO BOX 88?

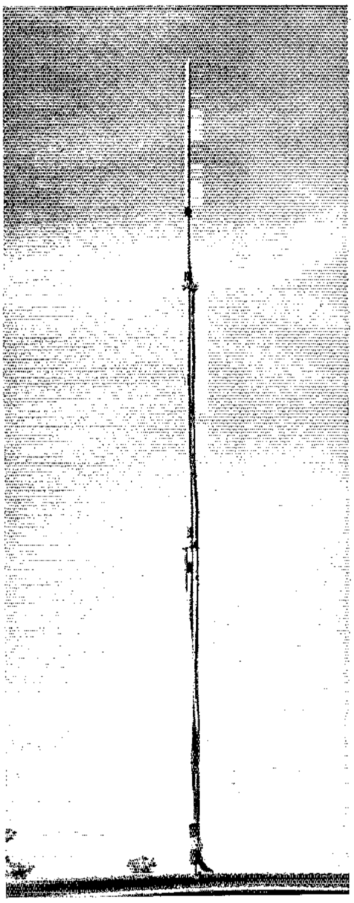
☐ Walt Brown, KAØDMB, Omaha, NE, recently worked his first Russian station, a UA3 near Moscow. Walt sent a QSL direct, with an IRC to guarantee a prompt return. Not only did Walt get a return, but the Russian ham enclosed a very nice two-page letter. The letter described his homemade equipment, some personal information and Amateur Radio experience. In addition, the Russian ham asked that the following information, concerning QSL procedures, be passed on: (1) Please do not use call signs on envelopes. (2) Only QSL cards, and not enclosures such as IRCs, should be sent via the QSL bureau address, Box 88 in Moscow. — *Dick Jugel, KØDG, Omaha, NE*

Radio direction finding is very popular in the People's Republic of China. This picture was taken by a reporter from the Chinese Sports Illustrated News Agency at a direction-finding contest. Although the equipment is made in China, details on construction, frequencies, call signs and modulation are as rare as a BY QSL. *(photo courtesy HB9AQZ)*

A VHF-UHF 3-Band Mobile Antenna

Three bands — 144, 220 and 440 — on one stick sound interesting? This antenna might allow you to condense that stainless-steel and plastic jungle atop your auto onto a single pole.

By J. L. Harris,* WD4KGD



The three-band antenna system mounted atop a pickup truck. *(photo by WD4FNS)*

In looking for a mobile antenna system for my Drake UV-3, I rejected the notion of one broadband antenna such as the discone because of band-switching problems not to mention its somewhat busy appearance. I also rejected the idea of three separate whips which I felt would give the relatively small roof area of my pickup truck a cluttered look. Three separate antennas confined to so small a space would also cast "shadows" on the vertical patterns of one another. In order to take full advantage of the three antenna terminals on the UV-3, I needed three separate antennas, but I wanted an omnidirectional pattern with no "holes."

The solution I chose was to use three stub-fed verticals on one whip. The stub-fed vertical, or J antenna, consists of a basic half-wave radiator end fed through a quarter-wave stub. This stub serves as an impedance transformer. It transforms the high impedance of the half-wave radiator to that of the low-impedance coaxial line. Few antennas lend themselves to omnidirectional patterns and ease of matching to coaxial line as well as the stub-fed vertical.

Construction

My approach is cheap, novel and effective and uses only four basic parts except for the coaxial lines: the whip and three easily fabricated blocks. These materials are available at most hardware or hobby stores. The whip is one piece of 3/8-inch (9.5-mm) aluminum tubing 60 inches (152 mm) in length. Be sure that the piece you select is straight and free of nicks or dents.

Overall construction is shown in Fig. 1. The three stub blocks are made from 3/8-inch (9.5-mm) aluminum stock. Refer to Fig. 2 and saw three blocks 3/8 × 5/8 × 1-1/8 inches (9.5 × 15.9 × 28.6 mm). Drill a 3/8-inch (9.5-mm) hole as shown so that the piece will slip over the mast. Tap a no. 6-32 hole into the 3/8-inch (9.5-mm) hole just drilled for a setscrew to hold the block in place. The third hole is used to connect the braid of the coaxial cable to the mast. It is at this point where the quarter-wave stub begins and the feed line ends. For RG-58/U and similar size cable use a 13/64-inch (5.2-mm) drill and tap the hole with 1/4-20 thread. For RG-8/U, use a 25/64-inch (9.9-mm) or "X" drill and tap with 7/16-20 thread. Prepare the coaxial cables by separating the center conductors from the remainder of the cable to the lengths given in Fig. 1. Cut off all but 3/8 inch (9.5 mm) of the braid and fold this back over the jacket. These sections can be threaded into the tapped holes. The blocks can then be mounted to the whip as in Fig. 1.

Matching

As mentioned earlier, the quarter-wave stub is an impedance transformer. The spacing between the coaxial cable center conductor and the whip (dimension "A" in Fig. 1) determines the impedance of this section and consequently the match to 50-ohm line. Using an SWR indicator, determine the optimum spacing "A." This dimension can vary greatly depending on the size of the cable and its dielectric material. Once I determined the correct spacing, I stood off the center conductor from the main support with small styrofoam blocks. Electrical tape was used to hold the quarter-wave section and styrofoam block to the main support.

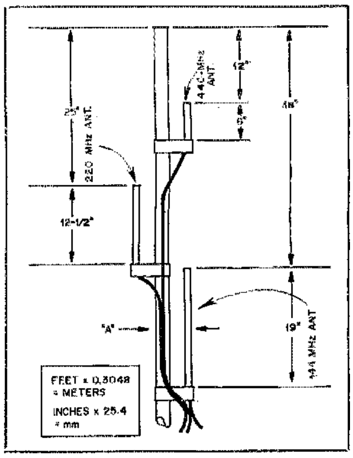


Fig. 1 — Construction dimensions of the three-band antenna. Cables should be routed and taped as shown.

*Rte. 5, Box 39, Henderson, NC 27536

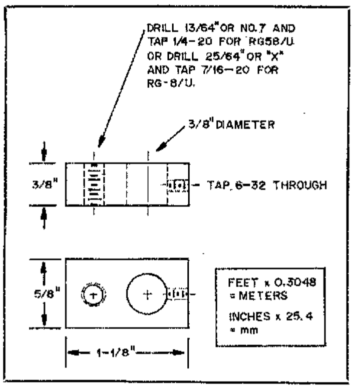


Fig. 2 — Detail drawing of the stub blocks used to connect and support and the quarter-wave sections.

The cables from the 440- and 220-MHz antennas should be routed as shown in Fig. 1 on opposite sides of the main support and away from other stubs.

The assembly is finished by taping all cables in place and coating the stub blocks with clear acrylic spray to prevent moisture from entering the cables. Although this antenna system is intended for mobile use and is constructed for this purpose, it should not be overlooked as a base station system. Just add 6-meters and you've got a 4-band array! E-plane patterns for the three bands are shown in Fig. 3.

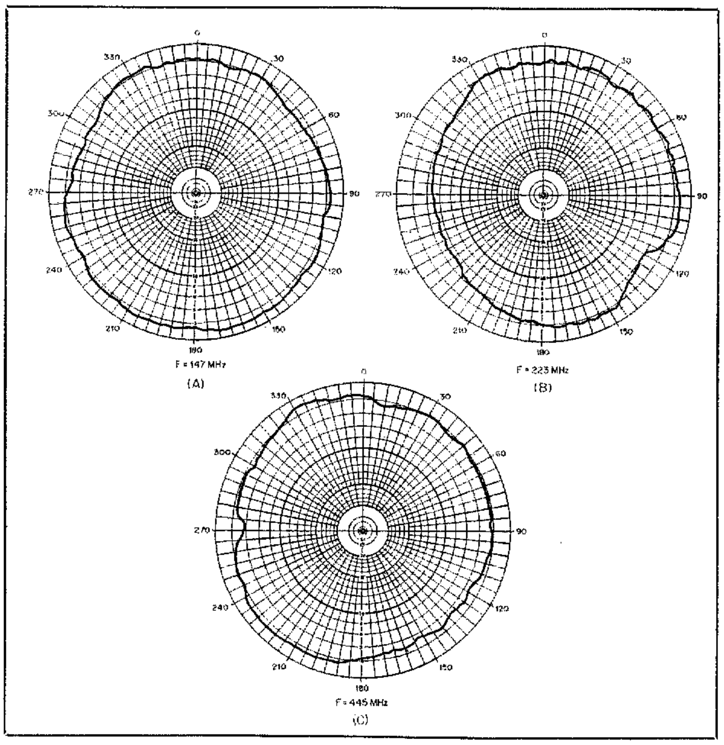


Fig. 3 — E-plane patterns for the three-band antenna. The patterns at A, B and C, respectively, are measured responses for 147, 223 and 445 MHz.

Feedback

☐ An omission occurred in "The Microprocessor and Slow-Scan Television," January 1980 *QST*, page 40, Fig. 8A. The box to the right of the "End of Line?" triangle should read "Erase to *End of Line*."

☐ The input intercept figures for the Drake R-7 receiver, "Product Review," January 1980 *QST*, page 49, were reversed. The corrected text should read: "These numbers equate to a 3rd-order input intercept of +17 dBm on 80 meters with the preamp turned off and −2.5 dBm with the preamp turned on."

☐ The diagram for W6HPH's two-element, 144-MHz antenna that appeared in "Hints and Kinks," October 1979, *QST*, should have indicated the part for mounting the BNC fitting as a brass bracket.

☐ Two SSTV frequencies were left off "The Considerate Operator's Frequency Guide," January *QST*, page 91. Both 7171 kHz and 21.340 MHz are generally recognized SSTV frequencies. Others are 3845 kHz, and 14.23 and 28.68 MHz.

☐ The list labeled "6-Meter Radio Control Channels" ("FM/RPT," December 1979 *QST*, page 77) is actually a list of "guard" channels which could be allocated for repeater use in the event that additional repeater frequencies are needed. It is suggested that frequency coordinators do not assign these channels. Actual R/C channels are 53.1, 53.2, 53.3, 53.4, 53.5, 53.6, 53.7 and 53.8 MHz.

☐ The accident involving two Union Pacific Railroad employees ("Stray," January *QST*, page 41), did not occur, according to John Champa, K8OCL, an ARRL technical advisor on safety matters from Columbus, OH. His information was corroborated by a Union Pacific spokesperson. Although butane can be considered dangerous if it is mishandled, Champa reports, it is not nearly as explosive as three sticks of dynamite. The "Stray" item was paraphrased from a club newsletter, which had published an account of the supposed incident.

Strays

CALLING PROFESSIONAL STUDENTS

☐ If you have received your acceptance letter from, or are now attending medical, dental, osteopathy, nursing, veterinary or other health-related professional school, you are eligible to join the Medical Amateur Radio Council, Ltd. (MARCO). This group of ham/health professionals meets regularly, on-the-air, to exchange medical and electronic data. Further information and applications from Milt Lowery, N5BLU, Baylor College of Dentistry, 3302 Gaston Ave., Dallas, TX 75246.

***QST* Congratulates . . .**

☐ Jack Boyce, WDØGMR, Kansas City, MO, who put the Kansas City Emergency Preparedness Office's radio equipment which had been unused and in storage for several years, back on the air. The four or five afternoons of work, a major donation from any volunteer, is even more significant because Jack is legally blind.

An Automatic CW Identifier

Need a simple, reliable station identifier to prevent breaking the 10-minute rule? Here's one that meets all major requirements.

By Earl R. Savage,* K4SDS

With each advance in the state of the cw art, staying legal with i-ds becomes more difficult. First there was semi-break-in and then *real* break-in. The straight key was followed by the bug, the electronic keyer and now the Morse keyboard. Soon it will be computerized voice-to-Morse conversion by means of the microprocessor. With all this, sharp filters and stable rigs, cw ragchewing is more like an eyeball QSO than phone can ever be.

Yet each advance makes one problem worse: It gets harder and harder to remember to identify every 10 minutes. One day the microprocessor will take care of such chores, but in the meantime, almost everything has been tried, from flashing lights and ringing bells on up.

Do you remember the revolving disc and the cam-actuated switch? How about the keying relay driven by an audio-tape loop? Or the photocell and the perforated disc? More recently the ROM has entered the picture with complex programming problems.

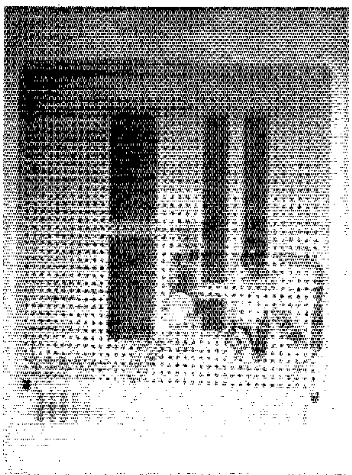
What we need is a simple, reliable automatic identifier. Here is one that you will want in your shack. All the major requirements are met: (1) fully automatic operation; (2) manual operation as desired; (3) ease of programming; (4) quick reprogramming as desired; (5) dependability; and (6) use of common, low-cost components.

The AUTO-ID'ER keys your call sign automatically every 10 minutes. If you start it manually before the set interval, it keys your call sign and resets for a new 10-minute interval. As a bonus, you can disable the timer and reprogram for your standard contest response. Other uses will present themselves. All this for a "new-parts cost" of only $10 plus a modest amount for the power supply and cabinet.

How It Works

A block diagram of the AUTO-ID'ER is shown in Fig. 1. U1 is an adjustable

*Box 351, New Castle, VA 24127



The AUTO-ID'ER constructed on a universal pc board and ready to be plugged into the author's keyboard.

timer provided with a manual override switch. The timer sends a pulse every 10 minutes to an R-S flip-flop which enables the key clock, U3. Both U1 and U3 are 555 ICs, the functions of which can be combined by using one 556 if desired.

The clock pulses the counters at an adjustable rate, which establishes the keying speed. Counter U4 addresses all memory ICs in parallel. Though only two are shown, you can have as many memories as needed. You will be pleasantly surprised later to see that the memories are inexpensive data selectors.

Two functions are performed by the second counter, U5. It addresses the memory selector and also feeds a "stop and reset" pulse to the control flip-flop. The memory-select IC, U8, sequentially feeds the outputs of the memories to the keying interface which you select to match the characteristics of your transceiver/transmitter.

Programming

Use of type 74150 multiplexers (1-of-16 data selectors) for memories is the key to the simplicity and low cost of the AUTO-ID'ER. It is necessary to understand how they operate in order to program them properly.

A 74150 has 16 input lines, each of which may be high or low. When one of the 16 lines is addressed, the *complement* of the information on that line appears at the output. If each input line is considered one Morse *bit*, 16 bits can be wired in. Thus, when sequentially addressed 0-15, these 16 bits appear *serially* at the output. If a transmitter is keyed with the serial bits shown in Fig. 2, the resulting signal is a dah and 2 dits. Of course, this is the letter D and the bits can be programmed to produce any letter or letters. Bits are recorded by these simple rules:

1) A dit is two bits — 1Ø (a high followed by a low).

2) A dah is four bits — 111Ø.

3) A letter space is two bits — ØØ.

4) A word space is four bits — ØØØØ.

Following these rules, DE is recorded as 111Ø1Ø1ØØØ1Ø. That is 12 bits — three-fourths of the 74150 capacity. But we can do better than that.

In order to increase the storage capacity of each 74150, we will use a technique called "folding." If we run through the 0-15 addresses twice and fold the inputs, the capacity will double — giving 32 bits! Here is how to fold a data selector (DS).

For purposes of illustration, we'll use a 1-of-4 DS. The sample DS will be programmed with the help of Table 1. At this point we won't be concerned with Morse output but with the four possible combinations.

Since we are going to address the DS twice, we'll start at pass no. 1, input no. 1. We'll progress to inputs no. 2, no. 3 and no. 4, and write in the first four bits: Ø11Ø. (Note: The first bit is always Ø.) For the

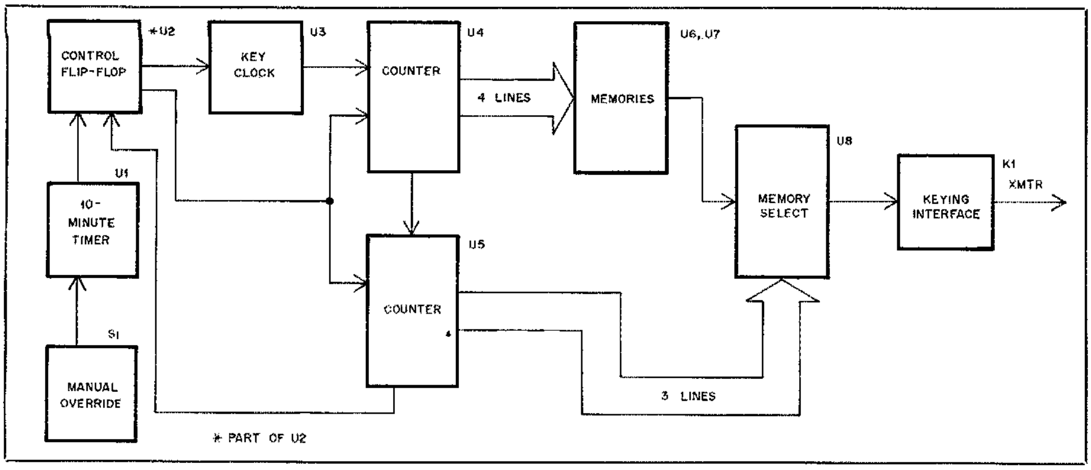


Fig. 1 — A block diagram of the AUTO-ID'ER.

second pass, we'll write in Ø1Ø1.

Now, observe that input no. 1 is required to put out ØØ on the two successive passes. *Remembering that the output will be the complement,* we'll wire the input to 1 (+5 V or high). Input no. 2 will be wired to Ø (ground or low) since it is connected to output 11.

Input no. 3 is different. It must be 1 on the first pass and Ø on the second. Therefore, we must wire it to a line which will change from 0 to 1 between passes 1 and 2. We'll call this line A. Likewise, input no. 4 goes to a line which changes from 1 to Ø, which we'll call line B.

But where do these lines A and B come from? They originate at the *third* address line (see Fig. 3). You will perceive that the output of the counter (4) will be on Ø on counts 0-3 and 1 on counts 4-7. Therefore, we'll call it line A. By the same token, when line A is inverted, it becomes line B. Thus, we have folded a 4-input DS into an 8-input DS.

Exactly the same procedure is used to fold a 16-input 74150 into a 32-input DS. Of course, there are four address lines so the fifth counter line becomes the A and B lines. As a further example, Table 2 shows how my call sign is folded into two 74150s. If you still have difficulty with the folding technique, see pages 140-144 of Don Lancaster's *TTL Cookbook*.[1] The process is not as complex as it may first appear.[2]

When your first 74150 is full, continue to the second and so on until your message is complete. If you get to the end of a DS memory and need just a very few bits to complete your message, you can steal a few rather than add another DS. If you are on your toes, you caught the fact that I cheated on Table 2. I broke the rules and simply left out two Ø bits which kept me from needing another 74150 (and it takes a *very* sharp ear to detect it on the air).

You may be able to use this technique to save a little money, space and wiring time. If not, and you have unused bits remaining, be sure to fill them with Øs.

Typical call signs will require three or four 74150 data selectors. Put in as many as you need. Connect all address and power pins in parallel. Output pins (no. 10) are connected sequentially to the 74151 DS as indicated. Unused 74151 input pins are grounded.

[1]Notes appear on page 21.

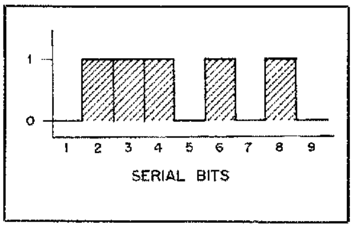


Fig. 2 — This keying sample is typical of the patterns produced by the AUTO-ID'ER.

Table 1
Sample Programming

Address	*Input*	*Pass 1*	*Pass 2*	*Wire to*
00	1	0	0	1*
01	2	1	1	0*
10	3	1	0	A
11	4	0	1	B

*1 = +5 volts; 0 = ground

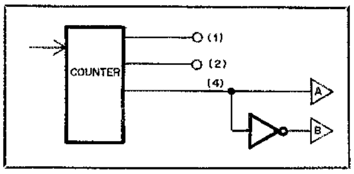


Fig. 3 — Origin of lines A and B in the AUTO-ID'ER.

The Circuit

The schematic diagram of the timing and counting subcircuit is given in Fig. 4. Components of the timer (U1) have been chosen to provide a range of about 7.5 to 11 minutes. This is determined by R1, R2 and C1, any or all of which may be changed to alter the range covered.

Not only is the value of C1 important, the quality is important also; the same applies to C2. Both capacitors should have low leakage. Excessive leakage will extend the timing period and require more series resistance. Because of the long timing period of U1, a capacitor with high leakage could prevent it from timing out at all. (If yours does not time out, you should check the operation and your wiring by substituting a smaller capacitor. This check should be made before going out to buy a better-quality capacitor.)

The components associated with U3 establish the speed of the keying clock (the actual speed is halved by the first stage of the counter). As shown, the range is from about 10 to 70 words per minute.

The stop-and-reset line from U5 to the flip-flop (two 7400 gates) must be inverted; this is done with another 7400 gate. The point of attachment to U5 will depend upon how many memories you need to contain your call sign. Connected as shown, the AUTO-ID'ER stops at the end of the fourth memory. You may have to make an adjustment here. If so, consider the 32 BCD line as 1 for memory count; the 64 line as 2; and the 128 line as 4. An AND gate will be required if the number of memories exceeds 4.

Fig. 5 provides the schematic diagram

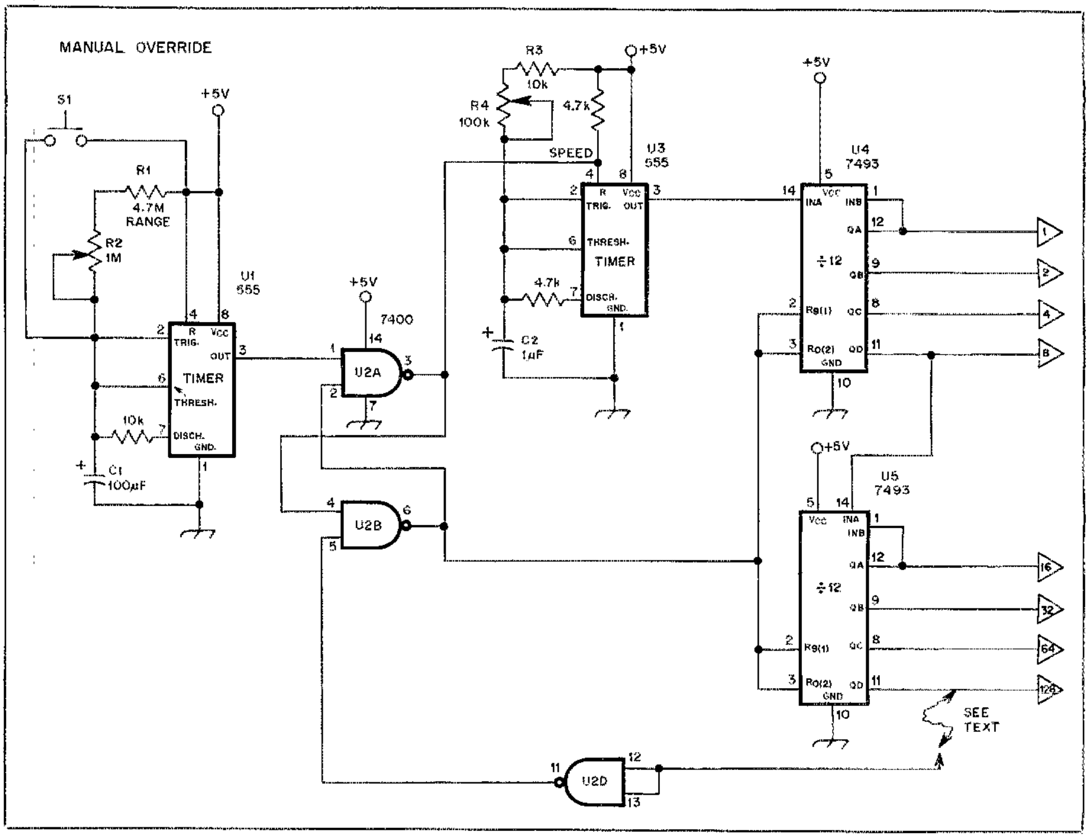


Fig. 4 — AUTO-ID'ER timing and counting subcircuit. Resistance values are in ohms.

for the program subcircuit of the AUTO-ID'ER. The input lines of U6 are numbered in the order of their selection. Programming is accomplished by connecting these lines to 1, Ø, A or B, as explained earlier. The origin of lines A and B is also shown.

U8, a 74151 1-of-8 DS, supplies the cw pulses for keying the interface. Output pin 5 does *not* give the complement of the input.

No power supply is illustrated because you must be as tired of seeing them as I am. The AUTO-ID'ER requires a regulated power source that furnishes 5 volts at 300 mA or more. Any standard circuit should suffice.

Keying Interface

You must choose and build the keying interface suitable for your transceiver/transmitter. Three choices are given in Fig. 6. Of course, you may build two or all three of them for maximum versatility. If your rig has unusually high voltage or current on the key line, be sure the keying transistor/relay you select can handle it. The ones in Fig. 6 are suitable for most rigs.

Table 2

Completed Programming Chart for DE K4SDS. See text.

			First Memory			Second Memory		
Pin	*Address*	*Input*	*Pass 1*	*Pass 2*	*Wire to*	*Pass 1*	*Pass 2*	*Wire to*
8	0000	1	0*	1	B	0	0	1
7	0001	2	1	1	0	1	1	0
6	0010	3	1	0	A	0	1	B
5	0011	4	1	1	0	1	1	0
4	0100	5	0	0	1	1	0	A
3	0101	6	1	1	0	1	1	0
2	0110	7	0	1	B	0	0	1
1	0111	8	1	1	0	0	1	B
23	1000	9	0	0	1	0	0	1
22	1001	10	0	0	1	1	0	A
21	1010	11	1	0	A	0	0	1
20	1011	12	0	1	B	1	1	0
19	1100	13	0	0	1	0	0	1
18	1101	14	0	1	B	1	1	0
17	1110	15	0	0	1	0	0	1
16	1111	16	1	1	0	0	1	B

*Always 0

Construction

Layout of the AUTO-ID'ER is not critical. You may use any of the common building techniques. With reasonably compact construction, the AUTO-ID'ER will fit into an 80 × 100 × 60-mm (3 × 4 × 2-1/2-inch) cabinet and leave space for a power supply.

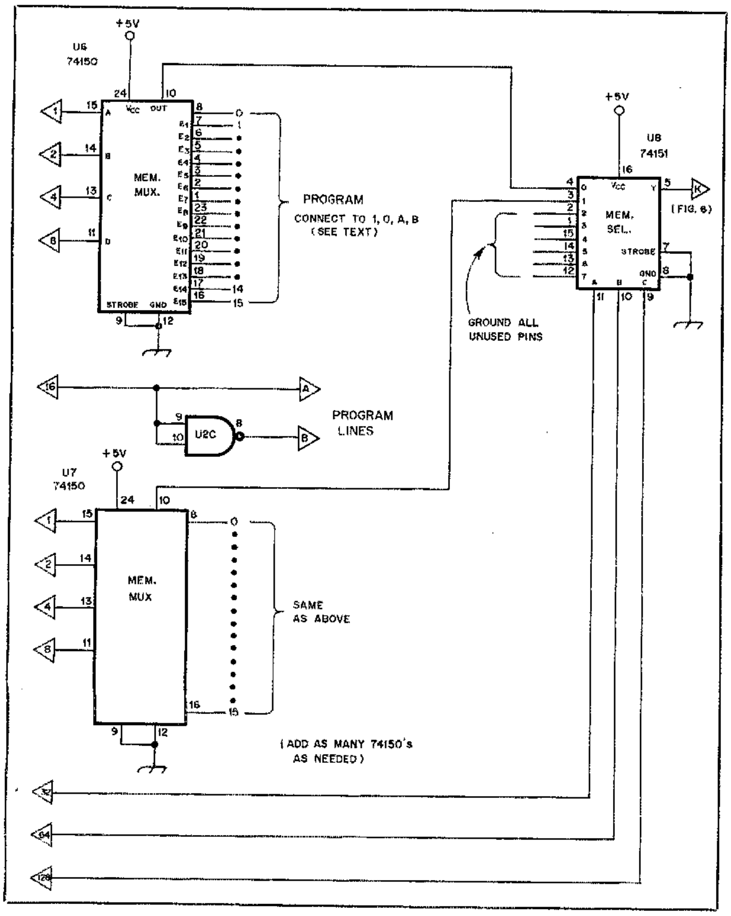


Fig. 6 — Keying interface subcircuits for use with the AUTO-ID'ER. The circuit at A is for negative (grid-block) keying, and that at B for positive keying. The relay keying at C may be used for either positive or negative keying. Resistance values are in ohms; k = 1000. Transistors are Radio Shack components or equiv.

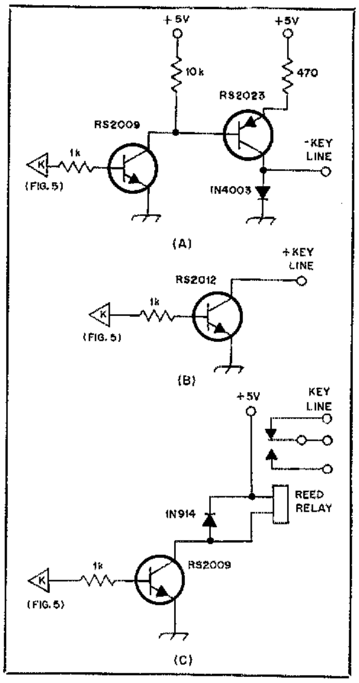


Fig. 5 — Program subcircuit for the AUTO-ID'ER.

The prototype in the photo first was constructed on a Radio Shack universal pc board (no. 276-154). This board was modified slightly to increase the capacity for the large 24-pin 74150s. Though only two of these DS memories will hold my call, there is obviously space for two more, enough to hold almost any i-d.

A modification of the board was made by dividing two rows of the multiple-hole solder pads. I used a Radio Shack no. 64-2178 cordless drill/saw as shown in Fig. 7 but the job can be done with a sharp knife, a steady hand and patience. Using this type of plug-in board with matching connector is an excellent way to add the AUTO-ID'ER to an existing piece of equipment.

Operation

Operation of the AUTO-ID'ER is simplicity itself. With the keying interface connected in parallel with your regular

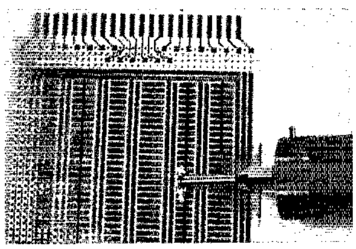


Fig. 7 — Modifications being made to the universal board to accommodate the 24-pin data selector memories.

keying device, the unit begins operating as soon as power is applied. Ten minutes later it sounds off, unless you kick it off manually first.

There are two points you may wish to consider. The first is that you should not cut the 10-minute limit too fine. It may be advantageous to set U1 for 9 or 9-1/2 minutes. Note that the interval after a manual trigger is a little longer than after an automatic trigger.

The second point is that on occasion the AUTO-ID'ER will sound off while you are sending. That leads to a resulting mixture of garbled cw, so you'll just have to stop sending and push the manual switch for another i-d. You can avoid this annoyance if you have some space (bits) left in the last 74150. In this case, move your i-d down and place a signal in front of it. On hearing the signal, you stop sending and let the AUTO-ID'ER take over. Another alternative is to add a circuit that will disable the clock of your keyer or keyboard when the i-d begins.

Summary

Your efforts in building the AUTO-ID'ER will be repaid many times over. When the accessory is up and running, you won't have to keep one eye on the clock as you ragchew. It is a relief to be free of that chore.

Whenever you tap switch S1 your i-d is keyed and the unit resets for a new 10-minute interval from that point. If you keep ahead of it, fine. If not, don't worry — the AUTO-ID'ER will do it for you and keep your operation legal. QST

Notes

[1] Lancaster, *TTL Cookbook*, Howard Sams and Co., Inc., Indianapolis, IN 46268.

[2] *Still have problems? Send your call with $1 and an* s.a.s.e. to the author for personalized coding instructions.

• *Basic Amateur Radio*

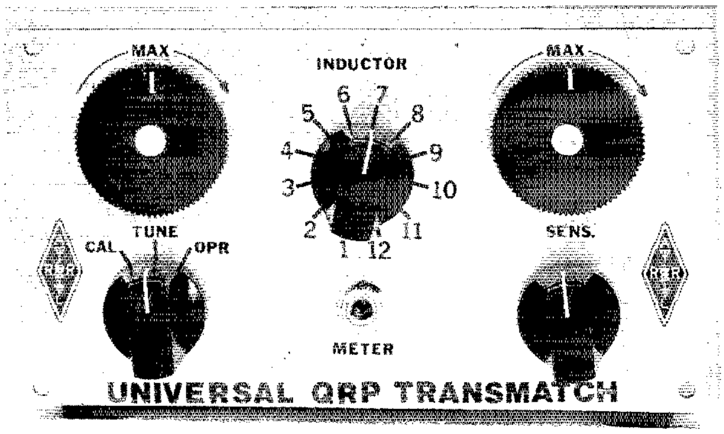
Matching the Transmitter to the Load

Most ham shacks contain a Transmatch, but do you need one? Under some conditions, "yes." Here's the rundown.

By Doug DeMaw,* W1FB and Bob Shriner,** WAØUZO

"My antenna won't load up properly because the feed line doesn't match the antenna impedance. Will a Transmatch cure the problem?" That's a commonly asked question among inexperienced amateurs. The answer is "no!" The exception would be if the Transmatch were installed at the antenna feed point. But, Transmatches are normally used at the transmitter end of the transmission line. So, the device will only "fool" the transmitter into "thinking" it has a proper load to look into. The mismatch condition at the feed point will remain the same.

So, why even use a Transmatch (transmitter to transmission line matcher)? Well, presenting a flat load (no reactance) to the transmitter has its advantages. First, the transmitter output tank circuit can be tuned normally if it looks into 50 ohms (most modern transmitters have a 50-ohm output characteristic). Second, a proper load will enable the transmitter to develop its full rated power output. This is especially true if a solid-state transmitter with an SWR shut-down circuit is used. The higher the SWR (standing-wave ratio) the lower the transmitter output power with most rigs of that type. A correct load for the transmitter will also help prevent arcing of the PA tank variable capacitors and switches.



Front-panel view of the QRP Transmatch with SWR indicator. Low-cost pc-board construction is used throughout.

There remain two more advantages which justify a Transmatch. If the unit is capable of functioning as a high-Q bandpass network when adjusted to match the load, a reasonable amount of harmonic attenuation can result. Some circuits offer as much as 30 dB of harmonic attenuation. This, of course, aids spectral purity and reduces TVI. The other benefit can be seen in the case of a narrow-band antenna (75/80-meter dipole, for example) where without a Transmatch the system works nicely over a narrow portion of, say, 80 meters. But, when the antenna is used for ssb work on 75 meters the SWR is sky high. The Transmatch will again "fool" the transmitter and provide a 50-ohm load anywhere in the 75/80-meter range. The SWR which still exists beyond the Transmatch is normally of little consequence (minimum power loss) from 160 through 20 meters if the feed line is not unusually long (more than 100 feet, or 30.5 meters) and if it is of good quality and size, such as RG-8/U or RG-11/U. The losses are greater in the smaller-diameter coaxial cables.

Transmatches are known by other names, such as "antenna couplers" and "antenna tuners." Technically speaking, either name is inappropriate unless the network is used at the antenna feed point,

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or if it is actually used to tune the overall antenna system to resonance at the operating frequency. Some hams even call them "Matchboxes," which is a name borrowed from the commercial product of the same name that was manufactured by the E. F. Johnson Co. (see Fig. 1). But, in essence, all such devices contain capacitors and inductors, which when adjusted properly will match one impedance to another.

When Isn't a Transmatch Needed?

It would be rather pointless to install a Transmatch in the antenna line if the SWR was 2:1 or less. All you would add would be another gadget to tune as you changed bands. A dreadful misconception prevails whereby some amateurs become distraught if the SWR indicator shows anything greater than a ratio of 1.3:1; they believe that their signal suffers immeasurably if the slightest amount of reflected power is observed. Balderdash! Very little (if any) difference will be noted in the hf bands between a 2:1 and a 1:1 SWR condition. Honest on-the-air checks with other amateurs will prove this to be true.

What is being said here is that if you're using a coax-fed dipole, vertical antenna or beam, and if the SWR is less than 2:1 in the desired operating range of the band, don't waste money and space on a Transmatch. But, if you plan to use an end-fed wire antenna, or operate over all of one of the lower bands with a frequency-restricted coax-fed antenna, then a Transmatch will be quite beneficial. If the system SWR is greater than 2:1 at the frequency for which the antenna has been cut, then you'd better plan to correct the problem *at the feed point*. That's where the action really is! *The ARRL Antenna Book*[1] is recommended as a source of information on antenna theory, matching methods and practical examples.

Design Considerations

You will find some discussion about the fine points of Transmatch design in the "Product Review" column in an upcoming issue of *QST* (Murch Transmatch). There are some major design considerations which a builder must observe if good performance is to be had.

1) Ensure a wide range of variable inductance.

2) Provide a wide range of variable capacitance.

3) Employ coils and capacitors which can stand up under the planned power level without arcing or overheating.

4) Keep all rf leads as short as possible. In addition, it is wise to select variable capacitors which have the lowest possible *minimum* capacitance. This will extend the impedance-matching range considerably at the higher frequencies, such as 15 and 10 meters.

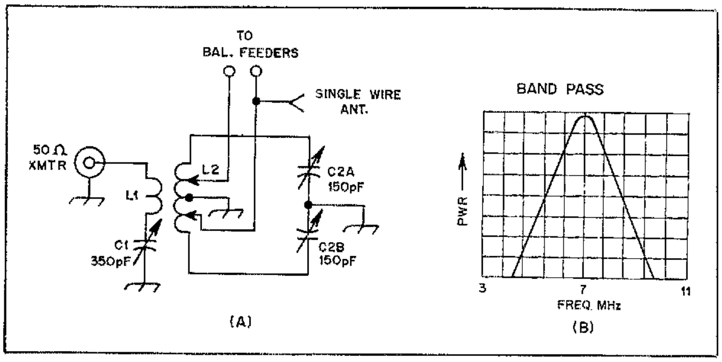

Fig. 1 — Bandpass type of Transmatch network which is suitable for use between coax and balanced feeders.

Common Transmatch Circuits

A bandpass type of Transmatch circuit is shown in Fig. 1A. The link (L1) must be capable of forming a resonant circuit with C1 at the operating frequency. Inductance L2 and capacitance C2 must also tune to resonance at the chosen operating frequency. The two taps (arrows) on L2 are moved in from the outer ends of the coil by equal numbers of turns until the balanced feeders are matched to the 50-ohm transmitter impedance. You will note that in addition to an impedance match there has been a transformation from an unbalanced condition (transmitter output) to a balanced condition (balanced feeders). A single-wire, end-fed antenna can be matched to the transmitter by connecting it to one of the coil taps as shown. A bandpass type of response will result if the Transmatch loaded Q is reasonably high. This is shown at B of Fig. 1. Frequencies *above* and *below* the operating frequency are attenuated. This is desirable in terms of TVI reduction and harmonic attenuation in general.

The popular T-matching network found in most of today's commercial and homemade Transmatches is seen in Fig. 2A. A variation of this circuit contains a dual-section variable capacitor at C1. The section which is not shown would be connected between J1 and ground. In practice, there is no difference in the matching range and performance of the network when a single-section variable capacitor is used at C1.

Fig. 2B shows two possible response curves. The solid curve illustrates a bandpass type of condition. The dotted curve indicates a high-pass response (no significant harmonic attenuation). The response obtained will depend upon the impedance-transformation ratio being dealt with, plus the final inductance-capacitance ratio of C1, C2 and L1 during a matched condition. An in-depth technical explanation of this phenomenon is well beyond the intent of this article. The user of this type of circuit should never assume that a T-network Transmatch will offer harmonic attenuation, however. If a rule of thumb is to be

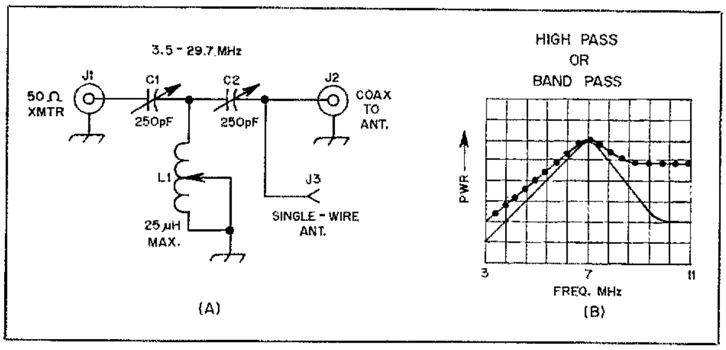

Fig. 2 — Basic circuit of the so-called "Ultimate Transmatch" (T-network) is shown at A. The curves at B illustrate two kinds of response (high pass and bandpass) which can result under different load and tuning conditions.

[1] Notes appear on page 26.

offered here, we might say, "use the maximum amount of capacitance at C2 which will result in an SWR of 1:1 through adjustment of C1 and L1." Laboratory tests at ARRL showed that minimum power loss (insertion loss) through the Transmatch will result when C2 is set for the greatest practical amount of capacitance. Our workshop project for this Basic Radio installment contains the circuit of Fig. 2A. The most outstanding feature of this type of network is its very broad range of impedance-matching capability. Although a tapped inductor can be used at L1, a rotary inductor will provide the greatest flexibility in matching a wide range of load impedances at J2.

An excellent matching network for harmonic attenuation is the low-pass type. This is known also as a pi network. The basic circuit is shown in Fig. 3A. The type of response from this network is shown at B of Fig. 3. The major limitation of this style of Transmatch is its matching range. In order for the circuit in Fig. 3A to match loads from 50 to 2000 ohms, for example, C1 would require a maximum capacitance of 4500 pF and C2 would require 9000 pF of capacitance. L1 would require a maximum inductance of 10 µH and a minimum inductance of 0.4 µH. These values are based on a loaded Q of 10 at 3.5 MHz. The maximum capacitance values would be used when matching 50 ohms to 50 ohms with L1 set at 0.4 µH. A 2000-ohm load at J2 or J3 would require roughly 1100 pF at C1, 227 pF at C2 and 10 µH at L1. What's the point of explaining all of this? Well, it was done only to illustrate the lack of practical component values for wide-range (3.5 to 29.7 MHz) frequency use when a host of impedances needs to be matched to 50 ohms, while maintaining a loaded Q (quality factor) of 10. Greater network flexibility could be realized with the specified L and C values, however, by allowing the Q to vary all over the ball park as the L and C values were juggled simply to obtain a matched condition. In a real-life situation, this is how most Transmatches are operated. Since the exact network Q is seldom known for a given matched condition, the level of harmonic attenuation is similarly unknown. Therefore, it is best to regard a Transmatch purely as a *matching device*. Whatever harmonic reduction that will result can be regarded as a bonus.

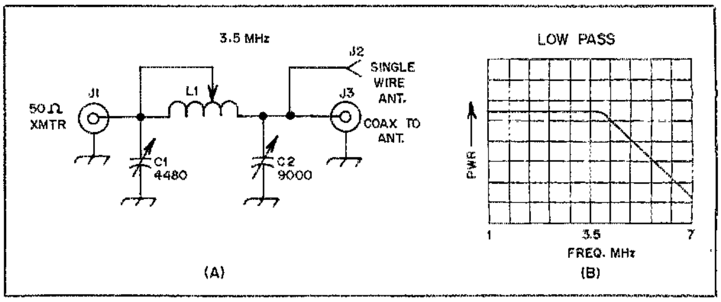

Fig. 3 — A pi-network (low-pass) type of matching network. This circuit has limited matching range (see text) but is excellent for harmonic attenuation.

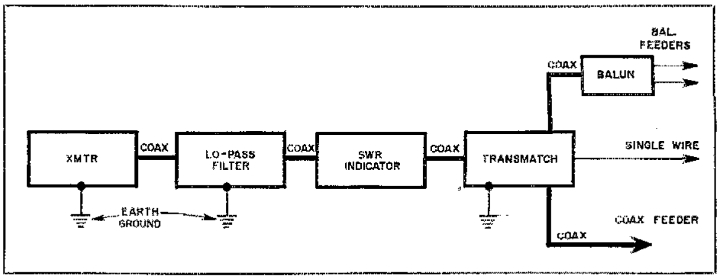

Fig. 4 — Block diagram of a typical setup in which a Transmatch and balun transformer would be used.

Practical Use of a Transmatch

In order to adjust a Transmatch easily it is necessary to use an SWR indicator with it. This will tell the operator when the network is tuned for minimum reflected power from the load. Some Transmatches have a built-in SWR indicator. Others do not.

Fig. 4 shows a recommended setup for using a Transmatch. A low-pass TVI filter is placed in the line immediately at the transmitter output. A quality earth ground is connected to the frame of the transmitter, the case of the low-pass filter and the chassis of the Transmatch, as shown. Coaxial cable (50 ohms) is used between the transmitter and the Transmatch. The SWR indicator (sometimes called a bridge) is always used *before* the Transmatch, as illustrated. If we were to locate it after the Transmatch we would never be able to adjust the Transmatch accurately. At best, we would be tuning the matching network for maximum power to the antenna (which should coincide closely with minimum reflected power in most instances). This assumes that coax feed to the antenna was being used and that the antenna SWR was reasonably low.

What About Baluns?

First of all, let's pronounce this popular word correctly. It is a "bal-un" (*bal*anced to *un*balanced transformer). It is not a "bal-oon" or a "bay-lun," as many amateurs pronounce it. Its function is clearly defined by its name: It converts an unbalanced condition (coax) to a balanced one (balanced feeders). Although the typical balun has a 4:1 impedance-transformation ratio (e.g., 200 ohms balanced to 50 ohms unbalanced), a balun can be built to handle almost any reasonable transformation ratio. The *transmission-line* type of transformer of Fig. 5A shows a 4:1 transformation. But, the broadband *conventional transformer* of Fig. 5B can be made to handle a wide range of transformations. The circuit at B is indeed a balun because of its function. Transformers of the type shown at A and B of Fig. 5 are used frequently in solid-state transmitters to provide an

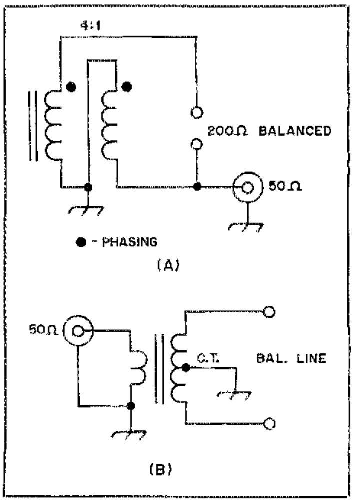

Fig. 5 — The circuit at A is for a transmission-line type of balun (4:1 ratio). A conventional balun transformer is shown at B.

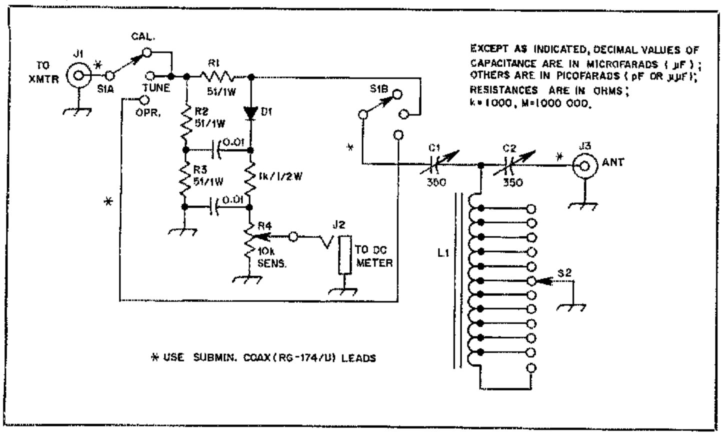

Fig. 6 — Schematic diagram of the QRP Transmatch/SWR indicator. Fixed-value capacitors are disc ceramic. Resistors are composition types except for R1, which is a carbon type of control.

C1, C2 — Miniature transistor radio 350-pF variable. Set trimmers on variable capacitors for minimum C, if trimmers are included as part of the unit.
D1 — High-frequency, small-signal diode. 1N34A, 1N914 or equiv.
J1, J3 — Phono jack, single-hole mount.
J2 — Miniature 2-circuit phone jack.
L1 — 44 turns no. 24 enam. wire spaced evenly over an Amidon T106-2 toroid core (26 µH). Tap at 8, 12, 15, 19, 23, 26, 28, 32, 35, 38 and 41 turns from C1-C2 end. (See text.)
R1, R2, R3 — See text.
R4 — 10,000-Ω control, linear taper.
S1 — Two-pole, 3-position rotary wafer switch. Three-pole switch with unused lugs shown in photograph.
S2 — Single-pole, 12-position rotary wafer switch.

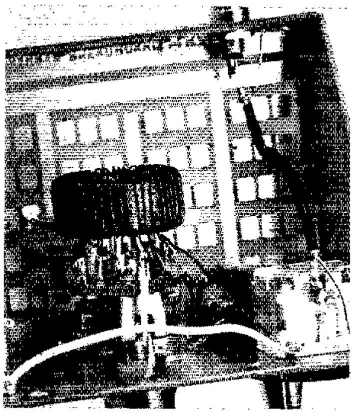

Fig. 7 — Close-up view of the tapped toroid and S2.

impedance match between a single-ended transistor driver and the bases of a push-pull amplifier.

Many commercial Transmatches contain high-power toroidal baluns. These are used when balanced line is employed to feed an antenna. A good example would be the use of 300-ohm twin-lead to feed a folded-dipole antenna, or open-wire feeders for use with a center-fed Zepp antenna.

Since a balun is a broadband type of transformer, it isn't too effective as an rf transformer at load levels above, say, 600 ohms. These devices work best at low impedance levels. This is because at higher impedance levels the inherent built-in reactances (unwanted) affect the phase balance of the transformer, and this becomes more significant as the operating frequency is increased. Additionally, much higher rf voltages are developed at high impedances than at low impedances, and this can cause arcing between the balun turns or between the turns and the toroid core. Many baluns have been destroyed quickly by amateurs who tried to match the output of a high-power rig to a high-impedance load. A charred and very hot toroid core resulted!

When a balun is used in a sensible manner, a shown in Fig. 4, it will add flexibility to the ham station. A typical case was tried and proven at KA1BUQ when an 80-meter "inverted-V" antenna was fed with 300-ohm TV line, routed through a 4:1 toroidal balun and into a homemade Transmatch. All-band (3.5 to 29.7 MHz) operation with an FT-101E transceiver proved effective. An SWR of 1:1 was obtained readily on each band, and good signal reports were received. The Transmatch of Fig. 1 (without a balun) would have worked nicely, too.

This Month's Project

We shall build a simple SWR indicator/Transmatch for the QRP rig described in Basic Radio earlier (December 1979 *QST*).[2] It can be used with other QRP rigs such as the Ten-Tec Argonaut or Heath HW-7 and HW-8 series. In fact, it is suitable for any rig with up to 10 watts of rf output power.

The circuit for our project is shown in Fig. 6. A resistive bridge (R1, R2 and R3) is used to indicate a null when minimum reflected power from the load is realized. The Transmatch becomes the fourth resistance in the balanced bridge. Thus when it presents a 50-ohm characteristic to the bridge circuit, the bridge is nulled. This will be indicated by no needle deflection on the dc meter which is connected to J2. If 51-ohm, 5-percent resistors are used, the bridge will be quite accurate for 50-ohm work. The builder can employ 47- or 56-ohm, 10-percent resistors at R1, R2 and R3, however. The end result will be plenty good enough for any antenna-matching situation. The important thing is that *all three* resistors are of the same ohmic value. In other words, don't mix 47- and 56-ohm resistors.

The SWR bridge is followed by a T-network Transmatch. C1 and C2 are miniature transistor-radio tuning capacitors. L1 is a tapped toroidal inductor. With the taps at the turns specified in Fig. 6, there will be inductance increments of 1, 2, 3, 5, 7, 9, 11, 14, 17, 20, 23 and 26 µH. This should be ample for most matching problems encountered from 3.5 to 29.7 MHz. If a perfect null isn't attainable, don't worry.

Construction

We will follow the same format used in the last several Basic Radio projects, using the Universal Breadboard described in *QST* for September 1979. Once more the panel and the side brackets can be fashioned from pieces of double-sided (copper on both sides) pc board material.

A parts-placement guide is hardly necessary for this project because only three of the isolated pads on the breadboard foundation are used. They serve only as tie points for some of the parts. You may use any pad you desire for these terminals, but pick pads that are close to the related circuitry (keep the leads short).

The shield braids of the miniature coax cable leads should be grounded at both ends. The coax is used between J1 and S1A, from S1B to R1/R2 and between C2 and J3.

When winding the toroid coil, L1, be sure that the insulation is not ruptured so that any two turns short together. This would lead to a shorted-turn condition, thereby destroying the Q of the network.

There are two ways to place the taps on L1. A small loop can be made in the wire as the core is being wound — arranging it so that each loop occurs where the tap point belongs. A couple of twists in the wire at each loop will keep tension on the main winding. After the total winding (with all 11 tap loops formed) is finished, scrape the insulation off each loop by means of a knife blade. The bare loops can then be soldered to the lugs on S2 of Fig. 6.

Author Shriner used a different technique in establishing the tap points. The toroid was wound with the specified number of turns. Next, insulation was scraped *carefully* (and tediously) off each turn where a tap was required. Short wire leads were then soldered to the bare spots on the coil turns to permit connection to the lugs of S2. A close-up view of L1 prepared in this manner is shown in Fig. 7. Once the Transmatch is built (Fig. 8) and checked out it would be a good idea to coat the toroid winding with Polystyrene Q Dope or some similar low-loss coil dopant. If difficulty is experienced in obtaining a matched condition at 21 or 28 MHz, reduce the first tap on L1 from 8 to 4 turns or less.

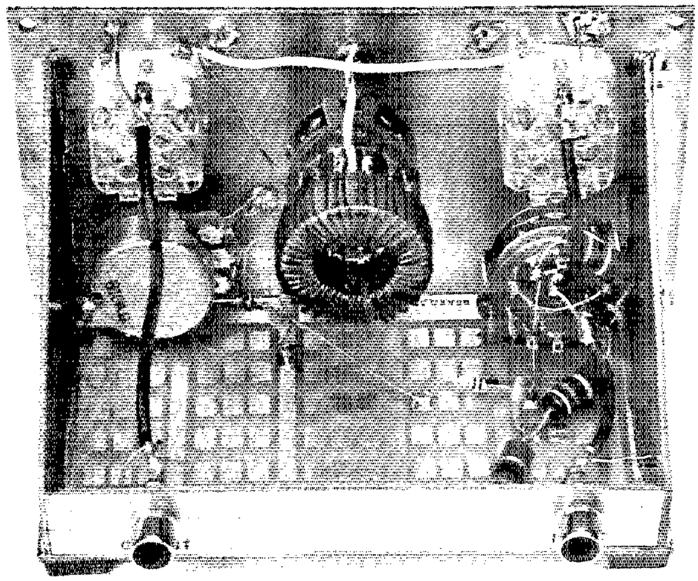

Fig. 8 — Interior view of the Transmatch. J1 and J3 are mounted on a rear apron made from a section of pc board.

Transmatch Adjustment and Use

The meter from the "RF Sniffer" can be plugged into J2 of Fig. 6 for use with this unit.[3] Alternatively, any 50- or 100-μA instrument can be used as an indicator. Even your VOM can be connected at J2 for a readout instrument.

Connect the SWR indicator/Transmatch between your transmitter and the antenna. Place S1 in the calibrate position (CAL). Set R4 for minimum sensitivity (counter-clockwise). Key the transmitter and adjust R4 for a full-scale reading on the meter. Now, switch S1 to the tune mode. Adjust C1, L1 and C2 for a zero meter reading (null). It may take several repeats of the control adjustments before the null is reached. Once that has been achieved, place S1 in the operate position and you're ready to chase DX! It's a good idea to log the settings of the three controls (in terms of "o'clock" readings) to save time when changing bands later and readjusting the Transmatch. Don't forget that you have a built-in dummy load when you operate your transmitter into the SWR indicator while S1 of Fig. 6 is at the CAL position. If the transmitter delivers more than 4 or 5 watts, it would be wise to use 2-watt resistors at R1, R2 and R3 of Fig. 6.

Closing Remarks

There are situations with any type of Transmatch in which it may not be possible to obtain an SWR of 1:1 with a given transmitter. The usual cause is a particularly high level of harmonic energy at the transmitter output (faulty design or tuning). When looking into a resonant load such as an antenna, the harmonic energy will be rejected by the antenna and will show up as reflected power. This can cause misleading results when trying to match an antenna at the desired operating frequency. If this happens to you, better check your rig for harmonics! This condition will not be observed if the transmitter is operated directly into a resistive dummy load, as the load will accept any frequency you supply to it.

Don't attempt to substitute an unknown toroid core for the one we have specified. The core has been chosen for the operating frequency, power level mentioned and inductance called for in the design (26 μH). The wrong core can render the Transmatch useless.

Now the question of the day: Do you really need a Transmatch? If so, warm up that soldering iron and go to work! QST

Notes

[1]Available from ARRL or your local dealer; $5.
[2]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, Box 969, Pueblo, CO 81002.
[3]*QST* October 1979, p. 15.

Strays

HELP PUT SOLAR POWER ON A FIRE TOWER

□ Charlie Colin, KA6FVN, works for the U.S. Forest Service in California. Both his isolated work location, a fire lookout tower, and his nearby home are without electricity. Charlie wants advice on building a solar panel and regulator circuit (August 1977 *QST*, page 24) and is looking for a pen-pal Elmer. Contact Charlie via 611 Hilmar St., Santa Clara, CA 95050.

I would like to get in touch with . . .

□ the eight stations that contacted the Musk Ox Expedition at the North Pole in 1955. Log misplaced in moving. Please write Vandergrift, 2308 Zinnia Ct., Lilleen, TX 76541.

RAIN IN MASSACHUSETTS

□ The Radio Amateur's Interstate weather Net — RAIN — now meets nightly on the Marlboro, MA, 01/61 repeater. If you can reach this machine, we'd appreciate your participation. — *Robert DeMatta, N1AMF*

Medium-Scan-Television Update

MSTV — a mode that adds motion to SSTV images.

By Don C. Miller,* W9NTP

During the last one-and-one-half years several developers of slow-scan television have been working on a new type of television called medium-scan television, or MSTV. MSTV will add motion to the SSTV image. This series of experiments was discussed in October 1978 *QST*.[1] The article mentioned that the Special Temporary Authorization (STA) permit from the FCC is valid until July 1980. During this past period of time several tests have been conducted and several conclusions made. This update provides the latest information for those who are interested in the tests. This article cannot include all the details of the equipment, so anyone not on the current MSTV mailing list should send a large manila, stamped, return envelope to W9NTP to keep up on the current status.

Equipment has been constructed for demonstration purposes and displayed at many hamfests and conventions across the country. Observations of many viewers and the restrictions of bandwidth on resolution have led the developers to specify a set of standards for the rest of the test period. These standards are given in Table 1.

Table 1
Medium-Scan-Television Standards

These standards are being used for 10-meter transmissions during current experimentation under Special Temporary Authorization of the FCC. (See text.)

Frame rate	2 frames/s
Line rate	256 lines/s
Horizontal line resolution	128 pixels
Vertical line resolution	128 lines
Horizontal sync pulse width	0.5 ms
Vertical sync pulse width	3.9 ms
Base video bandwidth	16 kHz
Type of modulation	Narrow-band fm
Rf bandwidth	36 kHz

A beacon is currently operating from Indiana on 29.150 MHz. This beacon operates on Saturday of each week, transmitting the first 10 minutes of each hour, starting when the 10-meter band opens. Several messages and tests are being transmitted. A voice-recorded message gives the present status of MSTV each week. In addition, approximately one-half of the time period is devoted to the transmission of a test image at the standard specifications of Table 1. If the beacon operator, W9NTP, is home, a call-in standby period will immediately follow the transmission of the recorded voice and test image.

How Is MSTV Received?

In order to receive the image it will be necessary to have a wide-band (36 kHz) 10-meter receiver on 29.150 MHz. In the United States there are old two-way fm receivers available very cheap but the writer has not found any type that is recommended. The development of a new economical receiver is being attempted in a short time period by one commercial company. Science Workshop[2] is currently developing a small receiver that will be crystal controlled and will have a discriminator and sufficient bandwidth to receive the low-frequency video. In addition the writer is working with a GLB[3] front end that may convert into many of the repeater kits that use 10.7-MHz i-f strips for 2-meter repeaters. If anyone would like to work in this area to speed up the development of MSTV it would be greatly appreciated.

There are several approaches to receiving the MSTV image. The most attractive one at the moment from economic and simplicity viewpoints is to use S-100 memory computer boards. This will require two memory boards and a video interface board. The computer memory boards are standard but the video interface board is unique. The design will be furnished to anyone wishing to build the MSTV system.

Another approach which is very attractive is to use a Robot 400 monitor with two memories. The added second memory board can be purchased at cost from the writer. This makes the Robot 400 useful for color SSTV and for graphic applications as well as for MSTV experiments. The problem of using the Robot 400 is the requirement of slow readout of the dynamic memories which must be refreshed at a faster rate than the MSTV pixel rate. For this reason it is required to have an external static buffer memory to do the actual data rate conversion. The S-100 memory board can be used here also. Only part of the 8-K memory is used in this application.

The third approach is to use a converted SSTV P7 monitor. The deflection circuits are triggered directly with the recovered horizontal and vertical pulses. Very little actual conversion is required from the SSTV mode. The image viewed is quite good and will permit anyone to take part in the reception experiments without much expense or development time.

Since only the individuals listed on the original STA are allowed to transmit during this phase, all other participants should apply their efforts to the reception of the image. There are many unknown factors in the reception of wide-band signals on an unpredictable band like 10 meters. Selective fading could easily tear the signal apart so that it would be impossible to synchronize the image. It is therefore recommended that the reader build some kind of a receiver that can receive the video and then apply the output to a P7 monitor or a digital scan converter as mentioned above. Those of you who may be too young in SSTV to know about the development of SSTV in the 60s will be able to experience some of the excitement of developing a new mode that was experienced by SSTV and ssb experimenters earlier.

After this initial phase of getting the first picture across the Atlantic Ocean has passed, the experiments will include computer processing of digital pictures to enhance and to simplify the data to do bandwidth reduction. Bob Suding, WØLMD,[4] has experimented with the transmission of digital slow-scan data and has had very good results. He believes that eventually a moving image can be transmitted with computer processing at normal TV rates in a bandwidth as low as 36 kHz. This must wait for the future. Let us try to keep the experiments going at a fast pace and record as much data as possible so that when we submit our STA report to the FCC next July we can show the inventiveness of radio amateurs. Thus, they will continue the STA and include more names to complete the development of medium-scan television to a successful new mode of operation for the radio amateur. QST

*Box 95, Waldron, IN 46182

Notes

[1] Miller, "Medium-Scan Television — A New Amateur Frontier, *QST*, October 1978, p. 30.
[2] Box 393, Bethpage, NY 11714.
[3] 1952 Clinton St., Buffalo, NY 14206.
[4] The new address of Dr. Robert Suding, WØLMD, is 1161 Reston Ave., Herndon, VA 22070.

A Microprocessor-Based Audible Clock

An audible clock has many applications in Amateur Radio. Use this information to get started with one.

By Dr. William S. Wagner,* AA4WW

An earlier issue of *QST* presented a "talking" voltmeter, one that could be programmed either to beep or to send Morse code for a measured potential.[1] A 6800 microprocessor-based microcomputer, appropriate interfacing, and a software package can also make an audible 12-hour clock. For example, a time of 02:41 would be sounded audibly as dah (pause) dit dit (longer pause) dit dit dit dit (pause) dit. A time of 12:09 would be dit (pause) dit dit (longer pause) dah (pause) nine dits, etc. The clock gives a reading once every 20 seconds, or three times a minute. This gives ample time to output the audible tones. Some other interval could be selected if desired, however, — 10 seconds or 30 seconds, for example. The length of the tones and the pauses are all software controlled. The clock can be set to any desired starting time by storing minutes at address 0001 and hours at address 0002.

A suitable interface circuit is shown in Fig. 1, and a software package in Table 1. As shown, a pulse with a 20-second period is necessary in order to drive the hardware interrupt of the microprocessor. The 60-Hz line is used to develop this pulse so that it has good accuracy. If the microcomputer oscillator clock is crystal controlled, however, then good accuracy could also be achieved by dividing it down to get the desired 20-second pulse.

With appropriate changes to the program and to the interface circuit, the technique illustrated here could be used for many amateur applications. One which comes to mind is a repeater clock to send the time in Morse code during identification. Another is to modulate beacon transmitters, enabling those who may be audio-recording received signals to detect the exact time of a band opening upon playback. The application is up to you.

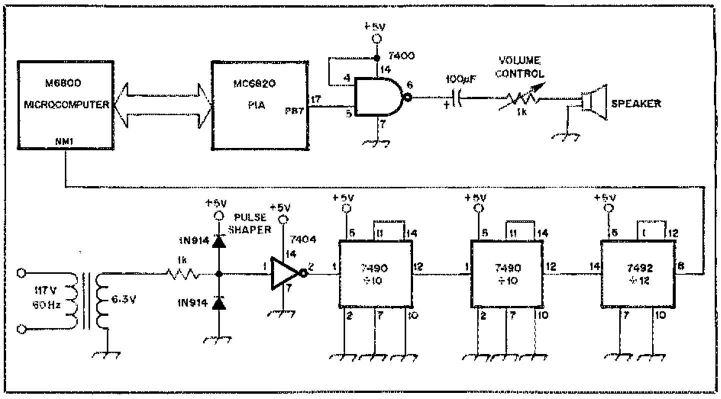

Fig. 1 — Interface circuit for the audible clock. The 60-Hz line frequency provides the frequency (time) reference. The divider chain provides an interrupt signal every 20 seconds to the microcomputer.

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[1] Wagner, "An Audible Digital Voltmeter," August 1979 *QST*, p. 32, and Hall, "Additional Notes on the Audible Voltmeter," p. 34 of the same *QST* issue.

Table 1

Program Listing for the Audible Clock

Address	Op Code	Label	Mnemonic/Operand	Comment
0000		SECONDS		RESERVED FOR SECONDS
0001		MINUTES		RESERVED FOR MINUTES
0002		HOURS		RESERVED FOR HOURS
0003	CE FF04	INITIALIZE	LDX FF04	B SIDE OF PIA IS OUTPUT
0006	FF 8002		STX 8002	
0009	3E	WAIT	WAI	WAIT FOR INTERRUPT
000A	20 F1		BRA F1	
00FD	7E 01A0	NMI VECTOR	JMP 01A0	GO TO CLOCK PROGRAM
Clock Program				
01A0	CE 0000	CLOCK	LDX 0000	
01A3	C6 03		LDAB 03	NUMBER OF READS PER MINUTE
01A5	0D		SEC	
01A6	8D 0E		BSR 0E	INCREMENT 20-SECOND INTERVAL
01A8	C6 60		LDAB 60	COMPARE MINUTES TO 60
01AA	8D 0A		BSR 0A	INCREMENT MINUTES
01AC	C6 13		LDAB 13	COMPARE HOURS TO 13
01AE	8D 06		BSR 06	INCREMENT HOURS
01B0	8D 15		BSR 15	GO TO OUTPUT (MINUTES)
01B2	8D 13		BSR 13	GO TO OUTPUT (HOURS)
01B4	09		DEX	
01B5	3B		RTI	GO BACK TO WAIT AGAIN
01B6	A6 00	INCREMENT	LDAA 00, X	LOAD TIME
01B8	89 00		ADCA 00	
01BA	19		DAA	ADJUST TO BCD
01BB	11		CBA	TIME TO CLEAR?
01BC	25 01		BCS 01	NO
01BE	4F		CLRA	YES
01BF	A7 00		STAA 00,X	STORE TIME
01C1	08		INX	POINT AT TIME
01C2	07		TPA	
01C3	88 01		EORA 01	
01C5	06		TAP	
01C6	39		RTS	
01C7	09	OUTPUT	DEX	POINT X AT BYTE
01C8	9F 10		STS 10	
01CA	96 02		LDAA 02	WHATS IN HOURS?
01CC	27 05		BEQ 05	IF IT'S ZERO
01CE	A6 00		LDAA 00,X	LOAD A WITH MINUTES (HOURS)
01D0	7E 0020		JMP 0020	GO TO AUDIO PROGRAM
01D3	7C 0002	ADJUST	INC 0002	MAKE IT ONE
01D6	20 F6		BRA F6	RESUME
Audio Program				
0020	FF 0015		STX 0015	
0023	8E 00C0		LDS 00C0	
0026				
.	.		.	
.	.		.	
.	.		.	
0060				
0062	27 41		BEQ 41	
0064				
.	.		.	
.	.		.	
.	.		.	
009F				
00A0	9E 10		LDS 10	
00A2	DE 15		LDX 15	
00A4	39		RTS	
00A5	7E 0140		JMP 0140	

Note: Addresses 0026 through 0061, addresses 0064 through 009F, 0100 subroutine for dit tone, and 015B subroutines for dah tones are the same as for the audible voltmeter. See page 33 of August 1979 *QST*.

Strays

CAN YOU HELP A DEAF HAM?

☐ For many years the deaf have been able to communicate by means of modified Teletypes which contain a special telephone adaptor. The adaptor permits the deaf to dial and receive the transmit messages over ordinary telephone lines.

The Teletype for the deaf (TTD) does not match the commercial or amateur networks. TTD uses a 5-level, 45.5-baud Baudot code. The mark is 1400 Hz, space is 1800 Hz with a mark hold (no tone in the holding position).

Does anyone know of a transverter to allow use of TTD in Amateur Radio? Can any of our inventive and experimenting hams come up with a simple piece of equipment to enable the hams and the deaf network to contact each other? Leonard Frank, K2TLW, 28-16 203rd St., Bayside, NY 11360, would like any available information or ideas.

Bug Box QSK

Build this simple and effective cw break-in system and enjoy the luxury of true QSK.

By David P. Shafer, W4AX

An earlier article of mine described a break-in system for cw operation that eliminates backwave and hash from the transmitter.[1] Grid-block bias was applied to the first mixer tube to eliminate backwave. A relay, activated by the key, controlled the screen-grid voltage supplied to the PA tubes to eliminate hash. Automatic break-in (QSK) was provided by a T-R switch.

That method was satisfactory, with one important exception common to systems in which the antenna is tied directly to the transmitter pi network. Suck-out, or the reduction of received levels, may occur because of energy absorption by the pi network. The degree of such attenuation depends on the configuration of station components and the band in use. Many excellent circuits using T-R switches were examined but all appear to have this common deficiency. In some cases TVI may be caused by signal clipping in the T-R switch.

It was therefore decided to devise a system for complete isolation of the receiver in QSK operation. Several methods described in numerous articles or found in manufactured ham gear were considered. In some transmitters, for example, transfer of the antenna for break-in operation is accomplished by means of the VOX relay. This often results in clipping of the first transmitted dit or dah. It usually becomes objectionable at about 20 wpm. In addition, the clacking of the relay may be annoying. If the VOX time-constant potentiometer is adjusted to delay the release of the relay for an appreciable interval, so as to avoid "crowding" the operator, true QSK is not realized.

The basic QSK circuit by VE3AU[2] appeared to be the most promising because of its simplicity and fail-safe feature. A modified version of this circuit has been in use with complete satisfaction for many years. The W4AX Bug Box was designed primarily for cw QSK operation. It is not intended to provide instantaneous QSK in ssb operation, nor does it control the shape of the rf envelope, dit speed or pulse length. These are functions of transmitter and keyer adjustments. The basic Bug Box circuitry consists of a single transistor which controls a vacuum relay. No changes in the transmitter, amplifier or receiver are necessary.

Theory of Operation

Refer to Fig. 1. For cw operation, S2 is thrown to the cw position. The key (hand, electronic or keyboard) should apply chassis ground potential at J5 or J6 when closed. This turns on transistor Q1, connecting negative potential to the vacuum relay K1. The initial surge of current through the 50-μF capacitor momentarily short-circuits the 220-ohm resistor, thus raising the voltage applied to relay K1 to a value somewhat higher than the nominal 26 volts. The armature movement of K1 from its normally open to normally closed contact is almost instantaneous. Ground potential is also applied through D4, the two rf chokes and the relay common and normally open contacts to J4 and on to key the transmitter. This starts the generation of rf. Note that the transmitter cannot be keyed until after the rf path from J2 to J1 has been completed. This fail-safe feature is desirable because it insures cold switching.

Opening the key simultaneously interrupts the dc paths to both Q1 and the transmitter. However, it is imperative that K1 remain operated until after the rf envelope has completely disappeared. This is accomplished by the network consisting of R2, C6 or C7, and D3 shunting the relay coil. While the key remains closed, the FAST or SLOW capacitor is in a charged condition and no current flows through D3 or its shunt resistor. At the instant of "break" (opening of the key), the energy stored in the capacitor discharges through D5. The duration of this "slugging" current depends almost entirely on the value of capacitance and the impedance of the coil. In the FAST position of S3, the relay will release in approximately 8 ms; in the SLOW position, about 48 ms.

During the "space" interval (between individual dits and dahs) the network is at zero potential. At the instant of "make," a surge of current flows through K1. Only a small charging current flows into the FAST or SLOW capacitor through the 100-ohm resistor and continues for a few ms while K1 is in an operated condition. Thus, the charging current cannot effectively lower the initial peak voltage applied to the relay. In other words, the timing network cannot "rob" the relay at the instant of "make."

The values in the network are chosen to insure cold switching at any keying rate. In both FAST and SLOW QSK, the relay must remain operated after each dit until well after rf has ceased. This interval is independent of the keying rate. For FAST QSK, the relay will release after each dit, at any speed up to about 50 wpm. This gives instantaneous break-in, provided the receiver agc is deactivated. In SLOW QSK, the relay will "hold over" between dits at speeds over approximately 10 wpm. This optional feature is built in to avoid unnecessary switching of the antenna back and forth to the receiver while the receiver is still muted by its agc, if used. In short, SLOW QSK provides break-in between words rather than individual dits.

While the relay remains on its normally open contact following the instant at which the key is opened, there is a path from J4 to J1 through 470 kΩ shunting the 0.06-μF capacitor. The resulting key-line

[1]Notes appear on page 32.

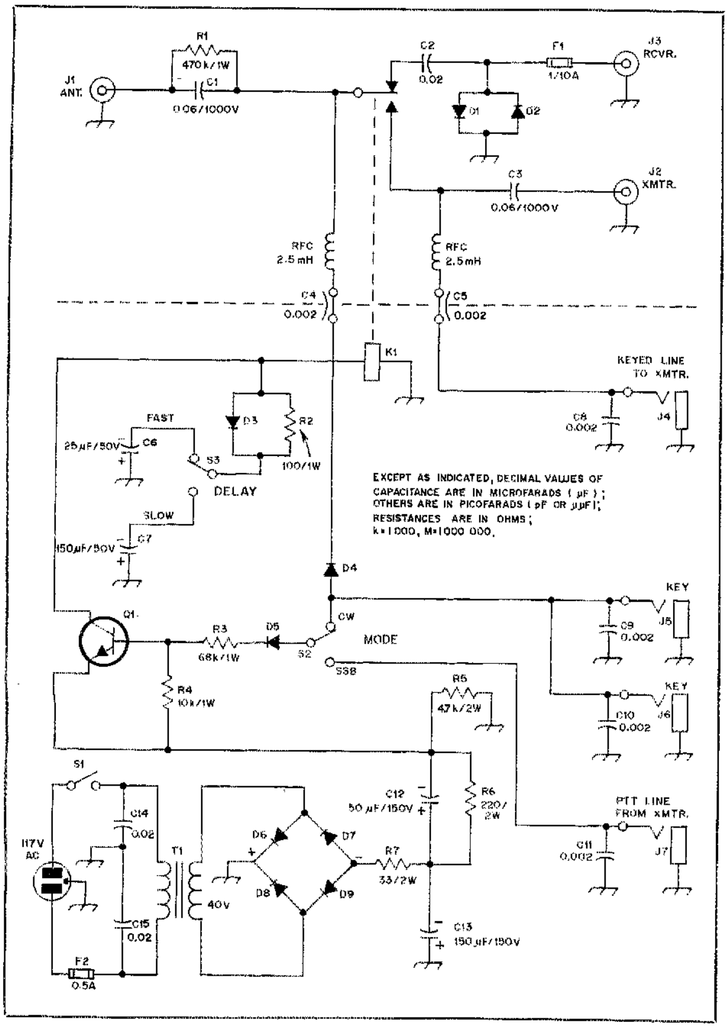


Fig. 1 — Circuit of the W4AX Bug Box. Capacitances are in μF and are disc ceramic except for those with polarity indicated, which are electrolytic, and those listed below. Resistances are in ohms (k = 1000), and are 1/2-watt carbon unless indicated otherwise.

C3, C4 — 0.002-μF feedthrough.
D1, D2 — 1N34A or equivalent.
D3-D9, incl. — 1A, 200 PIV, RCA SK3030 or equiv.
K1 — Vacuum relay (Kilovac HC1 or Jennings RJ1-A).
Q1 — Silicon npn gen. purpose transistor, 10 watts, 3.5 A (2N5784 or equiv.).
T1 — 117-volt primary, 40-volt 0.3 A secondary, Thordarson 23V117 or equiv.

current is only a fraction of a milliampere and produces no tail on the rf envelope. The resistor is used to dissipate any residual charge on the capacitor and antenna system which would be transferred to the receiver when the relay returns to its normally closed contact.

For ssb operation S2 is thrown to the ssb position. When transmission is to begin, ground potential is applied by the transmitter PTT line to J7 and turns on Q1. This operates the relay as in QSK operation. When the PTT button is released, K1 transfers the antenna to the receiver. As in cw operation no clipping of the rf envelope can occur even if the PTT line is opened while talking. The relay timing network is common to both modes.

Choice of Components

The fuse and parallel, reverse-connected diodes D1 and D2 protect the receiver against possible high-level surges from such sources as lightning. The writer blew the fuse on one occasion while testing a second antenna without disconnecting the one in normal use. The strong rf level might have damaged the receiver had it not been for the built-in protection. The 0.02-μF capacitor simply isolates dc from the receiver.

The Bug Box is very quiet in operation. The slight click of the relay, caused by the snappy transition on "make," can be heard at the operating position but not outside the room even in the wee hours of night. Relay operation can be made virtually noiseless if C12 is reduced to approximately 15 μF. The higher value is recommended, however, in order to prevent a shortening of each rf bit reaching the antenna. At low keying speeds, the difference can hardly be detected on a monitor scope. At speeds of 35 wpm or more, this "spacing bias" would be about 5 percent: not objectionable but less than the ideal 50 percent dot weight in the transmitted rf envelope. With the 50-μF capacitor, the spacing bias can hardly be detected at any speed.

Although the 0.06-μF capacitors connected to J1 and J2 are rated at 1 kilovolt, they are conservatively operated and will handle the legal limit. The author uses three 0.02-μF disc ceramic capacitors in parallel in each location.

Any one of several npn transistors similar to the RCA 2N5784, conservatively rated, may be used. The 2N3053 and 2N5321 are good substitutes. Ripple from the power supply is not a problem even with a smaller filtering capacitor; 100 μF is entirely satisfactory but 150 μF is recommended.

The retail price of the Kilovac[3] HC1 or Jennings[4] RJ1 vacuum relay is in the $60 range, depending on quantity. This is a bit steep, but well worth the investment. The coil resistance of both relays is 335 ohms and the nominal operating potential is 26 V. Cheaper reed type relays are available, but seem somewhat prone to sticking of the reed on one of the contacts or hanging up in midposition.

Shielding

The rf-circuit components should be shielded from the dc components. This prevents erratic switching by the transistor caused by exposure to high-level stray rf. The writer uses the Bud C-1796 utility cabinet with a built-in shelf. The relay is mounted in a hole cut in this shelf. J1 and J2 are type SO-239 connectors. J3 is a phono jack. These are mounted on the rear face behind the smaller section containing the rf components. J4 through J7 are located in a row behind the larger compartment housing the dc circuitry. Two key jacks, J5 and J6, are provided so that either a straight key or electronic keyer can be used at will. The switches and pilot lamp are mounted on the front face of the box. C8 through C11 are rf bypass capacitors. The chassis should, of course, be connected to a good ground for safety.

Gain Control

In QSK operation, it is desirable to

monitor the transmitted frequency rather than use a sidetone. This and other advantages of break-in operation are covered in another article.[5] Since the audio level of transmitted signals is usually higher than that for received signals, blasting must be prevented. There are several methods of doing this. For example, a second relay, controlled simultaneously with the antenna relay by the key, applies a partial ground to the receiver muting circuit to increase the agc bias. The degree of muting depends on the amount of resistance used for this purpose. Unpleasant popping may occur in this method however, but can be reduced (if not entirely eliminated) by proper timing of the auxiliary relay and smoothing the change in agc bias by a combination of capacitance and resistance.

A simpler and more effective way is to use a clipper on the receiver output — unless, of course, the receiver is equipped with a built-in limiter stage which would make this unnecessary. With the clipper, there is no popping whatsoever. The Bug Box remains as described and no changes in the receiver are made. Two 1-A, 200-PIV silicon diodes are connected back-to-back and bridged across the receiver output. The audio signal then passes through a 1-kΩ potentiometer to the speaker or headphones. Strong local and incoming signals are equalized in level by the diodes at a higher forward-current voltage threshold than is the case with germanium diodes. It is for this reason that the potentiometer is connected to attenuate the audio signal, after clipping, to a comfortable listening level. At W4AX, the clipper and an MFJ CWF-2 selective filter are housed in a small box (Bud CU-234) fastened to the receiver chassis.

Summary

The Bug Box provides quiet and reliable cold-switching QSK at full power, on all bands and at any keying rate. The addition of an audio clipper eliminates blasting and assures comfortable cw break-in operation with headphones or speaker. PTT is provided for ssb operation. Modification of other gear is unnecessary.

The writer is indebted to the many amateurs who have contributed helpful comments and suggestions during the development of this system. Several of them, here and abroad, are using the Bug Box. QST

[Editor's Note: Shortly after accepting Mr. Shafer's article for publication, we were saddened to learn of his passing.]

Notes

[1]Shafer, "Cleaner Break-In With the 32S-3," *QST*, November 1964.
[2]"A New High-Power Keyed Antenna Relay," *QST*, August 1967.
[3]Kilovac Corp., P. O. Box 4422, Santa Barbara, CA 93103.
[4]ITT, Jennings Div., P. O. Box 1278, San Jose, CA 95108.
[5]Shafer, "Why QSK?," *QST*, February 1979.

ARRL International DX Contest Awards Program

☐ The 1980 ARRL International DX Contest will feature a wide variety of plaques to be awarded to single and multioperator stations. The response to our inquiries for club and individual donors has been overwhelming and only a few were still unfilled at this writing. Many thanks to those who have expressed their support of the ARRL contest program! Are you interested in sponsoring one of the few remaining plaques or do you have a special one you'd like to sponsor? Contact the Contest Branch at ARRL hq. The ones already sponsored are listed in the tables that follow.

W/VE Phone

Single Operator	
All Bands	Frankford Radio Club
3.5 MHz	Gary Firtick, K1EB/W1EBC
14 MHz	Richard Loehning, N9ACP, and Mark Michel, W9OP
21 MHz	Hamfesters Radio Club
28 MHz	Roy and Kathryn Tucker, N6TK/AA6TK
QRP	Rockford Amateur Radio Assn.
Multiop-Single transmitter	
	Mad River Radio Club
Multiop-Multi transmitter	
	Buffalo Area DX Club

W/VE CW

Single Operator	
All Bands	Frankford Radio Club
1.8 MHz	W1TX Roy Fosberg Memorial — Connecticut Wireless Assn.
3.5 MHz	Northern Illinois DX Assn.
7 MHz	Ellis — Doucett Memorial
14 MHz	Neenah-Menasha ARC
21 MHz	Willamette Valley DX Club
28 MHz	Stan Kugler, W1XK
Multiop-Single transmitter	
	Mad River Radio Club
Multiop-Multi transmitter	
	North Florida AR Society — W4IZ (Hollis Graves Memorial)

DX Phone

Single Operator	
World	North Jersey DX Assn
Africa	William Shepherd, K3WS
Asia	Lafayette ARC and Acadiana DX Assn.
Europe	Ron Nevers, K1VTM
North America	Chod Harris, VP2ML
Oceania	Ray Stone, W5RBO
South America	Roy and Kathryn Tucker, N6TK/AA6TK
1.8 MHz	Arkansas DX Assn.
3.5 MHz	Robert Peterson, W3YY
14 MHz	Armond Noble, N6WR
21 MHz	Worldradio, Inc.
28 MHz	Mike Badalato, W5MYA
Multiop-Single transmitter	
World	Delta DX Assn.
Africa	Indy DXers
Asia	Kansas City DX Club
Europe	Roger DeBusk, K8LSG, Memorial
North America	Lynn and Rosie Lamb, W4NL/KA4S
South America	Liga Colombiana de Radioaficionados
Multiop-Multi transmitter	
World	Gloucester County ARC of Southern New Jersey
Asia	Mike Badalato, W5MYA
North America	Southeastern DX Club

DX CW

Single Operator	
World	North Jersey DX Assn.
Africa	San Diego DX Club
Asia	Sonoma County Radio Amateurs
Europe	Clarke Greene, K1JX
North America	Pete Grillo, W6RTT
Oceania	Ray Stone, W5RBO
South America	Alamo DX Amigos — San Antonio, Texas
1.8 MHz	Arkansas DX Assn.
7 MHz	Art Boyars, K3KU
14 MHz	Bencher, Inc.
21 MHz	John Minke, N6JM
Multioperator-Single transmitter	
World	Texas DX Society
Europe	South Florida DX Assn.
North America	The K5RC Multiop Crew
South America	Mike Badalato, W5MYA
Multioperator-Multi transmitter	
World	QRZ DX

Special

Single Operator	
Scandanavia (Highest score)	John Lindholm, W1XX
Rhodesia (phone)	DX Assn. of Connecticut
W/VE Low Power (combined)	Ken Bolin, W1NG
World (combined)	Yankee Clipper Contest Club
Israel (cw)	Martin Harstein, N6WW
Israel (phone)	Martin Harstein, N6WW
West Coast Big Gun (14 MHz phone USA)	Larry Pace, N7DD
Multioperator	
Caribbean (phone)	Joe Johnson, W5QBM Memorial

Club Competition Gavels

Unlimited: 50 or more entries	ARRL
Medium: 11-49 entries	ARRL
Local: 3-10 entries	ARRL

After we read the revised rules for the ARRL DX Contest in December *QST*, a couple of the rules were apparently not specific enough. QRP may be defined as 5 watts dc output or 10 watts dc input, as long as you can accurately measure it. QSOs with your own country count for multiplier credit only. W/VE and VE/W QSOs count for multiplier only. — *Tom Frenaye, K1KI*

A Cheapy-Charger for NiCad Batteries

Need a power supply for that portable gear? Use NiCad batteries and this simple, effective charger.

By Hans Schroeder,* AE9G

Have you found yourself avoiding NiCad batteries as a power supply for your portable equipment because of the charger hassle? I almost did. I had decided against using nickel-cadmium cells for portable operation of my QRP rig because buying and taking along a special charger was not attractive. But then I found a booklet with design information published by General Electric for use with their products.[1] I think the data is not strictly limited to GE cells, but can be applied as well to anonymous NiCad cells like those frequently advertised in surplus equipment flyers. My own charger turned out to be very simple, and some of the design information ought to be useful to fellow builders.

NiCad Characteristics

Sealed nickel-cadmium cells are a closed chemical system requiring no replenishment of any sort during their life, which should be at least 1000 charge-discharge cycles. What is harmful to the cells is too deep a discharge, especially reverse-charging, or excessive overcharge. Reverse charging happens easily in a series string of cells. When a series string is completely discharged not all the cells reach their end point simultaneously. The cell which reaches zero charge first will be reverse-charged by the continuing current flow caused by the cells which still have potential. Reverse charging causes hydrogen to be developed which is not reabsorbed but lost to the chemical cycle. If enough pressure builds up, the hydrogen will escape through the pressure-relief vent.

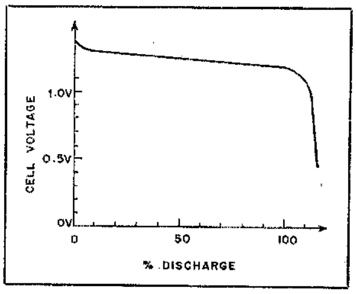


Fig. 1 — Typical nickel-cadmium-cell discharge characteristics.

The normal discharge characteristic of the NiCad cell is shown in Fig. 1. Ordinary cells — those which are not intended for high discharge-rate applications — are rated on a one-hour basis. That means that a size D cell which is marked 1.2 ampere-hours (such as the GE type GC-3) is able to supply 1.2 A for one hour. Charging currents are then specified as percentages of this one-hour current. For example, a trickle charge should be 2 percent of that one-hour current, or less. That current is intended to sustain the charged state of the cell, but is not adequate to charge a cell which has been discharged.

More commonly used is the normal, so-called "overnight" charging rate. This should use a current about 10 percent of the one-hour current. Besides charging the cell in a reasonable length of time (about 14 hours from total discharge), it is a rate at which the cell can be overcharged for some time without harm.

The limiting factor in overcharging is the rate at which the chemical system can reabsorb the oxygen which is developed when a charged cell continues to be charged. If the overcharge current is too high, oxygen is developed more rapidly than it can be absorbed. Excessive pressure develops, and this pressure bleeds off through the cell vents, with the resulting loss of oxygen to the chemical cycle. In addition there is an undesirable heat buildup. None of these effects occurs at the 10-percent rate.

Unknown Cells

If a cell is labeled with its capacity in ampere-hours it is an easy matter to use it in accordance with this information. If it is unlabeled, it is possible to charge the cell at a conservative rate for perhaps 20 to 30 hours to achieve full charge without risk of damage, and then experiment to find the one-hour current. After the one-hour current has been found the cell is in effect calibrated, and the proper 10 percent current for charging can be determined.

Table 1 lists suggested charging currents for common cell sizes. For odd cell sizes interpolate between given values on the basis of the volume of the unknown cell.

The Cheapy-Charger

According to these requirements a constant-current source delivering the desired current is needed. A bridge rectifier connected to the 117-volt power line with a suitable series dropping resistor could do a good job of that, but the

*2400 E. Bradford Ave., #706, Milwaukee, WI 53211

[1] *Nickel-Cadmium Battery Application Engineering Handbook*, 2nd Ed., 1975, General Electric Co., $5.

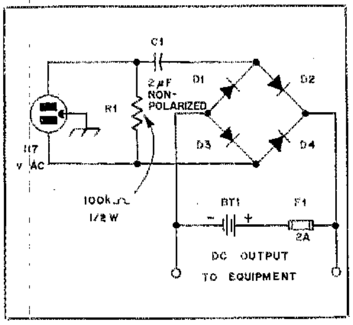


Fig. 2 — The circuit diagram of the AE9G NiCad supply and charger.
BT1 — 10 size-D NiCad cells in series.
C1 — Nonpolarized, approximately 2 µF, 200 V (see text).
D1-D4, incl. — 200 PRV general-purpose silicon diodes, 1N4003 or equiv.

resistor would have to dissipate a substantial amount of power. A much better choice is to use a "dropping capacitor" as suggested in the GE booklet. The circuit of such a charger is shown in Fig. 2.

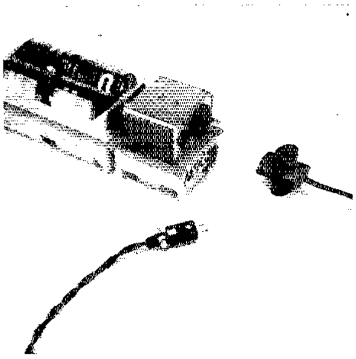
The circuit is simple enough that it is likely to be a 100 percent junk-box project. In my case it almost was — except for the Jones plug used for the dc output connection. The photo shows the charger with a 10-cell battery. To use the battery, plug in the dc cable; to charge, unplug the dc cable and plug in the ac cord.

A few comments on the circuit components: The bridge-rectifier diodes must be able to handle line voltage; current is unlikely to be a limitation. The function of the resistor is to remove any residual charge which might remain on the capacitor and then appear as a voltage between the two ac prongs. Anything between 100 kΩ and 1 MΩ will do. The capacitor value must be determined empirically. As a starting point, use 1 µF per each 40 mA of charging current desired. The value of capacitance used in this charger for a battery pack consisting of 10 size-D NiCad cells is 2.4 µF, which results in a charging current of 90 mA. With no cells being charged the short-circuit current is 95 mA, showing good current regulation.

Safety Considerations

The observant reader will have noticed that when the charger is in use there is no isolation from the power line. I do not find this to be a problem since no point carrying line voltage is exposed. [It would be desirable to use a 3-wire grounding ac plug and cord and connect the green ground wire to the chassis of the charger, as shown in the diagram. — Ed.]

If one of the cells is removed, full-wave rectified ac can be found between the open points, but that is a somewhat artificial situation. In general, any hazard points are about as accessible as the terminals in an ac wall outlet.



The supply/charger in completed form. The charger components are enclosed in the small aluminum box.

It is possible to operate some pieces of equipment (those not sensitive to a little 120-Hz hum on the dc, such as a keyer) from the battery pack while it is being charged. But in that case an isolation transformer should be connected between the power line and the charger. In most cases, though, the 120-Hz ripple caused by the charging current together with the internal resistance of the cells prevents using the dc output while the pack is being charged. The best solution is to build another battery pack, and *charge — cheap!*

Strays

SOLAR-ELECTRIC POWER ADVANCES

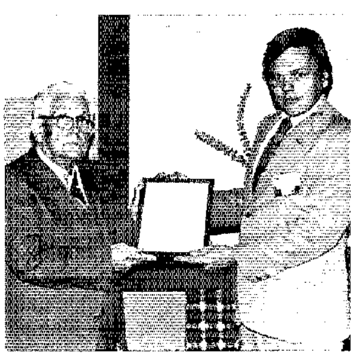
On August 29, 1979, radio station WBNO (a-m) in Bryan, OH, became the first commercial radio station to obtain power from the sun via photovoltaic solar cells. The energy collector consists of 33,600 individual solar cells providing 15 kW of peak-power capability.

WBNO is a daytime a-m station of the low-power class. The solar-array composite system furnishes 70 to 90 percent of the total energy needed annually by the transmitter, according to an article in the November 1979 *Broadcast Engineering*, page 36. The remainder of the station power is supplied by the commercial mains.

The solar array consists of 100 4- × 8-foot (1.2- × 2.4-m) racks of cells which occupy, collectively, a third of an acre. Nominal output voltage on the service bus is 128 dc. A bank of storage batteries serves as the buffer between the solar array and the station equipment. A capacity of 40 kWh is used. This requires 60 each, 310-Ah batteries, with a combined weight of 2 tons!

This experimental station was sponsored by the U.S. Department of Energy. Project management was by MIT Lincoln Laboratory. Dc-to-dc converters are used between the 128-volt bus and equipment which requires higher operating potentials.

This certainly appears to be a proper move toward energy conservation. Many low-power amateur repeaters could be powered economically by means of solar energy, although projects such as that of WBNO are still quite costly. Unit cost for solar-electric panels should decline as the consumer demand increases. Who knows how long it will be before amateurs can power their 1-kW stations from converted sun energy? How about it, you W6s and Florida W4s? — *Doug DeMaw, W1FB*



Walter G. Marburger, W8CVQ (left), received the ARRL Certificate of Merit for over five decades of activity on the vhf bands. The presentation was made at the 26th annual vhf conference, held at Western Michigan University. Representing the ARRL was the Michigan SCM W8MPD (right), who was one of Professor Marburger's electronics students at Western 23 years ago. *(photo courtesy W8MPD)*

Zapping Life Back into a Nickel-Cadmium Cell

Don't blame your charger because your batteries aren't up to snuff. Give your NiCads the zap treatment!

By George P. Schleicher,* W9NLT

The rechargeable battery has gained great popularity in recent years. Portable radios, pocket calculators, photographic flash attachments, and so on, are economically more attractive than if they had been equipped with "throw-away" batteries. Most of these low-power devices use the spill-proof nickel-cadmium (NiCad) cell which is now widely available. For some devices, the battery is specially constructed with welded connections between the cells. Some have an assembly of three or more cells encased in a molded phenolic housing for ease in handling.

Two sizes of NiCad cells are the most common: the AA and the sub-C sizes. Rechargeable cells are also available in the C and D sizes. Usually both the C- and D-size cells are rated at 1.0 to 1.2 ampere-hours. That is because under the glossy plastic C- or D-size exterior lies a standard sub-C NiCad cell.

A fully charged NiCad cell will have a potential of 1.25 volts. A cell is rated at the maximum current it can deliver for one hour when fully charged. At the end of that time the cell voltage should not have dropped to less than 1.0. A cell that has been discharged to that point should be recharged. Most manufacturers recommend that the charging current be one-tenth of the ampere-hour rating. Charging time would be about 10 hours but for the fact that the charging operation is only approximately 66 percent efficient. Thus a 15-hour charging time is often recommended.

Sometimes, when a NiCad-cell-powered device has not been used for a long period of time, the battery may appear to be dead. Yet, after the batteries are recharged, the device still performs poorly. If the battery voltage is checked it may be low, usually by the voltage of one cell. Can the dead cell be restored? Often yes, if the right technique is used. What has happened is that one cell has become so discharged that its terminal voltage has dropped to zero. Then the other cells in the string force current through the dead cell, tending to reverse-charge it. After a charge, the other cells are brought up to normal terminal voltage but the cell that was reverse-charged may remain at zero terminal voltage. Attempting to use the device will cause further deterioration of the bad cell. Attempts to charge the bad cell at a normal rate usually prove unproductive.

Restoring the Cell

The cure involves testing each cell in the battery to identify the one that has lost its output voltage and applying a short-duration, high-current charge to *only* that cell. The charging current will be heavy — 20 or more times the normal charging current — but only for a few seconds. It is best to have a continuously adjustable low-voltage power supply for this operation. It is also important that both the cell voltage and the charging current be monitored constantly during the zapping. The charging setup is shown in Fig. 1.

The operation involves connecting the charging circuit to the defective cell (power supply negative terminal to cell negative terminal) and increasing the voltage slowly until a maximum allowable current is reached: Use an upper limit of 1-1/2 to 2 A for a size-AA cell and 3 to 3-1/2 A for a larger cell. As the charging current is increased toward the maximum value, a close watch should be kept on the voltage measured across the cell. After about 10 seconds of heavy charge, voltage should appear across the cell and rise rapidly to between 1.0 and 1.3 volts. This rise should occur in only two or three seconds. The charging current should be reduced as rapidly as the cell voltage rises; it should be reduced to the normal charge rate (150 mA for most cells) by the time that the cell voltage rises to 1.4.

That's all there is to it — except that after a terminal voltage of 1.0 or more has been restored to the low cell, all of the cells in the battery should be discharged to 1.0 volt per cell. Then the battery should be given a full charge under the conditions recommended by the manufacturer of the battery or the battery charger. NiCads will be most reliable and deliver full rated power if they are discharged and fully recharged at least once every month. QST

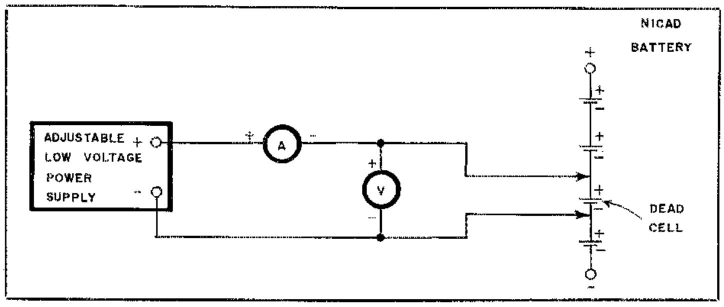


Fig. 1 — The NiCad Zapper is a power supply with charging-current and cell-voltage metering.

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A Versatile Timer Circuit

Need an i-d reminder or a repeater time-out warning device? Then stop, look and read about KA6A's circuit. Included are manual- and automatic-triggering schemes.

By J. J. Coleman,* KA6A

This article describes a four-part versatile timer circuit that is suitable for application as an i-d reminder or for repeater timeout warning. Several different triggering schemes, both manual and automatic, are described, along with explained variations. As you continue reading the following paragraphs you'll also find a description of general timer applications of the ubiquitous 555-timer integrated circuit. Additionally there are included some other logic and rf circuits. Suggestions are offered for those who enjoy experimenting with modifications, while those amateurs who merely want to build the circuit will find the necessary basic data for that purpose. Finally, enough information is offered about all four parts of the circuit so that any individual part may be used for other applications.

Timer and Oscillator Circuits

Appropriately enough, we begin at the end and work forward. Let's consider then how useful it can be to have an i-d reminder. If you work the hf bands, your imagination does not have to be stretched in order to agree that such a reminder is indeed practical, particularly if you are an ardent ragchewer. After all, the Amateur Radio regulations are specific about the station identification.

In general, an i-d reminder circuit would emit a brief tone or turn on an LED to remind the operator to identify before the 10-minute limit is reached. Amateurs who operate through vhf repeaters equipped with timers can benefit from a circuit that emits a short tone, warning that the carrier is about to drop. In both cases, an audio oscillator is a necessary requirement. Fig. 1 shows a 555-timer chip (U1) functioning as an audio oscillator. Actually, the correct description is an astable multivibrator configuration. In simple terms, the output at pin 3 turns on (+V) and off (0) continuously at a rate determined by the 1-kΩ and 180-kΩ resistors in conjunction with the 0.01-µF capacitor. If resistance R_C is much greater than R_B, the

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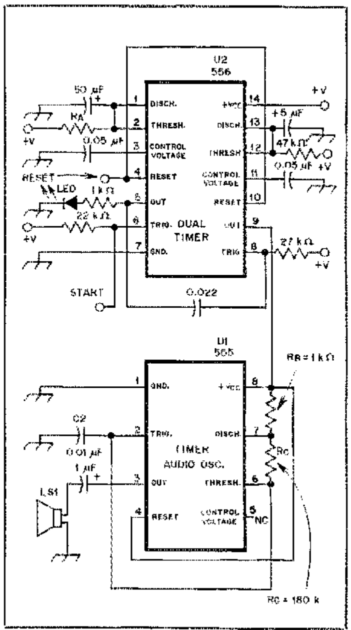


Fig. 1 — Oscillator (U1) and dual timer (U2). The timer interval is determined by the 50 µF capacitor and resistance R.

frequency is given by the formula $f = 1.6/(R_C \times C_2)$ where the resistance is in megohms and the capacitance is in microfarads. In Fig. 1, the frequency is about 900 Hz for values of 180 kΩ and 0.01 µF.

The audio-frequency square wave of the oscillator is used to drive a speaker. The resultant tone is somewhat harder than that of a sine wave, yet it is not unpleasant. There are no audible chirps or clicks produced by this oscillator. With a potential ranging from 5-16 V on pin 8 of the IC (U1) the oscillator will provide enough power to drive most small speakers with sufficient volume. Additional amplification is not necessary. Sidetone and code-practice oscillators can also be fashioned from this single IC.

U2 in Fig. 1 is a dual timer.[1] Except for common +V and ground, this type 556 contains two independent timer circuits. The left side of the chip (U2A) is used as an interval timer which measures, for example, the 30 or 60 seconds for repeater warning or the slightly less than 10 minutes for an i-d reminder. The right side (U2B) of the timer chip is turned on when U2A has completed the timing interval and determines the length of time the oscillator (U1) is on.

The values of components at pins 1 and 2 of U2A (pins 12 and 13 for U2B) determine the time interval. The formula is approximately $T_{sec} = 1.25 \times R \times C$ where resistance is in megohms and capacitance is in microfarads. In Fig. 1, R_A is not specified. A potentiometer, a single resistor or several resistances mounted on a ganged switch may be used for R. As an example, with a 100-µF capacitor and a 5-MΩ potentiometer, all times from 0 to 10.4 minutes are possible. Timer U2B with a 47-kΩ resistor and a 5-µF capacitor allows the oscillator to be on for 0.3 second.

Pin 3 (11) should be tied to ground with a capacitor. A typical value is 0.05 µF but other values will work as well. Pin 4 (10) is the reset pin which must be kept at +V in order for the timer to count an interval. This pin is brought to ground momentarily or indefinitely to stop the timer in midinterval.

Pin 5 (9) is the output pin. During the interval it is at +V potential but otherwise this pin is at zero voltage. The output of U2A is used to start U2B in addition to driving an optional LED for indicating that the timer is working. While timing its interval, U2B supplies voltage to the oscillator directly. An LED and a resistor could be put on this pin for use as a silent optical indicator.

Pin 6 (8) is the start pin. This pin is normally held high (+V) until a trigger momentarily drops the voltage level to ground potential. Once the timer is started, it will continue until it reaches the time specified by the RC combination or until it is reset. The trigger for U2B comes at the end of the

[1]Notes appear on page 37.

U2A timer interval. At this point, the U2A output goes low, and, through the 0.022-µF capacitor, momentarily drives the U2B start to zero. Other values of capacitance can be used for this connection. The circuit of Fig. 1 can be made from two 555s rather than one 556. Pins 1, 2, 3, 4, 5, 6, 7 and 14 on the 556 correspond to 7, 6, 5, 4, 3, 2, 1 and 8 on the 555 single timer IC respectively.[1,2]

Triggering the Timer

Now, we turn our attention to triggering techniques. It is necessary to develop a way to start timer U2A. Also, some way of allowing for the silent reset of both timers must be designed. For a ten-minute i-d reminder, a simple switch arrangement that starts the timer in one position and then resets in the other position will perform satisfactorily. For repeater timeout warning, it is possible to make use of the fact that many microphones have one connection that is grounded for transmit. The connection is part of the push-to-talk switch. The timer circuitry can be added to that connection for automatic operation. Finally, some form of rf actuation may be arranged for automatic RTTY or fm-timer triggering.

Fig. 2 shows a triggering scheme that offers many possibilities. The START pin of the timer is connected through a capacitor to a switch and to a switching transistor (Q1). The collector voltage of Q1 is normally high (+V). If the switch is closed or Q1 is driven into saturation, two things happen. First, the START pin of U2A goes momentarily low and starts the timing interval. Second, transistor Q2, which is normally low (0.1 V) goes high (+V). This allows the timer to function, since the reset voltages of both U2A and U2B will be high as required. The timer will go through the complete cycle unless the switch is opened or the drive on Q1 is removed. Then Q2 will again saturate bringing both pins 4 and 10 low. This stops the timer silently, since pin 10 is the reset for the driver (U2B) of the oscillator.

For manual switching or a microphone connection, transistor Q1 and the Zener diode are not necessary. The Zener diode provides protection of the transistor from overvoltage on the emitter-base junction. There is a measure of freedom in the selection of resistance and capacitance values. The values indicated on the drawing are not necessarily critical. Furthermore, other transistors may be substituted for the 2N2222A. The Zener-diode voltage, however, must not exceed the maximum rating of the transistor and may be as small as 1 volt.

For direct rf triggering, a source of rf-dependent dc current is necessary to saturate Q1. Two possible sources are shown in Fig. 3A as part of a Monimatch type of SWR indicator.[3] It is also possible to steal current from a commercial SWR bridge such as the Swan SWR-3, which has a circuit similar to Fig. 3A. Caution is in order for use of this circuit at frequencies higher than 30 MHz. [Editor's Note: The Monimatch is a frequency-sensitive device and is normally built for use between 1.8 MHz and 30 MHz.]

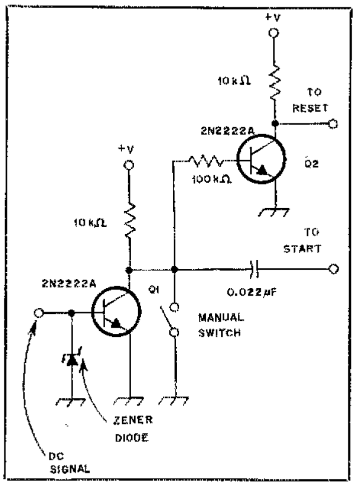


Fig. 2 — Triggering and reset diagrams for the timing circuit of Fig. 1.

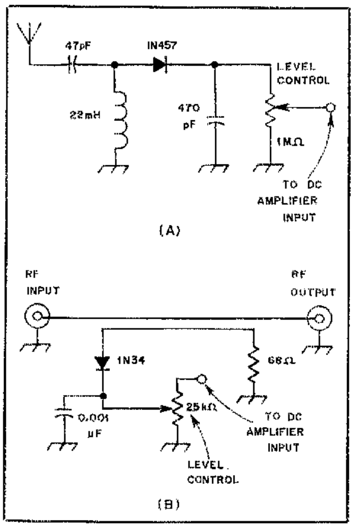


Fig. 3 — Direct (A) and indirect (B) schemes for obtaining an rf-dependent direct current.

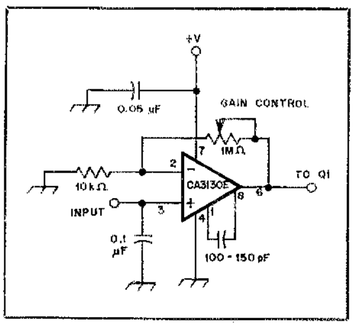


Fig. 4 — Dc amplifier used to obtain sufficient drive for the triggering circuit of Fig. 2.

An alternative scheme requiring no direct transmitter connection is a variation of a field-strength meter circuit such as shown in Fig. 3B. Circuits for field-strength meters abound.[4] Of course a commercial circuit could be used. This circuit worked nicely with just a few inches of wire wrapped around the antenna coaxial feed line for a 2-meter installation. As before, component values are not very critical. Substitutions are possible.

Both the circuits of Fig. 3 require some dc amplification for low rf power levels. A circuit was designed to provide this amplification (Fig. 4).[5,6] The IC is a single-supply op-amp biased to give a noninverting gain of from 0 to 100. The 0.05- and 0.1-µF capacitors bypass rf to ground. The same amplifier configuration has been used to extend the range of several commercial Monimatch-type devices for QRP use.

The final circuit, presently in use by blind amateur WD6EBW, uses the field-strength detector, dc amplifier, transistor switching and a fixed timer duration of about 50 seconds. This has proved to be plenty of time for most 2-meter repeater transmissions. To tune-up the sensitivity controls on the dc amplifier (Fig. 4) and the field-strength detector (Fig. 3), the potentiometers are adjusted alternately in small increments until the LED lights up on transmission. The LED indicates that the timer is indeed working. Adjustments are made first by a sighted amateur. These should then be left alone. The circuit is sensitive to as little as 0.5 W at 147 MHz. The power supply can be a 9-V battery or a 12-V dc supply. The circuit draws only 20 mA (less without the LED).

Finding Parts

One final note about parts. The circuits described here are quite forgiving with the result that many substitutions are possible. If it is necessary to buy parts, I recommend buying twice the amount necessary. The extra components are useful for developing a junk box. Many of the parts suggested for these circuits are available from Jim-pak,[7] a firm that manufactures a line of hobbyist supplies, sold at reasonable prices.

I trust one or all of these circuits will appeal to you. Possibly, by adding one additional box to your shack, your operations on the hf bands will remain legal. With one of these aids, you can also avoid out-talking your local repeater timer. QST

Notes

[1]Keeler, "555 Basics and More," *73 Magazine*, November, 1978.

[2]Jung, *555 Timer Cookbook*, Howard Sams and Co.

[3]*The Radio Amateur's Handbook*, forty-ninth edition, ARRL, 1972, p. 574.

[4]Elementary Electronics, *1979 99 IC Projects*, Davis Publications, Inc.

[5]Riley, "An IC Audio Tune-Up Device for the Blind Amateur," June 1972 *QST* and Riley's personal communication with G. C. Bush, AA6RB.

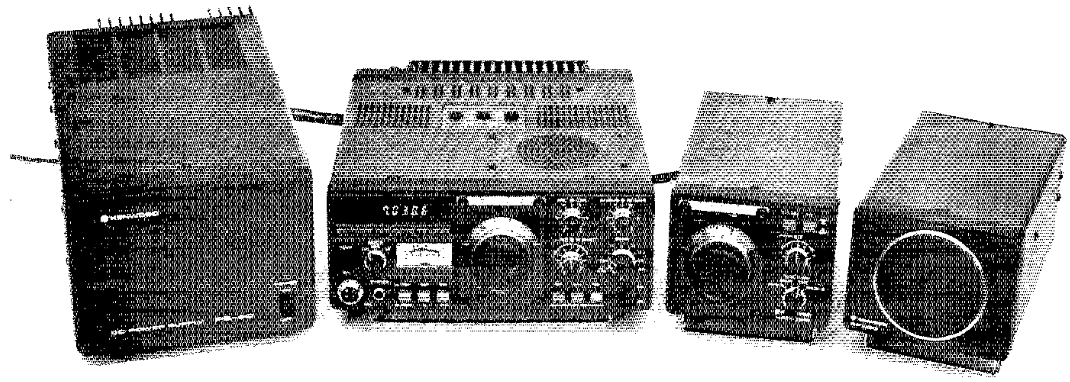
[6]Jung, *IC Op-Amp Cookbook*, Howard Sams and Co.

[7]Jim-pak, 1021 Howard St., San Carlos, CA 94070.

Product Review

Conducted By Paul K. Pagel,* N1FB

The Trio-Kenwood TS-120S HF SSB Transceiver



The Kenwood TS-120S ssb/cw five-band transceiver is shown here with the matching PS-30 power supply, VFO-120 remote VFO and SP-120 external speaker. The combination makes a compact, flexible station whether mobile, portable or fixed.

Kenwood has welcomed another member (baby brother to the TS-820S), the TS-120S, to the ever-growing family. It's easy to see the Kenwood folks had mobile operation in mind when they designed the TS-120S. The size, weight and operating voltage required for the '120 make it ideal for use in land, air and maritime mobile service. Portable and fixed-station operation are readily achieved with an ac-operated supply. Weighing in at a mere 12.3 lbs (5.6 kg), the transceiver proper may be carried as hand baggage aboard an aircraft while the power supply is sent along with the luggage. Or, that added weight may be left behind and the rig operated from any 13.8-V dc source capable of supplying approximately 20 A of peak current.

The matching PS-30 power supply is hefty. In addition to supplying the required voltage and current demands of the '120S, a terminal block at the rear of the unit provides a source of 13.8 V dc at 5 A for powering other units. For example, a 144-MHz or 220-MHz transceiver might be powered from that source. Thus, only one supply would be needed for both hf and vhf/uhf capability.

The '120 has both analog and digital readout, RIT, i-f shift, built-in VOX, 25-kHz calibrator, provisions for crystal control, an internal speaker (with provisions for an external speaker), and a noise blanker designed to eliminate ignition-type noises. Additionally, the design of the '120 is of the "no-tune" variety — set the band switch and operate! How simple can you get?

This rig is broadbanded from 3.5 MHz to 30 MHz: The power output of the transceiver is so constant from one end of a chosen band to the other, it appears as though you're looking at the output of a battery! The measured output power is in excess of 100 watts from 80 through 15 meters. It provides 85 watts across the whole 10-meter band.

With the optional VFO 120 (note the VFO 520 or VFO 820 cannot be used), cross-frequency flexibility is optimum. The remote VFO also has receiver incremental tuning (RIT) and a "T-F" function. The T-F function allows the operator to check the *transmit* frequency for occupancy while in the receive mode and operating "split" cross-frequency. This is done by simply pushing the T-F button; it requires no receiver tuning. Both the main and remote VFOs are gear-driven from the main tuning knobs: No backlash was noted during use. Obviously, the digital display is the primary method of frequency readout. The analog dial may be used as an alternative, but is not as accurate. While the knob skirt has 1-kHz markings which track fairly well, the analog frequency dial (graduated in 10-kHz increments) on both the transceiver and the remote VFO was found to differ by approximately 3.5 kHz from the digital display.

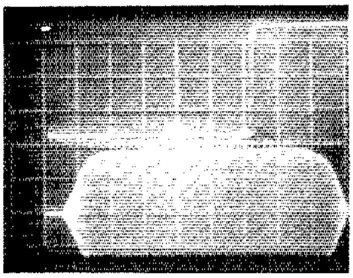


Fig. 1 — The keyed cw waveform of the Kenwood TS-120S. The test was performed on 80 meters. Horizontal divisions are each 5 milliseconds. The upper waveform displays the actual key-down time. Roughly seven (7) ms after key-up, the wave starts to decay. With such smoothly rounded leading and trailing edges, no clicks will be generated. The weighting is "heavy," however, because of the time lag between key-up and the decay of the wave.

The transceiver will tune approximately 60 to 70 kHz outside of each 500-kHz range. This may prove of some worth to MARS operators. Depending on the band in use, the digital display will indicate the frequency of either the high or low end of the tuning range normally, but the opposite end will be awkward digits once the 500-kHz edge is passed. For example, on the 7-MHz band, the upper limit is displayed as 7,562.7 while the lower limit (below the band edge of 7.0000 MHz) appears as 929.2. On 28.5 MHz, the upper limit (past the correctly displayed 28.9000 MHz) will show as 062.7 while the lower limit is displayed as 28.429.1. The analog dial scale is blank beyond the 0 and 500 marks, but the knob skirt markings may be used, and "mental mathematics" performed to ascertain the frequency. The transceiver will function in both receive and transmit over the entire range. With the band switch at the WWV/JJY position, transmission is inhibited, but the receiver is operable for 15-MHz WWV reception.

While operating ssb, nice sharp peaks were noted on the monitor 'scope. The audio quality reports received were excellent, even when using a relatively inexpensive microphone. There is no speech-processing unit built into the '120S.

Some transceivers are designed for ssb

*Assistant Technical Editor, ARRL

operation and leave cw as a kind of afterthought. It was difficult to argue against the performance of the TS-120S. The only item we felt was missing was full break-in (QSK) operation as opposed to the "semi-break-in" incorporated into this and most other transceivers. While running "full-bore" cw on 40 meters, the '120S proved itself a pleasure to operate. VOX keying was quick and reliable (unlike some others) and the clicking of the T-R relay was found to be not unduly loud. When wearing headphones, the operator may be totally unaware of the relay noise. If manual switching is desired, the conveniently located (for right-handed operators) send-receive switch may be used. It is off to the left side of the transceiver and clear of other controls. PTT is, of course, available.

The key jack presents +9 V to the key, so if a transistor-output keyer is used, ensure that the proper polarity is available. The keyed waveshape is shown in Fig. 1. The 'scope presentation of the transceiver output shows smoothly rounded leading and trailing edges. It was not possible to make the keying too "hard" even when attempting to over-drive the rig. The weighting is a bit heavy, however.

The cw monitor note (800 Hz) reflects the "heaviness" of the keying; if high-speed cw is used, the note might tend to sound somewhat "mushy" above 40 wpm. The sidetone volume is adjustable by means of an internally located pot; the cover must be removed from the transceiver for access to this control. No trace of hum could be found on the signal and the dynamic regulation of the power supply was such that no dips or overshoots were noted on the waveform.

Although there is no agc-selection switch on the '120, Kenwood remembered the cw operator once again. When the mode switch is changed from ssb to cw, the agc action of the TS-120S is altered. A faster agc time constant is employed on cw, while the desired slower action will be noted on ssb.

While certainly the IF SHIFT feature is an asset to ssb operation, coupled with the optional 500-Hz cw filter (YK-88C) and RIT, it is a most effective means of reducing QRM while on cw. This function is a welcome carry-over from the TS-820S and the R-820, both reviewed earlier in *QST*.[1,2] Installation of the cw filter takes less than 15 minutes. The filter is simply soldered to the pc board in the allotted space and a jumper plug (for diode switching of the filters) is moved to an adjacent socket. The addition of the cw filter may be desired if cw operation of any magnitude is planned.

The rear panel of the '120S supports the antenna connector, key jack, external-speaker jack, power connector, a hefty grounding terminal and two DIN connectors. One of the DIN connectors is used for cabling of the remote VFO (optional) while the other is a remote jack for use in connecting a linear amplifier or other equipment. A good portion of the rear panel is occupied by a heat sink and pluggable cooling fan, both used to allow the final amplifier transistors to "breathe" properly. The fan is notably quiet and operates only when the heat-sink temperature reaches a specific level. After an hour-long cw QSO at full output, the heat sink was warm to the touch. The heat sink at the rear of the PS-30 power supply was somewhat warmer than that of the transceiver, but not hot enough to cause injury if contacted inadvertently. Both heat sinks should be kept free of surrounding objects, however, to allow for good ventilation during operation. If for some reason the TS-120S heat-sink temperature should rise abnormally, protection circuitry incorporated in the rig will return it automatically to the receive mode until it has cooled properly. The final amplifier transistors are further protected against high VSWR levels. If the VSWR should climb too high, the output power of the transmitter is lowered by reducing drive to the final amplifiers. The owner's manual recommends the VSWR be below 1.5:1 and that a Transmatch be used for impedance matching between the transceiver and antenna when greater mismatches are encountered.

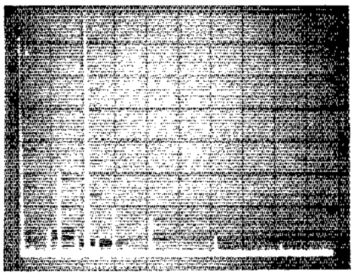


Fig. 2 — A spectral photograph of the transmitter output of the TS-120S operating on 21 MHz at rated cw input power. The vertical divisions are each 10 dB. The horizontal divisions are each 10 MHz. The synthesizer spur at approximately 10.5 MHz is down approximately 49 dB. Other spurs are at least 60 dB down. The TS-120S meets the present FCC requirements for spectral purity.

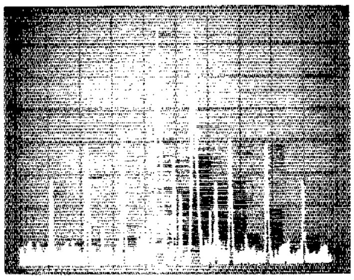


Fig. 3 — This photo represents full-power, 7-MHz, two-tone testing of the TS-120S. Each vertical division is 10 dB. The horizontal divisions are 1 kHz each. Third-order products are approximately 36 dB down from the full PEP output level. All measurements were taken in the ARRL lab.

The Receiver Circuit

The receiver section of the '120S employs a single-conversion scheme with an i-f of 8.83 MHz. Signals arriving at the antenna are met by an i-f trap then impedance-matched by a wide-band transformer for application to a bandpass filter. This filter is common to both reception and transmission. No preselector peaking is required. From here, the signal is fed to two MOSFET rf amplifiers, providing approximately 20 dB of amplification. At the

TS-120S Manufacturer's Claimed Specifications

Frequency range: 80-meter band — 3.50-4.00 MHz.
40-meter band — 7.00-7.30 MHz.
20-meter band — 14.00-14.35 MHz.
15-meter band — 21.00-21.45 MHz.
10-meter band — 28.00-29.70 MHz.
WWV — 15.0 MHz.
Mode: Ssb/cw.
Grounding: Negative ground only.
Power requirements: Receive — 0.7 A 13.8 V dc; Transmit — 18 A 13.8 V dc.
Final power input: 80- to 15-m band — 200 W PEP for ssb operation.
160 W dc for cw operation.
10-m band — 160 W PEP for ssb operation.
140 W dc for cw operation.
Audio input impedance: 500 Ω — 50 kΩ.
Audio output impedance: 4 Ω — 16 Ω.
Audio output: More than 1.5 watts (with less than 10% distortion) into an 8-ohm load.
Rf output impedance: 50 Ω.
Frequency stability: within 100 Hz during any 30-minute period after warmup.
Within ± 1 kHz during the first hour after 1 minute of warmup.
Carrier suppression: Carrier better than 40 dB down from the output signal.
Sideband suppression: Unwanted sideband is better than 50 dB down from the output signal.
Spurious radiation: Better than 40 dB down from output signal.
Harmonic radiation: Better than 40 dB down from output signal.
Image ratio: Image frequency better than 50 dB down from the output signal.
I-f rejection: I-f frequency is 70 dB or more down from output signal.
Receiver sensitivity: 0.25 μV at 10 dB S + N/N or better.
Receiver selectivity: Ssb — 2.4 kHz (−6 dB) 4.2 kHz (−60 dB). *Cw 0.5 kHz (−6 dB) 1.5 kHz (−60 dB).
Semiconductors: IC — 26. FET — 16. Transistor — 90. Diode — 142.
Dimensions (WHD): 9-1/2 × 3-3/4 × 11-9/16 inch (241 × 94 × 293 mm).
Weight: 12.3 lbs (5.6 kg).
Color: Gold-brown.
Price class: $700.
Manufacturer: Trio-Kenwood Communications, Inc. 1111 West Walnut, Compton, CA 90220.
*Optional cw filter installed.

[1] DeMaw, "Product Review," *QST*, September 1976.
[2] Rusgrove, "Product Review," *QST*, July 1979.

mixer, the signals meet the VCO output from the PLL and are converted to the i-f. Ceramic filters, noise blanker, crystal filter and three stages of i-f amplification are next in the path of the signal. A diode-ring demodulator and successive audio amplifiers are the last steps taken before the signal is heard in the speaker/headphones.

The Transmitter Circuit

Both high- and low-impedance microphones may be used with the TS-120S. The mic gain control is simply adjusted to a higher level when low-impedance microphones are used. After amplification the audio is passed to the balanced modulator. The resulting double-sideband signal at the i-f (8.83 MHz) is filtered to remove the unwanted sideband. After further amplification the signal is fed to a MOSFET balanced mixer, combined with the VCO output and converted to the final transmitted frequency. The BPF (bandpass filter) removes spurious signal components and the "scrubbed" signal is amplified in three stages in the wideband amplifier. The driver and push-pull final amplifiers then pass the signal through an rf filter and on to the antenna.

Some Notes

A few typographical and transliteration errors were found in the text of the owner's manual. It reminded the reviewer of the earlier years when imported amateur equipment was just making headway. From an operational point of view, the manual covers all areas well. Unfortunately, the only page devoted to troubleshooting is aimed solely at *operational* failures, not those caused by defective components. A comprehensive service manual is available from Kenwood, and would be a worthwhile investment, however.

With a dummy load connected to the transceiver, spurious responses ("birdies") were found in the receiver every 100 kHz across each band and a couple of other spots on the dial. Most of them were very low level responses (the strongest ones being at the extreme ends of the bands); in no case did any of them cause the S meter to deflect. In fact, with an antenna connected, the atmospheric and band noises coupled with the incoming signals masked all but a few. The responses would probably not be noticeable under most circumstances and should not cause any difficulty in reception.

While the 120 was being used at one location only two blocks away from W1AW, receiver overloading was experienced from the strong signal of that station. There is no front-end attenuator provided on the transceiver, which might have offered some assistance under these strong-signal conditions. In a suburban environment away from such strong local signals, no problems with receiver overloading were encountered. The receiver was checked in the ARRL lab and the following figures were obtained: noise floor −139 dBm, blocking dynamic range 108 dB, IMD dynamic range 75 dB. These figures develop an input intercept figure of −26.5 dBm. These are worst-case numbers developed on 80 meters using the optional 500-Hz cw filter. Noise-blanker operation did not degrade these figures. Transmitter tests performed in the ARRL lab with a spectrum analyzer resulted in the displays shown in the accompanying photographs. See Figs. 2 and 3. — *Paul K. Pagel, N1FB*

HEATH HM-2140 DUAL HF WATTMETER

If you are a post-holiday shopper looking to spend the contents of that modest cash kitty your YL gave you as a Yuletide gift, either the Heath HM-2140 or the HM-2141 dual-meter wattmeter is worth your consideration. The principal difference between these two instruments is that the -2140 monitors forward and reflected power over the range of 1.8 to 30 MHz, while the -2141 is designed for the range of 50 to 175 MHz.

Being interested mainly in the lower-frequency amateur bands, I chose to construct the HM-2140 wattmeter. I've not been disappointed.

As shown in the accompanying photograph, Heath has packaged the HM-2140 in an attractive metal enclosure, with two large, rectangular panel meters that provide good visibility. These are used to monitor forward and reflected power besides displaying the VSWR measurement. Additionally, provision is made for reading either PEP or average power. Let this desk-top instrument rest beside your other equipment and you'll notice how it catches the eye of visiting amateurs.

Although Heath engineers have designed the HM-2140 for use in the Amateur Radio bands, it can be employed for other services which operate between 1.8 and 30 MHz. No additional plug-in modules are required to obtain full use of this device within this frequency range.

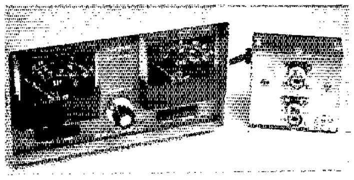
The HM-2140 meets the needs of the operator who is satisfied with low power, or the one who insists on operating transmitting gear full bore at the top legal power limit. Two meter scales are furnished for forward-power indication. The lower scale covers up to 200 watts PEP; the upper range is for power up to 2000 watts PEP. Push-button switching is provided for accommodating either low or high power. There are three scales on the meter: the low range, PEP up to 50 watts; the high range, up to 500 watts reflected PEP; and VSWR covering from 1:1 to 3:1. Push-button switching provides convenient changeover for measuring average or peak-envelope power. The circuit is designed to work into a 50-ohm line.

Because this Heath instrument contains an integrated circuit, a small amount of power is required for its operation. This may be provided by an internally mounted 9-V battery or an external Heath GRA-43-1 converter supply. This optional ac power source may be ordered separately. An LM-324 quad operational amplifier IC serves as an integral part of the peak envelope power-indicating circuit. This has a low supply-current drain (800 μA). Frequent replacement of the battery should not be necessary. Condition of the battery may be checked readily by the metering circuit.

About the Circuit

There are two main areas in the PEP-indicating circuit. The first is a peak detector with gain and the second is a unity-gain buffer network with an offset adjustment. This arrangement preserves the calibration of the rf sensor and contributes to reliable adjustment of the meter.

A practical feature of the HM-2140 that I like is the remote sensing unit. This part of the wattmeter is connected in series with the antenna transmission line for sampling the rf fed to the antenna system. The sensor is connected to the wattmeter by means of a flexible umbilical cable that avoids connecting clumsy coaxial cables directly to the wattmeter. Use of the sensor at a remote position, however, is optional, for the HM-2140 is so designed that the sensor can be placed inside the wattmeter enclosure if the operator so desires. This part of the HM-2140, incidentally, is factory wired and calibrated. Instructions stipulate that the sensor is not to be adjusted. Doing so or otherwise tampering with the sensor can void the warranty.



There is no sacrifice of portability with this new Heath HM-2140 dual wattmeter. The net weight is 4 pounds (1.82 kg). Overall dimensions (HWD) are 4-1/8 × 7-1/2 × 6-3/8 inches (inches × 25.4 = mm). Heath has priced the HM-2140 in the $70 class. It may be purchased from the Heath Company, Benton Harbor, MI 49022, or from Heathkit retail stores.

Comments

Constructing the HM-2140 provided me with two evenings of enjoyment. The carefully planned instructions were thorough, with a well-arranged order of assembly. I liked the workmanship of the Heath circuit board, which contributed to the delight of assembling the wattmeter.

Gratified that the unit passed the initial "smoke test," I proceeded to give it two weeks of on-the-air testing, followed by laboratory testing with a Bird wattmeter. For checking the low-power range, a steady 50-watt signal was fed through the HM-2140 into a 50-ohm dummy load. Band-by-band behavior was observed from 160 through 10 meters. The major scale markings of the Heath wattmeter coincided with the Bird meter indications in each case. A slight difference could be noted for the in-between indications, yet these are within the manufacturer's tolerance ratings.

To note how the HM-2140 behaved where excessive reactance is involved, a deliberately *large* amount was introduced while operating on 10 meters. This caused the reflected power calibration potentiometer in the sensor to heat, apparently as the result of an unwanted resonance that developed in conjunction with an internal ferrite bead. This is not viewed as a fault of the device, however.

The final test involved a high-power run while using a linear amplifier. The HM-2140 performed equally well at this power level.

Readers who are unfamiliar with in-line rf power metering will benefit by reading Doug DeMaw's discussion of practical considerations for this type of instrumentation. His article appeared in December 1969 *QST*. He explains the design philosophy of such circuitry including the basic Bruene configuration. The latter was introduced in April 1959 *QST*. The HM-2140 is based on these principles. Additional information may be found in *The ARRL Antenna Anthology* published in 1978. — *Stu Leland, W1JEC*

THE BRODER LOGIC TRAINER MODEL 100

". . . with no previous logic experience [students] may achieve a very high level of competency in minimum time. . . ." I'm the ideal reviewer, then, because I know nothing about logic circuitry but am anxious to learn. That was my first reaction to this training device. My second reaction was, "What a *neat* gadget!" It is fun to play with and that is the first sign of a good learning device — it piques the old curiosity.

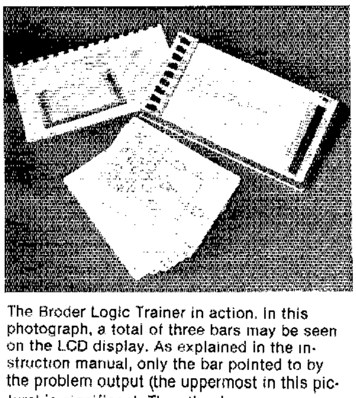
The Broder Logic Trainer is housed in a small box with eight on/off switches on the left and 20 LCD display bars to the right. A set of cards fits into the space between. Each card has a circuit printed on it. The student determines the on/off state necessary at the input to work the problem correctly. If the student is right, an LCD display bar appears at the output (see the photo).

The Broder Logic Trainer also comes with a manual that provides a learning text and answers to the program cards. The text and cards cover gates and sequential logic, including flip-flops, counters and shift registers. The text has additional short sections and a few problem cards on binary adding, Boolean algebra, logic component voltage, logic families, noice immunity, troubleshooting, clock frequency, switch circuit problems, Venn diagrams and symbolic logic.

How well does it work? In going through the manual I found I had no problem with the section on gates, which comprises about one half (20) of the cards. The text is clear and with a little practice, the correct display bars appeared at the output.

Sequential logic was a different story, however. The explanations in the text were not adequate for this reviewer's understanding. At this point, I began using a large classroom text as my main source of information and the manual and cards as a supplement. This worked fine. Again I began to see LCD displays in the right places.

The hands-on approach of this gadget is a great idea. I found that I learned rapidly and retained the knowledge longer when I had the immediate feedback of the LCD display to confirm that I'd worked the problem correctly. Perhaps someone who has a little background in logic — say, home computers or the like — would not have needed another text. I found that I did. While this doesn't in any way make the Broder Logic Trainer a less-useful device, it is probably not a complete course for the inexperienced. It is, however, an excellent workbook and supplement to any logic course. It would be of great help to anyone undertaking home study or attending a course that has no lab time available. It's definitely an enjoyable and effective way to learn. The Broder Logic Trainer, Model 100. L. J. Broder Enterprises, Inc., 3192 Darvany Dr., Dallas, TX 75220. Price: $69.95 with manual and 9-V battery. — *Jeanette M. S. Zuimes, AB1P*



The Broder Logic Trainer in action. In this photograph, a total of three bars may be seen on the LCD display. As explained in the instruction manual, only the bar pointed to by the problem output (the uppermost in this picture) is significant. The other bars are disregarded.

New Books

☐ *Morse, Marconi and You*, by Irwin Math. Published by Charles Scribner's Sons, New York, NY. Hard cover, 7-3/4 × 9-1/4 inches, 80 pages, $8.95.

The idea behind this book is excellent: to take the reader through the fundamentals of electricity and radio electronics theory by providing easy-to-understand projects accompanied by clear, elementary text. Despite its small size and a sprinkling of errors, the book hits its mark.

After disposing of communications before radio in three pages, the author delves into the fundamentals of electricity. The first construction project is a simple flashlight circuit. From here, the reader is led through other projects, culminating in a "versatile shortwave receiver." Although it doesn't seem likely that a youngster who knew little about radio electronics when beginning this book could successfully build this sophisticated project without assistance, that may not be a serious drawback. First of all, a careful reading of the six-page chapter provides a solid introduction to the principles of a regenerative receiver. Secondly, it certainly doesn't hurt to encourage a beginner to seek help from more-experienced friends or relatives.

The building projects between the simple flashlight and the receiver are often useful and always educational. They include an electromagnet, telegraph set, telephone and the author's specialty — a light-beam communications system. This project will be a bit too much to chew on for most youngsters, but will make absorbing reading for everyone unfamiliar with communication via light waves.

The author, WA2NDM, is well versed in Amateur Radio, having written a column in *CQ* for several years. While he devotes only a couple of pages to Amateur Radio *per se*, Math's book is a decent introduction to the hobby. The progression of projects, from a telegraph key to the shortwave receiver, gives the reader a solid foundation on which to expand his or her knowledge of radio.

There are a few problems that detract from the book's effectiveness. There is no explanation of the difference between ac and dc, for example. Theory explanations are purposely brief, but a single sentence would have sufficed. The table of international Morse code characters has three flaws: It is written in the now less-accepted dot-dash form and both the U and the W are represented as two dots and a dash. In addition, it omits the useful double dash in favor of the seldom-used comma. Both ARRL and *Ham Radio Horizons* are victimized by careless errors: The author suggests writing to the "Amateur" Radio Relay League for information on a Novice course, and *Ham Radio Horizons* is said to be published in "Greenvale," NH.

A redeeming feature is the artwork — 77 figures, many of which show pictorial representations of circuit components. The large number of figures also makes the book's relatively hefty price tag a bit easier to bear.

Aimed at youngsters and others who have yet to develop a serious interest in electronics, this small book will provide many hours of enjoyment. The author feels that hands-on experience is preferable to detailed explanations of electronic principles. He may just have a point! — *Joel P. Kleinman, WA1ZUY*

☐ *Man-Made Radio Noise*, by Edward N. Skomal. Published by Van Nostrand Reinhold, a division of Litton Educational Publishing, Inc., New York, NY. Hard cover, 6 × 9 inches, 342 pages plus index, 148 illustrations, $19.95.

Man-made radio noise, so familiar to radio amateurs, is a form of pollution that affects services beyond our treasured hobby. Fortunately, more and more attention is being devoted to the noise problem. In-depth studies are being conducted in a continuing effort to better understand the nature of such interference with the hope that someday much of it can be eliminated. *QST* readers who wish to sample current thinking about radio noise will do well to examine Edward N. Skomal's recent book. The author has been studying natural and man-made noise since 1964. His investigations include experimental studies, theoretical developments of generation and propagation processes and the evaluation of noise as it affects radio communication. He is indeed well qualified. His credits include membership in the IEEE, the International Union of Radio Scientists and the American Physical Society. Additionally, he has served on an advisory committee to the Office of the President on national telecommunications planning. Currently he works for the Aerospace Corporation in El Segundo, CA.

Man-Made Radio Noise contains information for both the engineering and nonengineering reader. After explaining basic terms and defining the difference between manmade and naturally occurring noise, the author deals with other forms, including automotive ignition noise, and how separate sources produce interference that combines into a composite pattern found in most urban areas. Mr. Skomal provides sufficient information so that predictions of average power, quasi-peak and peak-noise field intensity can be confidently made.

The book contains chapters on electric power generation and transmission line noise, interference caused by industrial, scientific, medical, consumer and transportation equipment. The author even delves into elevated and airborne incidental noise. The latter sections are based on data gathered at heights up to 26,000 feet over major cities on three continents.

There is a broad scope of information in *Man-Made Radio Noise*. It is not a "nuts and bolts" hands-on treatment of cures for interference. Rather, it is more theoretical. If you like the challenge of calculus to enrich your understanding, Mr. Skomal has included a liberal amount to tease your brain. Look this book over the next time you are in your favorite book store or public library. — *Stu Leland, W1JEC*

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

CAPACITANCE- AND INDUCTANCE-MEASURING DEVICES

The capacitance bridge and the gadget I made for measuring inductances have been most useful. The latter isn't a true bridge, but it operates on the principle that at resonance the voltage comes to a peak across either L or C in a series circuit. Diagrams for both of these devices are shown on these pages.

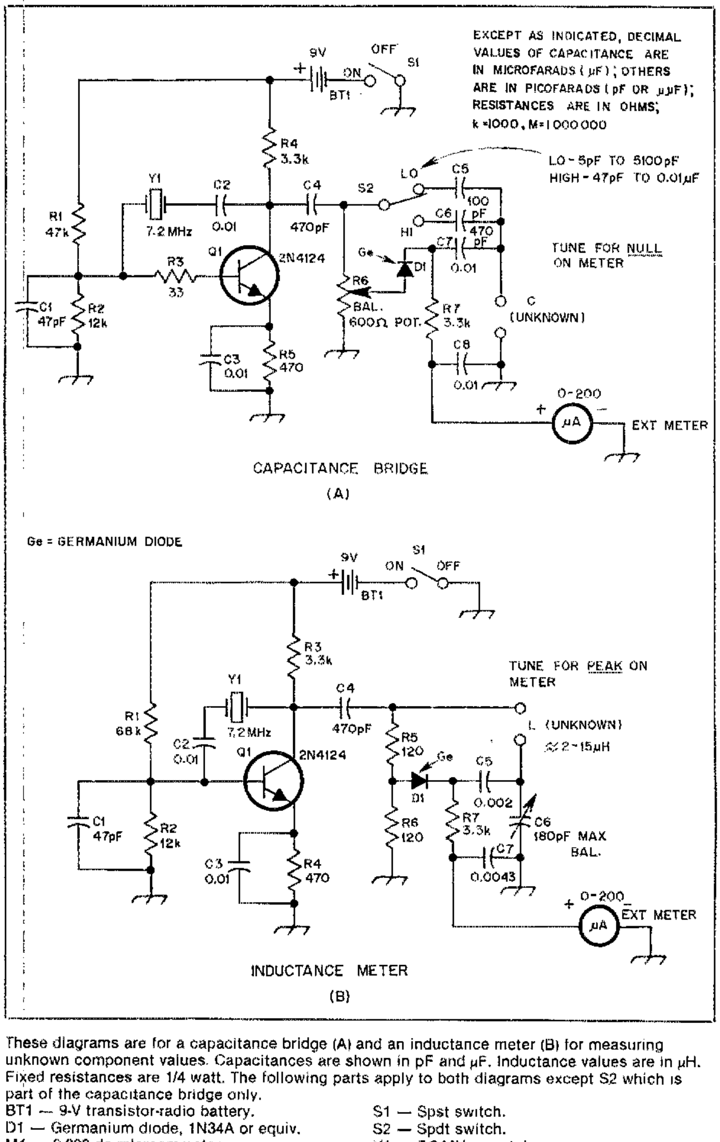
There is nothing critical about parts values in either circuit. In the capacitance bridge, the 100-pF capacitor standard gives a midscale reading of 100 pF in the LO position of the range switch. In the HI position, the 470-pF standard gives a midscale reading of 470 pF. Theoretically, this should have been 1000 pF, but I was unable to get solid dips on the meter with such a large capacitance while using the HI range. I dropped the value to 470 pF as a practical measure.

The value of the variable capacitor that is part of the movable arm of the inductance meter must be such that resonance with an unknown inductance can be attained at 7.2 MHz, the frequency of the internal generator. Other crystal frequencies may be used or you may obtain a signal from a dip oscillator.

Calibration of the capacitance-bridge dial is in both pF and µF with known values being placed in the unknown leg for calibration purposes. The dial of the inductance-measuring gadget is calibrated in µH, again using known values of small inductances such as rf chokes as standards. Only the resistance or impedance bridge for measuring antenna impedance (not included here) is calibrated in ohms.

The circles of aluminum, cutouts made from small speaker cutouts, are useful as instrument dials. I use them on my capacitance bridge, the inductance meter and the resistance bridge I constructed for measuring feed-point impedances of antennas. I cover these cutouts with white card stock on which I mark the calibrations. A coating of Q-Dope protects the pencil markings from smearing. A soft pencil, such as used for machine scoring of tests, is excellent for marking the dials. A dab of epoxy cement will secure the dials to the shafts. Fine tuning adjustments are made easily by placing a finger on the dial edge. — *J. Frank Brumbaugh, Sarasota, FL*

*Assistant Technical Editor, *QST*



These diagrams are for a capacitance bridge (A) and an inductance meter (B) for measuring unknown component values. Capacitances are shown in pF and µF. Inductance values are in µH. Fixed resistances are 1/4 watt. The following parts apply to both diagrams except S2 which is part of the capacitance bridge only.

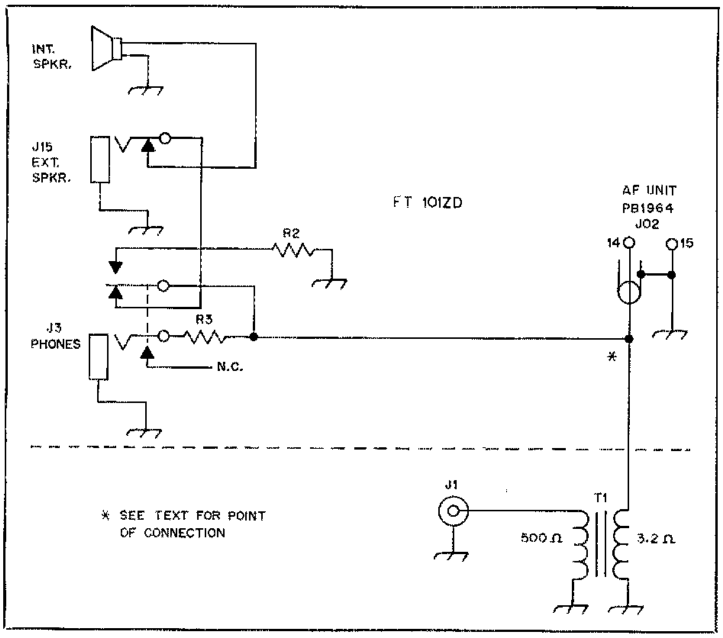
BT1 — 9-V transistor-radio battery.
D1 — Germanium diode, 1N34A or equiv.
M1 — 0-200 dc microammeter.
S1 — Spst switch.
S2 — Spdt switch.
Y1 — 7.2-MHz crystal.

A 500-OHM AUDIO OUTPUT FOR THE FT-101ZD

Owners of the Yaesu FT-101ZD who wish to operate RTTY are at a loss for a 500-ohm audio source. The FT-101ZD has a low-impedance (4 to 16 ohms) audio output only. Attempting to derive audio in parallel with the external speaker jack is awkward. Without the benefit of impedance matching this method requires too high an output level. The raucous sound of an RTTY signal echoing through the shack (and the house) can soon make one unwelcome in one's own home! If the external speaker is disconnected, one cannot hear the signal as he zeros in. The circuit in the accompanying drawing may be added to the '101ZD unobtrusively and provide the needed 500-ohm source without external hook-ups and their inherent shortcomings.

There's a reason for tapping the audio line as shown: If the headphones or an external speaker are plugged into their respective jacks, the audio output at J1 remains uninterrupted. This may be desirable if one does any RTTY work at the wee hours and wishes to remain on good terms with other members of the family.

Two simple additions are required: a single-hole mount phono jack and a 3.2- to 500-ohm miniature audio transformer. The phono jack is mounted on the rear panel at the outside edge of the chassis adjacent to the external-speaker jack. The miniature audio transformer is secured to the transceiver chassis by soldering the pc mounting tabs to the left-hand wall



In N1FB's 500-ohm audio-output modification, components above the dotted line are part of the FT-101ZD transceiver. The added components are J1 and T1. J1 is a single-hole-mount phono connector T1 is a miniature 3.2- to 500-ohm audio transformer.

beneath the chassis as viewed from the front panel with the transceiver inverted. There are two unused holes in the wall and one of these is used to mount a small three-lug terminal strip with 4-40 (M3) hardware. The transformer is placed between the terminal strip and the nearby voltage regulator. Clean the mounting tabs of the transformer and the chassis with an abrasive (sandpaper or emery cloth) and use a high-wattage soldering iron to ensure a well-soldered joint. Shielded wire is run from the 3.2-ohm primary connections to the audio-output connections available at the terminal strip mounted on the same chassis wall near the MIC and PHONES jacks. (A yellow, shielded cable connects the af board output from JO2 to this terminal strip.) A single-conductor wire is then connected between the 500-ohm secondary and the phono jack on the rear panel.

The 500-ohm audio source may now be permanently connected to the RTTY system. Audio output levels will be compatible with those needed for speaker or headphone reception; the use of either of these will not affect the 500-ohm output. — *Paul K. Pagel, N1FB*

LONGER LIFE FOR FRONT-PANEL LIGHTING

I seem to have had more than my share of problems with front-panel illumination on my 2-meter and 450-MHz fm rigs as the lamps were popping like corn over a hot fire (yes, my power-supply voltages are correct!).

Some lamps are mostly for show. Others, like the channel-number light on the Kenwood TR-8300, are essential. Furthermore, to replace the lights in my Tempo VHF/ONE required major disassembly of the radio. On top of all this, replacements for some of the lamps are not easy to find. Clearly, something needed to be done.

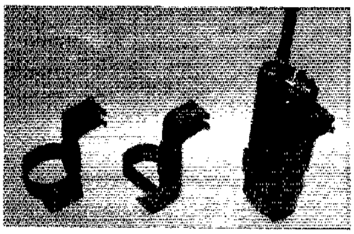
My solution to the problem is to reduce the voltage across the lamps by means of a dropping resistor. Nothing will guarantee infinite life for the lamps, but so far I have found that reducing the lamp potential to about 8-V dc has made a tremendous improvement.

Selecting the proper resistors involves an exercise in Ohm's Law plus a little experimenting. The resistor should allow about 8 volts across the lamp. Be sure that the resistor power rating is adequate. A good rule of thumb is to select a resistor with a power rating of two times the power actually dissipated in the resistor. Finding a place to mount the resistor is left to the reader.

So far, I have lost no lamps during operation at reduced voltage. All have adequate brightness. This is a welcome change, since Murphy's Law says that lamp failure will happen both often and during a trip far from a radio store. — *Roy Hejhall, K7QWR, ARRL Technical Advisor, Phoenix, AZ. From the Arizona Repeater Association publication* The Squelch Tail.

RELAY CHATTER

Chatter from an antenna relay can be rectified by inserting a diode and a series resistor in one leg of the coil circuit to reduce the voltage by 25 percent. This applies to ac-operated relays. Make sure that the diode will handle both the voltage and the current drawn by the relay. If chatter is still present, place an 8-μF capacitor across the relay coil. — *Louis A. Gerbert, W8NOH, Grand Rapids, MI*



Reshaped automobile beverage holders provide a good means for keeping a hand-held radio accessible in a car.

MOBILE HOLDER FOR HAND-HELD RADIO

Ever been bothered while operating mobile with a hand-held transceiver that refuses to stay put on the car seat or dash? A simple solution consists of an automobile beverage holder that can be converted to hold a hand-held set. The holder keeps the hand-held readily accessible without the need for any permanent installation.

The secret of the conversion lies in reshaping the beverage holder while using controlled heat from an infrared lamp to gradually soften the plastic ring of the holder. When heat is applied and the plastic becomes pliable, a piece of scrap wood, the approximate width and depth of the transceiver, can be inserted gradually through the ring opening. With the aid of a towel or soft cloth, the warm plastic can then be shaped to the wooden form, alternating between heating and shaping. The plastic should be held in place for one to two minutes until it cools sufficiently to retain the new shape. When the plastic is cool, the radio can be checked for a snug fit in the holder. If this is done slowly, avoiding overheating, the plastic can be shaped without difficulty.

One refinement is to bend the edge of the holder base in an upright direction. This prevents any significant vibration to the transceiver when the vehicle is moving. — *Allan Hale, WA9IRS/WB8UZG, Cincinnati, OH*

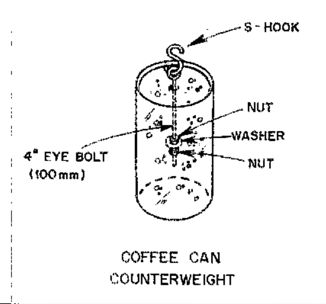
AIDS FOR CIRCUIT-BOARD MAKING

Readers of Doug DeMaw's article on making circuit boards that appeared in September 1979 *QST* may benefit from this information. One tool that was not mentioned in the article, but is useful for fabricating pads, is a metal punch kit. Such punch kits as Whitney-Jensen punch set No. 5 Jr. come with seven punches and dies. With these, one can easily make pads of various sizes up to 1/4 inch (6 mm) in diameter. A punch kit can be purchased for about $20.

Also, 3- to 5-minute drying epoxy cements are available at hardware stores. Use of these eliminates waiting overnight for drying. — *John J. Schultz, W4FA, Voice of America, APO New York*

COFFEE-CAN COUNTERWEIGHT

A simple counterweight for an end-fed wire or dipole antenna can easily be made by filling a two-pound coffee can with Sacrete (premixed



A coffee-can antenna counterweight suggested by W2EPN. The can, a two-pound size, will hold approximately 10 pounds of concrete.

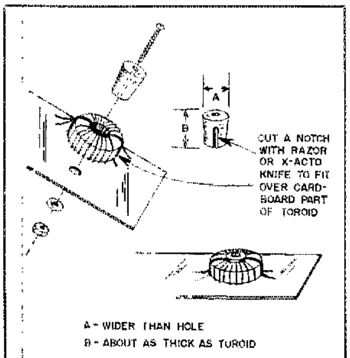
cement). An eye bolt is pushed down into the concrete while it is soft and kept in position by passing a rod (or stick) through the eye, allowing the rod to rest on the edge of the can while the concrete hardens. For convenience in removing the weight to lower the antenna, an S-hook may be used as shown in the sketch.

A two-pound coffee can filled with concrete weighs approximately 10 pounds. This has proven sufficient for the purpose. It is also more practical and attractive than using bricks to keep an antenna taut. — *Roy Foody, W2EPN, Bayport, NY*

CORKS FOR TOROID MOUNTING

Recently I tried mounting some toroids on the circuit board of my RTTY converter. Although I had some plastic inserts, there were not enough. A package of assorted corks, bought at a hardware store, provided a solution to the problem.

To use this method of mounting, find corks a bit wider than the hole in the toroid. Drill a 1/8-inch (3-mm) hole in the middle of the cork, cut a notch on each side to fit the dividers of the toroid (if present) and insert a no. 40 screw with washer. The screw should be long enough to pass through the cork and circuit board. The cork seems to be an excellent mount. It does not damage the wires, provides a snug fit, grips well and is inexpensive. — *Raymond B. Bass, W7YKN, Reno, NV*



W7YKN suggests this method of using corks for mounting toroids. Dimension A should be wider than the opening in the toroid. Dimension B should be the same as the thickness of the toroid.

COMMENTS ON SB-220 MODIFICATION

Referring to the "Hints and Kinks" item, "On Upgrading Your SB-220 Linear Amplifier" (November 1979 *QST*), W3OJB writes that the circuit shown can provide excessive voltage across the time-delay relay coil, K1. He suggests a better approach is to wire the B lead of the relay coil to point D, which is the midpoint of the high-voltage primaries. Doing so will provide a more constant voltage, unaffected by the surge-resistor function in the filament-transformer primaries.

W8JTD agrees that this change is desirable. Accordingly, he suggests deleting steps 3 and 4 on page 56 of November *QST*, substituting the following new steps. First, twist together, solder and tape the ends of the leads mentioned in steps 1 and 2. Then solder a lead to relay-coil terminal B. Connect the free end to terminals 2 and 3 of amplifier terminal strip AF (these terminals are strapped together for 230-volt operation).

While the relays in the SB-220s at both W8JTD and WØPT, wired according to the November "Hints and Kinks" diagram, continue to perform flawlessly, W8JTD attributes this performance to the tolerance of the relays used at both stations. He does recommend, however, that the above modification be made, especially where relays of marginal quality are used. The diagram should be modified to show these changes for the sake of future reference. — *Stu Leland, W1JEC*

INEXPENSIVE NAMEPLATES

For identification at hamfests and conventions, attractive homemade nameplates, such as those shown in the accompanying photograph, can be fabricated at a fraction of the cost of engraved Bakelite plates. Obtain a small amount of 1/16-inch model airplane plywood from a hobby store. It is generally sold in pieces 4 × 10 inches (inches × 25.4 = mm). With a fine saw or sharp knife cut this into strips 3/4 × 3 inches.

Sandpaper the wood smooth. Use Stik-On letters, available at many stationery stores, to spell out your name or call sign. No glue is necessary to secure them to the wood. With a small brush apply a coating of varnish to the surface of the wood. When dry, cement a metal pin-back to the side of the wood without the letters.

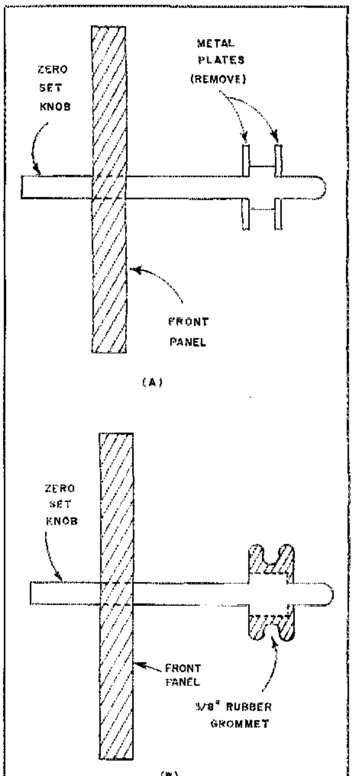
Small strips of thin white or colored plastic can be used instead of wood. Half-inch letters are appropriate. They are available in many sizes and colors from hobby stores as are the pin-backs.

An inexpensive nameplate made from hobby materials.

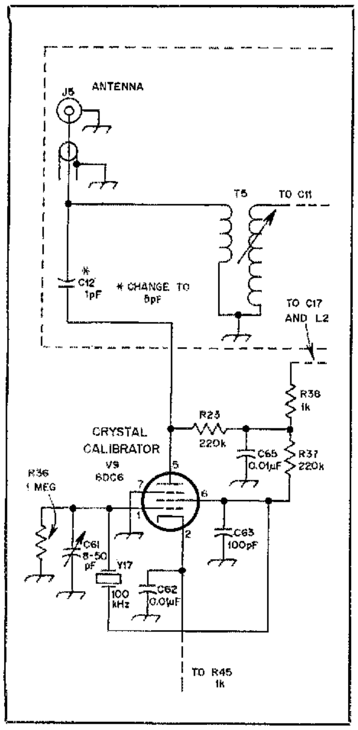
Desk nameplates are made in a similar manner, but the wood should be 3/16- × 1-1/4-inch pine. It is sold at lumber yards. Letter size should be 1 inch. A small block of wood glued to the back of the desk plate will hold it upright. — *Hyman Wallin, Silver Spring, MD*

ZERO-SET DIAL MODIFICATION FOR THE "SB" SERIES

One problem with the Heath "SB" series is that the zero-set dials on the SB-102, 303 and 401 occasionally become inoperative following breakage of the zero-set drive pulley. After replacing three of these pulleys I decided to fix the problem for good. One way to remedy it with minimal cost is to replace the two metal plates on the pulley with a 3/8-inch (10-mm) rubber grommet. The plates can be removed easily with pliers. The rubber grommet will not slip on the dial, nor will it damage the edge of the dial as did the old metal pulley. The rubber grommet should be glued to the old shaft so that it doesn't fall off or slip after prolonged use. Super Glue works very well for this purpose. This modification restores the zero set to perfect working condition. — *Gary M. Kalata, WA2RFK, Cherry Hill, NJ*



Damaged zero-set drive pulleys on the Heath SB-102, SB-303 and SB-401 series may be repaired with the aid of a rubber grommet. See text for WA2RFK's explanation.



N1FB suggests the above modification for increasing the calibrator injection level of the Collins 75S series receivers. Resistance values are in ohms.

INCREASING THE 75S-( ) CALIBRATOR INJECTION LEVEL

The amplitude of the Collins 75S-( ) receiver crystal calibrator is generally adequate up to the 10-meter band. There, especially at the high end of the band, the signal level is much lower. This level may be increased by changing the value of the coupling capacitor, C12, which normally has a value of only 1 pF. Substituting a 5-pF capacitor (or larger, depending upon the level desired) will result in an increase of 4 to 5 S-units which should be sufficient for most applications.

To replace C12, the rear-most shield can, which covers the rf amplifier input switching wafer of the bandswitch (S4), must be removed. The fiber shaft which couples the different switch sections must be removed first; it was decided to move the shaft toward the *front* of the receiver rather than out through the rear chassis hole provided. The band-switch index may simply be moved to one side once the shaft coupler is loosened and the mounting nut and washer removed. This avoids having to pull the fiber shaft through three wafer sections; only one section need be involved. Caution must be observed to prevent misalignment of the vacated wafer, but providing that no rotary motion is applied to the shaft, the wafer will remain in position. Next, the two nuts and washers securing the shield can are loosened and the shield removed. The capacitor is then replaced with the new unit and the process reversed. To ease reassembly, a small dab of silicone grease may be placed at the end of the fiber shaft to permit a smoother reentry into the wafer hole.

Check the calibrator signal at all positions of the band switch. If at any position you cannot get an S-meter reading, it may indicate a slight misalignment of the two shafts at the coupler. Simply loosen the set screws and adjust slightly. — *Paul K. Pagel, N1FB*

ANTENNA CORROSION REMOVER

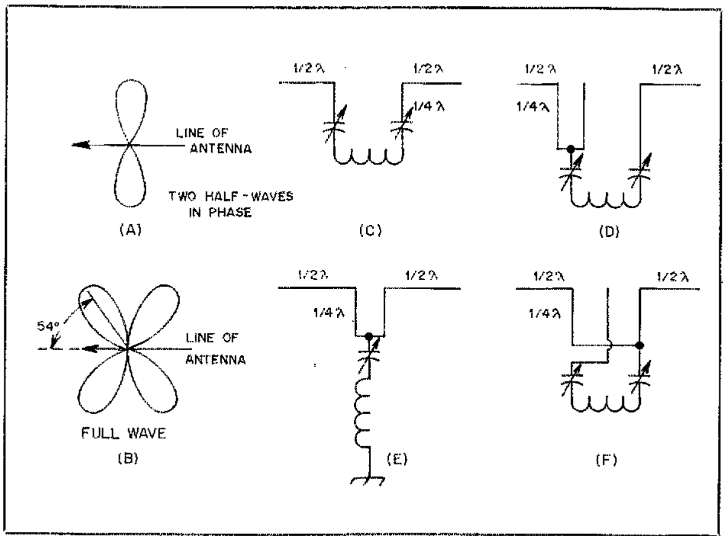
After several years of service, particularly in metropolitan locations, antennas and other exposed aluminum parts often corrode or oxidize to the extent that the electrical characteristics are impaired. One measure which can restore such parts is to apply one of the commercially available aluminum cleaners such as Duro Aluminum Jelly or Burnside Aluminum Brightener. After the metal has been cleaned, it should be thoroughly washed to remove any residual cleaner, dried and coated with an anti-corrosion or anti-rust film spray or sealed with lacquer. Care should be taken when cleaning coil assemblies or where sleeve sections connect to maintain continuity. Aluminum cleaners should not be used on anodized aluminum parts. These are easily cleaned with household aluminum polish. — *Allan Hale, WA9IRS/WB8UZG, Cincinnati, OH*

THE OLD TIMER'S NOTEBOOK: CHANGING ANTENNA DIRECTIONAL CHARACTERISTICS

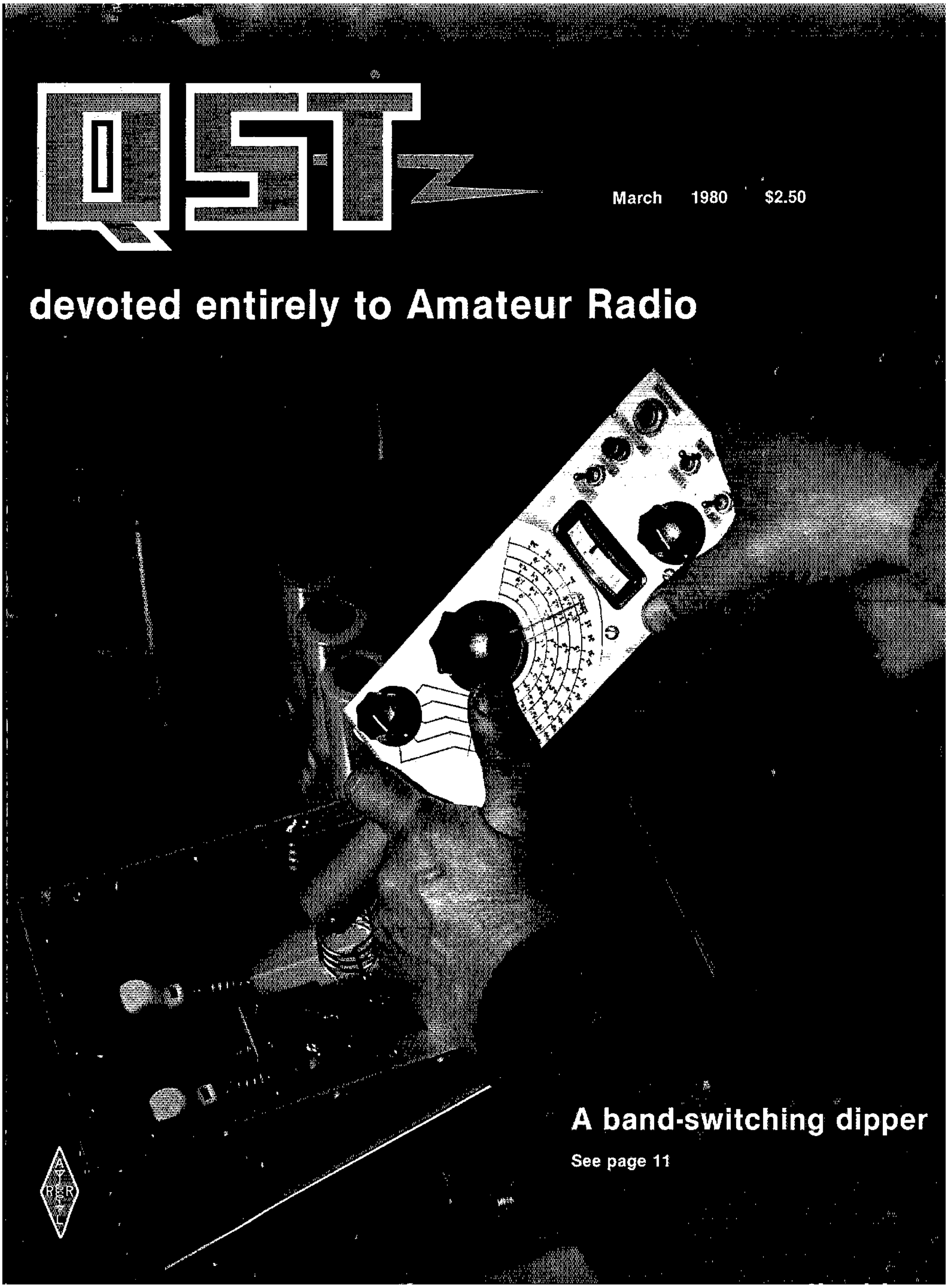
It is not generally realized that some change in the directional properties of a center-fed full-wave antenna can be brought about by changing the feed method. Quoting from a letter from Edward W. Sanders, W3AKU: "In *QST* several articles have appeared in which mention has been made of the use of an antenna system having two half waves in phase on the flat-top. Such a situation results in an antenna directional at right angles to the axis of the flat-top and is accomplished by the use of a full-wave flat-top with an odd quarter-wave feeder connected to the center. If we increase the length of the feeder one quarter wavelength by means of loading coils or by switching-in the appropriate length of wire, we will have two half waves on the flat-top, but they will be out of phase, corresponding to an end-fed full-wave antenna. This system will produce a four-lobed characteristic as shown at B in the accompanying drawing."

The reversal of phase in one half-wavelength section of the antenna can be brought about in a number of ways. A section of wire measuring a half wavelength can be inserted in *one* feeder, or a loading coil having the same equivalent length can be substituted for the half-wavelength section. A third method is shown in the lower center of the drawing (E). In this case the two quarter-wavelength feeders are simply connected together and the whole system worked against ground. A short ground lead is necessary in this case. In all three of these methods the feeders are no longer nonradiating but become part of the antenna.

To have the feeders nonradiating with either method of antenna phasing, it is necessary to use a third feeder wire which can be connected appropriately to the other two (see drawing). The two right-hand feeder arrangements, D and F, illustrate the method of connection. D provides two half wavelengths in phase and a signal pattern as indicated at A. Configuration F puts the two half-wavelength sections out of phase giving the directional characteristic of pattern B. This corresponds to feeding the two half-wavelength antennas from a Zepp feeder and with the currents in each horizontal element being out of phase. The directional characteristic in this case corresponds to B. The change can be made quite simply and quickly by installing a switch to shift one of the active feeders from one side of the coupling apparatus to the other. — *Hints and Kinks for the Radio Amateur (1945)* QST



Feeder changing methods for altering the directional pattern of an antenna. Configurations C and D will give a pattern similar to A. E and F render a cloverleaf pattern shown at B.


QST
March 1980 $2.50
devoted entirely to Amateur Radio
A band-switching dipper
See page 11

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THE COVER

It's a wide-range dip-meter, and a great deal more. Why not build this useful, state-of-the-art instrument for your shack? See page 11.

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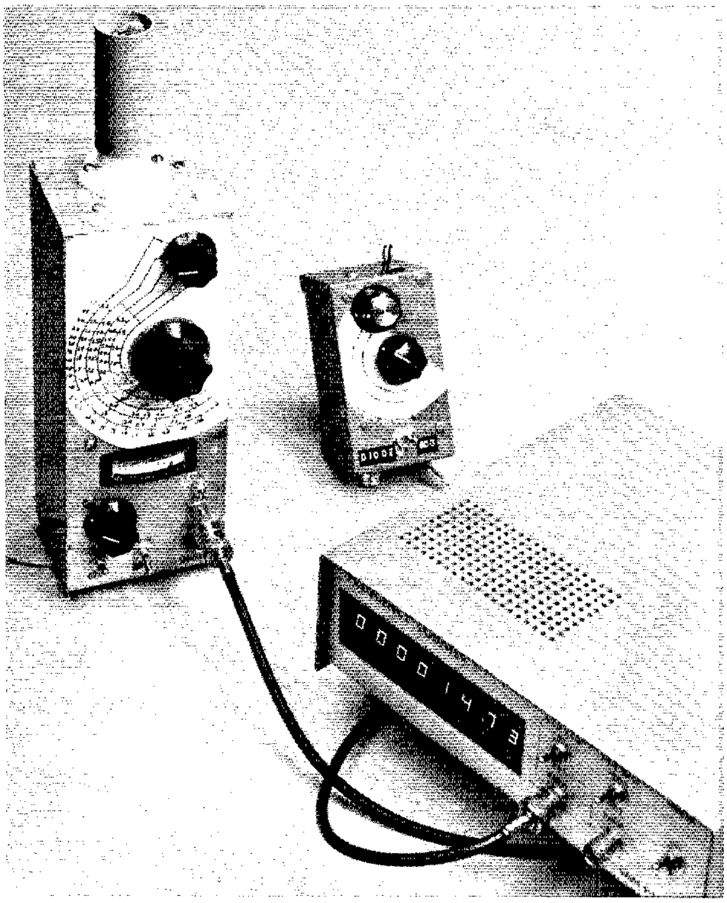
A 1980 Dipper

This state-of-the art dip meter covers 1 to 57 MHz without plug-in coils. It features several innovations not found in commercial models.

By Fred Brown,* W6HPH



The W6HPH dip meter at the left has features not found in many commercial dip meters. Among the advantages offered by the W6HPH design are band-switched frequency coverage, an output jack for a frequency counter and square-wave modulation. Use of an "edgewise" meter leaves more panel space for controls. The frequency scales are hand lettered on opaque paper. An additional tuning head for extending the frequency range into the vhf/uhf range is shown between the dipper and the frequency counter.

Grid-dip meters, or simply dip meters, (most are now solid-state) have undergone only minor improvements since they were first introduced by *QST* in 1926. Current models still use "old-fashioned" plug-in coils and most do not provide for connection to a frequency counter. The author's first band-switching dipper, built over a decade ago, covered 1.3 to 36 MHz.[1] It has served well over the years, but many times the need was felt for a more versatile model with a wider range.

The instrument described here, besides performing the basic dip-meter, wavemeter and signal-generator functions, has the following features not found in commercial versions:

- Band-switched frequency coverage from 0.83 to 57.4 MHz.
- A frequency-counter output jack for precise digital readout.
- A capacitance probe for dipping toroidal, pot-core or shielded tuned circuits.
- 1000-Hz square-wave modulation.
- An accessory socket for connection of additional tuning heads to extend the frequency coverage into the vhf or uhf range.

The Circuit

As shown in Fig. 1, JFET Q1 functions as a conventional Colpitts oscillator. Its frequency is determined by C1 and the value of inductance switched in by means of S1A. Another section of this 5-position switch, S1B, connects the correct value of capacitance to the source of Q1 to control the level of feedback.

The rf voltage on the source of Q1 is rectified by D1, and the resulting dc voltage is applied to JFET Q2 through the 1-megohm sensitivity control, R2. D2 provides a fixed source bias for Q2. These two components act as one arm of a bridge. The other arms consist of R3, R4 and R5. Dc voltage from D1 unbalances the bridge and results in deflection of the 0- to 1-mA meter. Audio from the drain of Q2 is capacitively coupled to emitter-follower Q3. The low output impedance of Q3 feeds headphones when the dipper is used as a wavemeter or signal tracer for a-m signals or as a heterodyne receiver for cw signals.

Transistor Q4, in series with the source of Q1, acts as a switch for square-wave modulation of the oscillator. Square-wave modulation was chosen because it avoids the fm problems associated with sine-wave modulation. During the modulation cycle the oscillator is turned either completely off or on by the square wave. The result is a-m without fm. The square wave is generated by the multivibrator, Q5 and Q6.

*1169 Los Corderos, Lake San Marcos, CA 92069

[1] Brown, "A Band-Switching Grip-Dip Meter," *CQ*, February 1966, p. 60

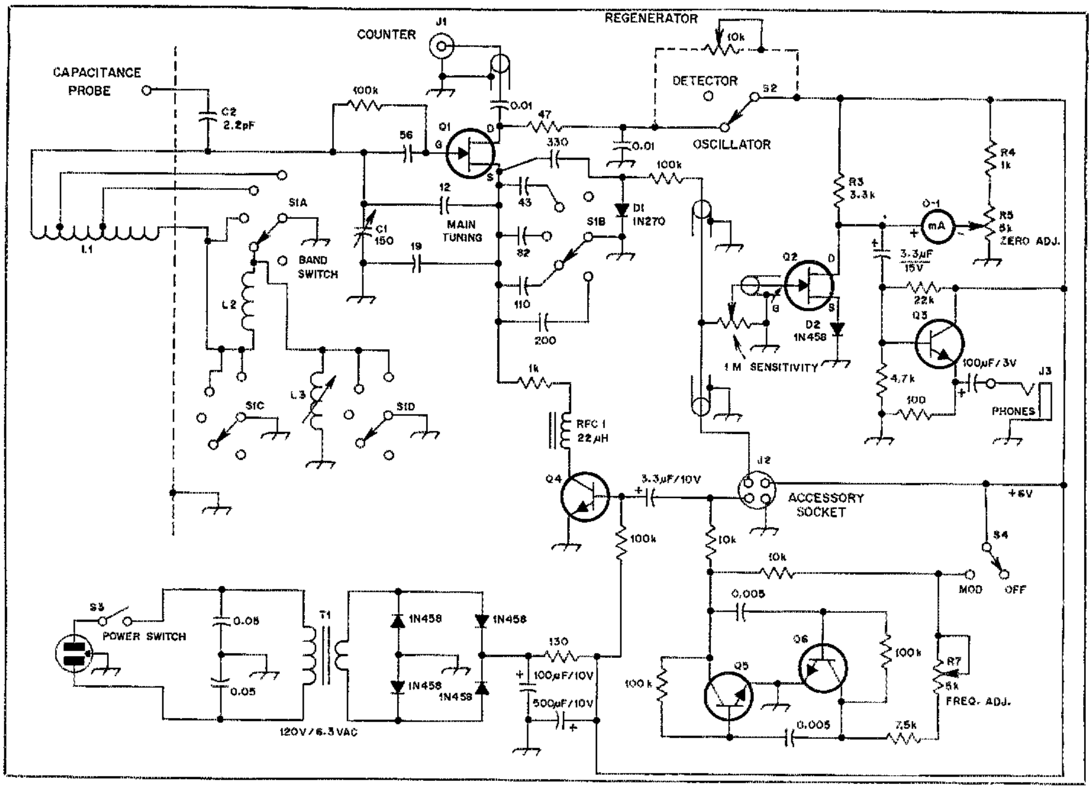


Fig. 1 — The W6HPH dipper circuit. Power is supplied through a small 6.3-volt filament transformer (T1). Q1 and Q2 are 2N3819s. All other transistors are 2N2222s or equivalent. Resistances are in ohms. Except as indicated decimal values of capacitance are in microfarads (µF). Other capacitance values are in picofarads (pF).

J1 — Coaxial jack.
J2 — Four-pin jack.
J3 — Phone jack.
L1 — 7.7 µH, 39 turns of 3/4-inch Miniductor, 16 turns per inch. Tapped 2-1/4 turns and 10-1/4 turns from the "hot" end.
L2 — 36.5 µH, 22 turns of no. 30 enam. wire on Amidon FT-50-61 toroidal core.
L3 — 167 µH, Archer no. 27-1430 or J. W. Miller no. 43A154CBI.
RFC1 — 22-µH iron core rf choke, J. W. Miller no. 70F225AI or equiv.
S1 — See text.
S2, S4 — Spdt switch.
S3 — Spst switch.

Some commercial instruments, such as SWR meters, have narrow-band amplifiers tuned to 1000 Hz. To accommodate such an amplifier requirement, a frequency control, R7, is included in the dipper circuit for precise setting of the modulation frequency. Surprisingly, the modulation frequency turned out to be remarkably independent of power-supply voltage. A line voltage change of 10 percent moves the frequency only 9 Hz.

A 47-ohm resistor in series with the drain of Q1 develops about 250 mV of rf voltage across it, more than enough to drive a frequency counter. This signal is delivered to a phono jack located on the front panel — a jack which also can be used as a signal-generator output.

The primary purpose of J2 is to accommodate additional rf needs for vhf and uhf coverage. It also provides a 6-V dc source and low-level 1000-Hz audio for general experimental work. Furthermore, J2 serves as an input for the audio amplifier, with the output appearing at J3. Finally, a 6-V battery may be connected to this socket for the purpose of making the dipper a completely self-contained portable unit.

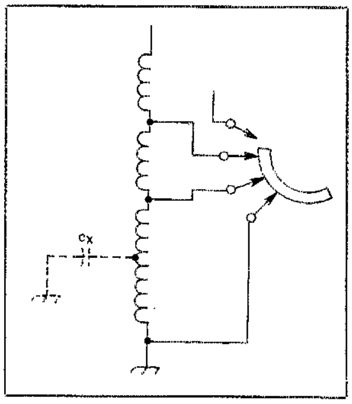


Fig. 2 — Stray-capacitance path in an inductive circuit. Even though both ends of a coil are grounded, the distributed and stray capacitance between the coil and ground, C_X, can still give rise to a resonance.

Band Switching

One problem with a band-switching dipper is the presence of false dips caused by resonances within the switched inductor. Fig. 2 shows how a resonance can occur even though both ends of a coil are grounded by a switch. The stray capacitance between the coil and ground, in conjunction with the coil inductance, forms a parallel-tuned circuit. If its resonant frequency lies within the tuning range of the dipper, it will cause a permanent dip at that frequency.

This dipper, however, is entirely free of false dips. Ideally, a shorting-type switch, such as shown in Fig. 2, should be used for switching the inductance, so that all

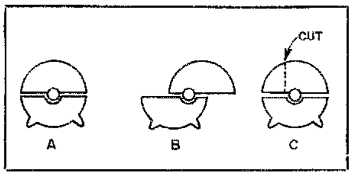


Fig. 3 — A straight-line variable capacitor with straight-line capacitance characteristic is shown at A, and a straight-line-wavelength variable is shown at B. C illustrates how a straight-line capacitance unit can be modified to approximate a straight-line-wavelength response by cutting off the left-hand part of the rotor plates. To avoid possible erratic operation resulting from dirt collecting around the bearings on the capacitor assembly, solder a piece of braid between the shaft and rf ground.

taps on the unused part of the coil will be grounded. Since a shorting type switch was not available, an ordinary 5-position, 4-section wafer switch was used. Two of the extra sections, S1C and S1D, are employed to ground unused taps on the upper frequency ranges.

False-dip problems are also minimized by placing the lowest-frequency coils, L2 and L3, inside the box where there is no inductive coupling to L1. As a result, most of the inductance on the two lowest bands is contained inside the box. This reduces the amount of inductive coupling available for dipping an external LC circuit, which makes the dip weak or hard to find at times, on the lowest band. Where weak coupling is a problem, capacitive coupling, by means of C1, can be used. Of course, capacitive coupling is necessary, in any case, for toroidal or shielded coils.

Receive Mode

When switch S2 is in the detector position, the dipper functions as an indicating wavemeter. The sensitivity was checked at 10 MHz by link coupling L1 to a signal generator. To produce a noticeable deflection of the meter, 50 mV was needed, but when the signal was 70 percent amplitude modulated it could be heard in headphones even when the level was down to 1 mV.

This instrument can also be used as a heterodyne receiver of weak or unmodulated carriers by placing S2 in the *oscillator* position and carefully tuning for a beat note. In this mode, signals as weak as 100 μV can be heard. It's interesting to note that the heterodyne receiver was a predecessor of the superheterodyne. In recent years the heterodyne type of receiver has been rediscovered, and renamed the "direct conversion" receiver.

If a 10-kilohm regeneration control is connected across S2, as shown in Fig. 1, the dipper can serve as a regenerative receiver. With careful adjustment, signals as weak as a few μV can be heard. In fact, several 40-meter cw and ssb stations can be copied when the dipper is coupled to an antenna. Nevertheless, the dipper is definitely not recommended as a substitute for a communications receiver! In the author's case, the regeneration control is not incorporated as a permanent feature.

Construction

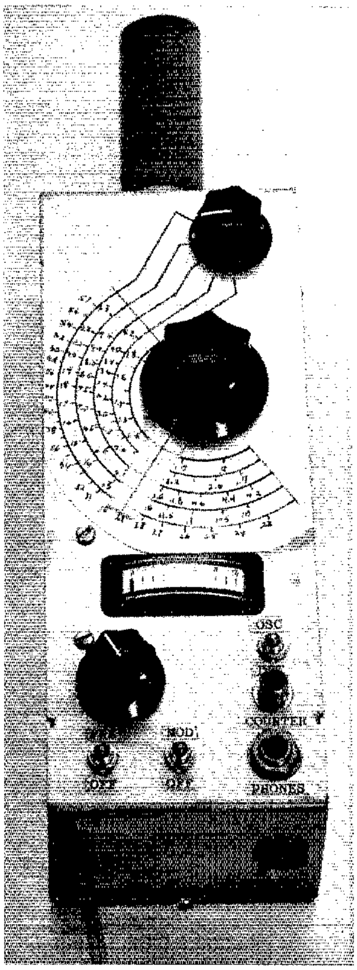
This instrument is built in a 2-3/4- × 3- × 8-inch (70- × 76- × 203-mm) LMB chassis box, but a smaller box could have been used. Parts are so arranged as to keep rf leads short. A miniature switch is recommended for S1. It should be mounted between the tuning capacitor, C1, and the external coil, L1. Q1 and associated components can be mounted on a terminal strip or small circuit board and placed near S1.

If a straight-line-capacitance variable capacitor is used for C1, the frequency scales will be badly crowded at the high-frequency ends. A straight-line-wavelength capacitor is recommended. Fig. 3 shows the difference. Because the author was unable to find a straight-line-wavelength 150-pF variable capacitor, a straight-line-capacitance 420-pF unit was modified by diassembling the capacitor, cutting down the rotor plates, and reassembling it. The task is not easy, especially with a close-spaced capacitor. If the reader should want to tackle such a project, however, Fig. 3C shows how a straight-line-capacitance variable can be modified to give fairly linear frequency scales. It will be necessary to start with a 300-pF (or larger) variable capacitor to end up with 150 pF after modification. If, after cutting down the rotor plates, the maximum capacitance is over 150 pF, it can be lowered by removing stator plates one at a time.

Taps on L1, and the inductance values of L1, L2 and L3, should be adjusted so that there is a small amount of overlap at the ends of the tuning ranges. The ranges in this particular dipper ended up as follows: 0.83-1.88 MHz, 1.8-4.2 MHz, 4.0-9.8 MHz, 9.4-23 MHz and 22-57.4 MHz. The Q of L2 and L3 must be fairly high: If the Q is below 50, the dipper will not oscillate over the entire range. Ordinary slug-tuned coils wound on 1/4-inch or 3/8-inch (6- or 10-mm) dia forms will not provide adequate Q. If toroids are used, inductance can be trimmed by removing or adding turns.

A short length of 3/4-inch (19 mm) PVC pipe is slipped over L1 and anchored to the box in order to prevent damage to the coil from accidental collisions. With some dippers, readjustment of the sensitivity control is necessary when coils are changed or when tuning from one end of a band to the other. This dipper is remarkably uniform in sensitivity. The variation in meter reading is only ±15 percent throughout the entire frequency range.

The 2-volt dc output at D1 is sufficient to give full-scale deflection when the sensitivity control is completely advanced, provided Q4 has sufficient transconductance. Most 2N3819s do, but the variation among those devices is greater than 3:1. Those units at the low end of the transconductance range may not have sufficient gain. The I_{DSS} of the 2N3819 also varies over a wide range (10:1) and, depending on the individual FET, use of two silicon diodes in series for D2 may be necessary. One may suffice, however, or even none at all.



This view of the W6HPH dip meter shows the accessory socket which is mounted on the apron at the right side of the photograph.

The capacitance probe, C2, is connected to a test-prod jack on the front apron of the box next to L1. When capacitive coupling is used next, a test prod, connected through a short flexible lead with an alligator clip, is plugged into this jack. Capacitive coupling works so well it is surprising that this feature was never incorporated into a commercial dipper.

Observations of Long-Delayed Echoes on 28 MHz

The LDE mystery solved?

By A. K. Goodacre,* VE2AEJ/3

Observations of wireless echoes of long delay were first reported more than 50 years ago by Stormer and van der Pol.[1] Since then, many occurrences have been documented in the literature[2] but systematic searches for long-delay echoes have either proved negative[3,4] or produced only a few examples.[5] My interest in long-delay echoes was first kindled by the report of Hans Rasmussen, OZ9CR, of the simultaneous reception of lunar echoes (delay 2-1/2 seconds) and "ghost" echoes (estimated delay 4 to 5 seconds) on 1296 MHz.[6]

While operating Amateur Radio station VE7AIZ in Victoria, BC, I carried out several trials in late 1959 and early 1960 on the 50-MHz band to hear lunar echoes from signals transmitted by Gail Allwine, W7RDY, near Seattle, WA. I have retained my chart recordings over the intervening years so, out of curiosity, I decided to look at these charts again. Much to my surprise, several possible long-delayed echoes appear to have been accidentally recorded.

The delay times of the 50-MHz echoes range from about 1 second to possibly as much as 17 seconds. I noticed that sometimes echoes obtained within a short inverval of time exhibit delays which are very nearly in the ratio of 2:1 (e.g., 3.31 and 1.67 seconds; 11.37 and 5.67 seconds; 7.85 and 3.93 seconds). This suggests that some sort of periodic structure may exist in the delay times. Using the method of Broadbent[7] to search for periodicities, I discovered that most of the delay times were integral multiples of 138 milliseconds. This result must be treated with some caution, as a statistical analysis of the timing errors associated with my homemade chart recordings indicated that my equipment was only marginally capable of detecting a time quantum as small as 138 ms. But, such a value immediately suggested to me that the unusual features on my charts were probably associated with ionospheric propagation, as it takes about 138 ms for a radio wave to travel around the world or to go to the antipode, be reflected, and return by the same path.

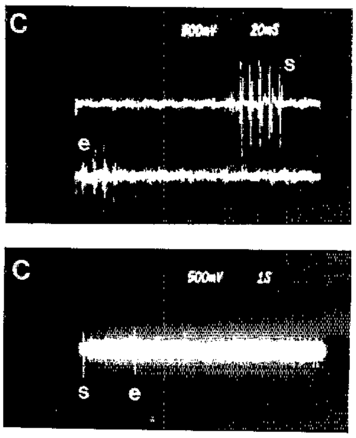


Fig. 1 — 28-MHz transmitted signal (s) and long-delayed echo (e) received on Dec. 1, 1978, at approximately 2300 UTC. Delay time is 2.05 seconds.

With the idea of ionospheric control in mind, I tried, from September 1977 to January 1978, to receive long-delayed echoes on the 14-MHz amateur band. In order to refract my transmitted signal into the ionosphere, I generally operated when the band was ceasing to support ground-to-ground communication. Using this technique I heard a total of 19 weak echoes. Doppler shifts were observed in all cases where I was able to measure the difference between the received and transmitted frequencies. Twelve of the echoes were distinct enough to measure their delay times. But unlike the postulated 50-MHz echoes, the 14-MHz echoes tended to be integral multiples of 133 ms or 144 ms rather than 138 ms. The difficulty with the 14-MHz experiments was that the transmitted pulses were not particularly distinctive, being single pulses a few hundred ms in duration. The received signals could conceivably be from other transmitters, although I took care to operate in those parts of the amateur band where Morse code transmission does not normally occur.

On February 14, 1978, I happened to be searching for long-delayed echoes on the 28-MHz amateur band and recorded a very strong, clear echo in which each of the four consecutive transmitted pulses was Doppler-shifted by different amounts ranging up to about 1 kHz and delayed by different intervals of time ranging from 9 to 10 seconds. This indicated that better results might be obtained on 28 than on 14 MHz, but that it would be necessary to use a fairly wide bandwidth to allow for Doppler shift and to keep the duration of the transmitted signal short enough so that the individual pulses would not be scrambled in the echo. With these requirements in mind, I have been able to document a few good examples of what I believe to be long-delayed echoes on 28 MHz.

Experimental Technique

I feed approximately 400 watts at 28 MHz to a wide-spaced 5-element Yagi antenna and use a receiver bandwidth of 4 kHz to listen for possible long-delayed echoes. My antenna concentrates the radiation toward the horizon and points to the west to minimize the effects of man-made electrical noise originating from the city of Ottawa, to the east. I generally operate when the band is just ceasing to support ground-to-ground communication. Forecasts by the Geomagnetic Service of Canada enable me to concentrate on the periods when the earth's

*1286 Woodside Dr., Ottawa, ON K2C 2G9
[1]Notes appear on page 16.

Table 1

Delay Times of Echoes Depicted in Figs. 1 through 3.

Echo	*Date and approx. time, UTC*	*Delay time in seconds*
A	Nov. 14, 1978 0000	7.04
B	Nov. 17, 1978 2300	5.38
C	Dec. 1, 1978 0000	2.05
D_1	Dec. 1, 1978 0000	2.76
D_2	Dec. 1, 1978 0000	4.28
E	Dec. 1, 1978 0000	1.53
F	Dec. 14, 1978 0100	2.21
G	Jan. 13, 1979 0100	8.97

geomagnetic field is quiet. To obtain a distinctive signal I send groups of three to nine pulses at a rate of 130- to 150-pulses per second (PPS). I avoid rates of 60- and 120-PPS since most repetitive electrical noise exhibits one or the other of these rates. I transmit a signal every 10 to 20 seconds. The receiver output is recorded on magnetic tape and the counter reading is noted whenever a possible echo occurs. Timing calibration is provided by recording CHU time signals before and after each attempt to hear echoes. Then the tape is played back into an oscilloscope and the echoes and time signals are photographed. I then carefully measure the photographs to obtain the delay times. The combined error, because of errors in measuring the photographs and slight irregularities in the speed of the tape recorder, is estimated to be about 20 ms.

Results

While operating for a total of about eight hours from the middle of November 1978 to the middle of January 1979, I obtained a few echoes that are sufficiently strong and clear to be displayed photographically. See Fig. 1 to 3. The echoes are labeled chronologically from A to G. One of the better examples is echo C, given in Fig. 1. The upper part shows the details of the transmitted signal (s) and the echo (e). The bottom part shows the signal, the echo and the general background noise. The signal is, in reality, much stronger than the echo, but it appears to be about the same strength because of the nonlinear response of the receiver to strong signals. Although echo C is not too strong, it reproduces the features of the transmitted signal quite well.

Figs. 2D and 3D show what appear to be two echoes originating from the same transmitted pulse. The second echo is somewhat questionable, but the first echo exhibits exactly the same pulse repetition rate as the signal. Note that the first echo is either truncated or fades into the background noise. Echo G (Fig. 2) seems to consist of two overlapping echoes, the second one only slightly weaker than the first. Echo E may also be two overlapping echoes but, if so, the second one is much weaker than the first.

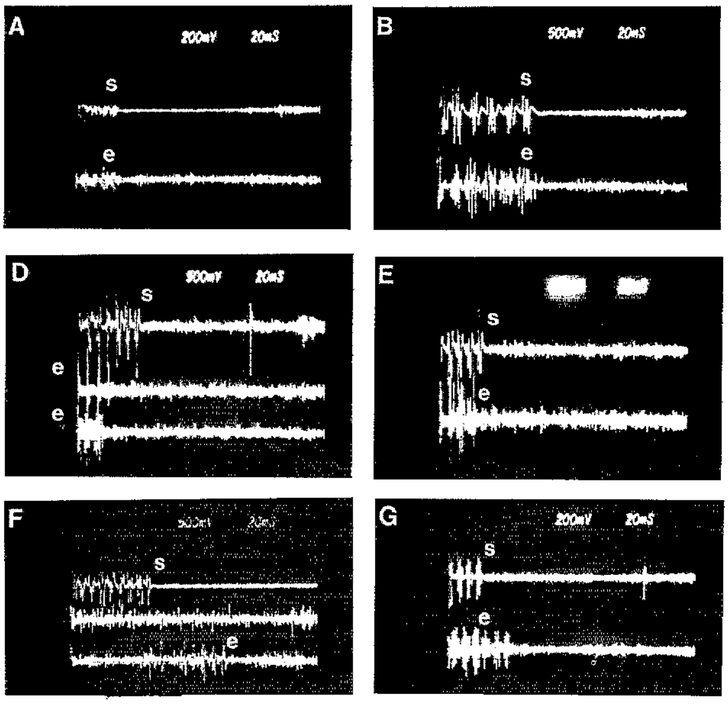


Fig. 2 — Other examples of 28-MHz long-delayed echoes. The transmitted signal is labeled s; the echo is labeled e. Details are given in Table 1.

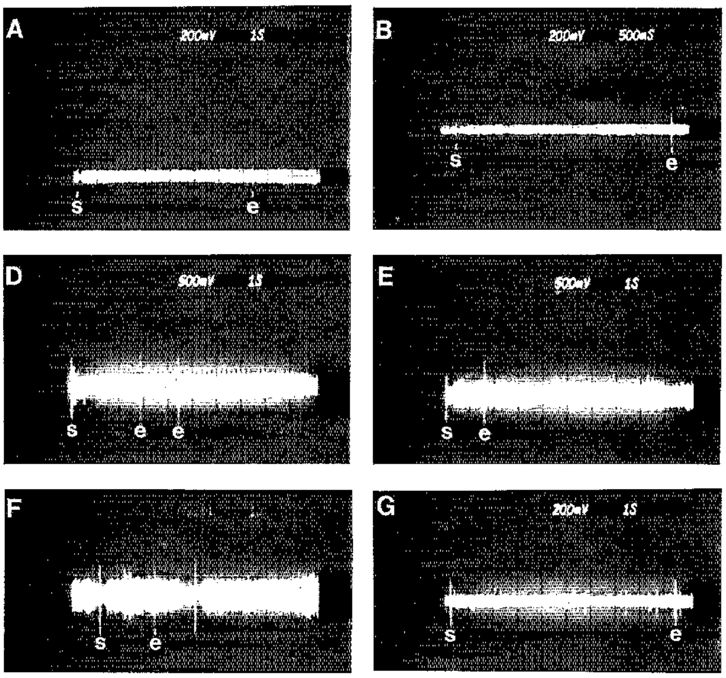


Fig. 3 — Long-delayed echoes as in Fig. 2, but showing general background noise in addition to the transmitted signal (s) and echo (e).

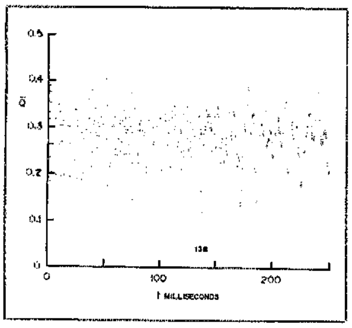


Fig. 4 — Plot of $\bar{Q}$ vs t for the eight delay times given in Table 1. See text for definition of Q. Note the pronounced minimum at t = 138 milliseconds.

In most cases the echo returns within the passband of the receiver, but in the case of echo F, the returned signal is characterized mainly by the switching transients which occur as the transmitter is turned on and off. In this case the main part of the echo may have been Doppler shifted outside of the receiver passband. Although it is not good engineering practice, I allow switching transients to remain in my signal so as to render the signal more distinctive.

Echo A is weak and of marginal quality but exhibits the same pulse repetition rate as the transmitted signal. In Fig. 2, echo B is quite strong but somewhat blurred; in this picture the tape has been played at one-half speed to enhance the detail.

Analysis of the Delay Times

The delay times of echoes A to G are given in Table 1. It can be seen that any unit of time which might be common to these delay times is much less than one second, but it is not obvious what this unit might be. In order to see whether the delay times are "quantized," I have used the method of Broadbent, referred to earlier, to search for periodicities in the range from 10 to 250 ms. Briefly, the procedure is to take a number, t, and form the ratio, E_j/t, where E_j is the delay time of the j^{th} echo and see how far the quotient departs from being an integer. For example, if $E_j/t = 13.7$, the closest integer is 14; but if $E_j/t = 13.4$ the closest integer is 13. In the first case the difference is −0.3; in the second case it is 0.4. If the departure of E_j/t from the nearest integer is termed q_j then the root-mean-square value

$$\bar{Q} = [1/N \sum_{j=1}^{N} (q_j)^2]^{1/2}$$

will be a measure of whether a given periodicity, t_o, exists in the delay. If all of the delay times are exact integral multiples of t_o, $\bar{Q}$ will be zero; but if the process is carried out using uniformly distributed random numbers, the quantity $\bar{Q}$ tends to be a normally distributed random variable with a mean value of 0.29 and a standard deviation of $0.013/N^{1/2}$ where N is the number of delay times considered.

Fig. 4 shows $\bar{Q}$ as a function of periodicity, t, for the eight delay times in Table 1. A distinct minimum occurs at 138 ms, a value that has some physical meaning, but the question is whether such a minimum might not occur even with a set of random numbers. To demonstrate that this is unlikely, I have calculated $\bar{Q}$ as a function of t for 100 different sets of random numbers and plotted, for each value of t, the greatest and least values obtained for $\bar{Q}$ (Fig. 5.) In only two cases out of 100 is a value of $\bar{Q}$ obtained that is as small as that obtained from the delay times in Table 1. As a conservative estimate, I believe there is only about one chance in 20 that the delay times of echoes A to G are not related to each other through the time quantum of 138 ms.

Discussion

Since the time for a radio wave to travel around the world is about 138 ms, the periodicity of 138 ms contained in the delay times of the long-delayed echoes presented here strongly suggests some form of ionospheric control of the phenomenon. This is consistent with the results of Sears, who generally observed long-delayed echoes when the operating frequency was near the F2-layer critical frequency. In his case, the antenna was radiating mainly vertically upwards and most power would be coupled into a horizontally traveling wave under this condition. In my experience, the best long-delayed echoes occur when long-distance, east-west propagation is good. Of course, this may not be the only condition conducive to the production of long-delayed echoes.

I believe that the long-delayed echoes that I hear have been trapped in a duct, possibly between the E layer and the F layer, and that the signals have either traveled around the world several times or have been confined to either the daytime or nighttime ionosphere, traveling back and forth repeatedly from one end of the duct to the other. I believe the signal escapes from the duct and returns to earth by reflecting off an ionized meteor trail. This would explain the Doppler shifts which both Sears and I observe.

Recently, Muldrew has suggested a mechanism to generate long-delayed echoes that involves signals from two transmitters interacting to produce a ducted electrostatic wave.[8] Muldrew's mechanism could explain the occurrence of long-delayed echoes up to ultrahigh frequencies (≈2000 MHz) and, hence, explain Rasmussen's observations, but it is not clear whether this mechanism can explain the time quantum apparent in my results.

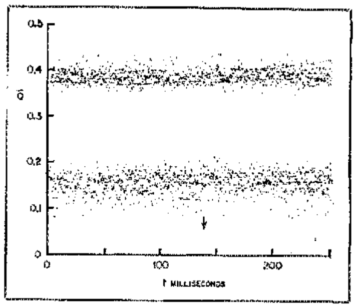


Fig. 5 — Plot of extreme upper and lower values of $\bar{Q}$ vs t as obtained from 100 sets of random numbers used as input data. Note how the minimum in Fig. 4 (marked by arrow) falls well below most of the points in this plot.

Finally, although I believe that the delay times of long-delayed echoes are quantized, the actual value of the time quantum may be different under different circumstances. For example, the periodicites in the 14-MHz data referred to in the introduction are 133 and 144 ms, and the 50-MHz data exhibited additional periodicities of 120 and 152 ms. It is interesting to note that the arithmetic mean of the 14-MHz periodicities is about 138 ms. The arithmetic mean of the 50-MHz periodicities is 136 ms. If the earth's shadow on the ionosphere defines a discontinuity between the daytime and nighttime ionosphere, the maximum two-way travel time on the daytime side is about 160 ms and about 120 ms on the nighttime side. I have recorded short-delayed echoes on 28-MHz Morse code transmissions from other stations. In one case, delays of 115 ms were observed and in another case the delay was 156 ms. The presence of ducts in both the daytime and nighttime ionosphere might, therefore, produce periodicities other than 138 ms in long-delayed echoes. QST

Notes

[1]Stormer; van der Pol, "Short-wave Echoes and the Aurora Borealis," *Nature*, vol. 122 (1928), pp. 681 and 878 (two articles).
[2]Villard, Graf and Lomasney, "There Is No Such Thing As A Long-Delayed Echo AR Long-Delayed Echo AR . . ." *QST*, February 1970.
[3]Budden and Yates, "A Search for Radio Echoes of Long Delay," *Journal of Atmospheric and Terrestrial Physics*, vol. 2 (1952), p. 272.
[4]Duffet-Smith, "An Automated Search for Radio Echoes of Long Delay," *Journal of Atmospheric and Terrestrial Physics*, vol. 37 (1975) p. 455.
[5]Sears, "Long-Delayed Radio Echoes," *SU-IPR Report No. 584*, Stanford University, 1974.
[6]Rasmussen, "Ghost Echoes on the Earth-Moon Path," *Nature*, vol. 257 (1975) p. 36.
[7]Broadbent, "Quantum Hypotheses," *Biometrica*, vol. 42, p. 45, and vol. 43, p. 32 (1955 and 1956).
[8]Muldrew, "Generation of Long-Delay Echoes," *Journal of Geophysical Research*, vol. 84 (1979), p. 5199

[Editor's Note: The author's mention of ionospheric ducting as a likely cause of long-delayed echoes makes an article on this subject that appeared in September 1979 *QST*, page 20, of interest.]

Microcomputers and Radio Interference

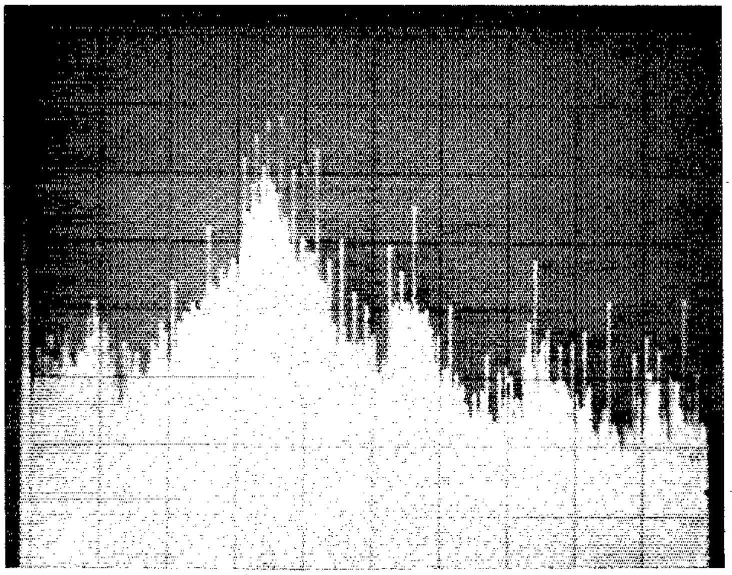
A microcomputer can perform wonders in the ham shack. It can also be an abominable polluter of the radio-frequency spectrum.

By Paul E. Cooper,* N6EY

Just about every amateur already is, or soon will be, deeply involved with microprocessors and microcomputers. The number of things they can do around the ham shack alone is enough reason for this involvement, but in addition the darn things are so seductive that a ham is sure to get hooked.

Unfortunately, too little has been said about the problem of microprocessor or microcomputer compatibility in a communications environment. All microprocessor-based devices, and especially the microcomputer, are a potential source of interference. They are also vulnerable to interference from strong electromagnetic fields. These devices utilize shifts in voltage levels for logic operation, and in modern devices these level shifts are *very* fast, of the order of fractions of a microsecond.

Some idea of the interference problem can be obtained by visualizing the spectrum of a steady stream of short pulses at a fixed repetition frequency. Such a wave shape produces many frequency components, each separated from the next by the repetition frequency. These components extend up in frequency to a limit depending on the sharpness of the rise and fall times of the pulses. If a train of pulses with a repetition frequency of 50 kHz and a rise-and-fall time of a small fraction of a microsecond is generated near a communications receiver, signals can be observed every 50 kHz throughout the tuning range of the receiver. These signals will vary in amplitude (the pattern of the amplitude variations depending on the pulse duration) and will gradually show an overall decreasing trend in amplitude as the frequency of observation is increased. Unfortunately, the sensitivity of the modern receiver is such that this decrease seems to take place all too slowly!



Spectrum analysis of "hash" radiated from a microcomputer system, taken in the ARRL lab. This display was obtained with a short antenna placed a few feet away from an unmodified Radio Shack TRS-80 system, with the antenna coupled directly to the analyzer input. The horizontal axis displays frequencies from dc to 100 MHz, each reticle division representing 10 MHz. Each vertical division represents 10 dB, so it may be seen that there is approximately 48-dB difference in signal strength from spike peaks to valleys across the spectrum. It is significant to note, however, that the frequencies of the spikes shift around, depending in part on the program sequence being executed and in part on the information being fed to the video display.

Now, if pulses are removed from this pulse train at more or less random intervals, the effect is to add background "hash" all across the spectrum. In digital devices, a counter following a crystal clock oscillator produces frequency spikes closer together as the frequency decreases. The net result of all this is that the typical microcomputer produces interference in the form of many multiple cw-type interfering carriers all across the spectrum, broadband hash that shifts in

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nature as the computer program progresses. Some microcomputers even have programs that will produce musical selections on an a-m radio held near the keyboard. This kind of "music" we could do without!

In the presence of a strong electromagnetic field, voltages can be produced by nonlinear action in the active devices of the computer. These voltages can produce false operation. Most amateurs have experienced or heard about false operation of electronic keyers and keyboards when the linear amplifier is being used. In the case of the computer, this can be even more severe and at times more subtle.

Obviously, the answer would seem to be proper shielding and grounding. Amateurs have always had to contend with interference problems — first the a-m radio, then television and high-fidelity systems, and surely there will be more. Each case has its own problems and we have gradually learned to cure or live with each.

. . . the typical microcomputer produces interference in the form of many multiple cw-type interfering carriers . . .

We all know that consumer electronics often leaves a great deal to be desired from the compatibility point of view. No manufacturer wishes to add anything to the product that will add to the cost! The "personal computer" follows the same pattern. The Radio Shack TRS-80 microcomputer is by far the largest-selling microcomputer at this time — over 100,000 units have been sold. The TRS-80 is a very attractive machine to many amateurs — low price, lots of software, plenty of peripherals and good distribution and repair facilities. To illustrate, Macrotronics produces a communications interface device and software for RTTY and cw for the TRS-80 (and also the PET microcomputer). The same machine can be used for logging, contests, calculations and so on. K4TUZ also offers an interface device and software for the TRS-80.[1] Programs are available for just about all the common microcomputers. HAL, Microlog, Info-Tech and others have microprocessor-based dedicated communication terminals.

Compatibility with the Ham Shack

Since the TRS-80 is the most common microcomputer, an examination of this unit will serve to illustrate the compatibility problems, and perhaps help in attacking the problems when they arise. Examining a TRS-80 is a little discouraging. The basic unit is in a plastic case, the video monitor is in a plastic case, the expansion interface is in a plastic case, etc. Obviously the Tandy Corporation didn't make many concessions to eliminating radio-frequency interference! This is understandable from the manufacturing point of view — it wouldn't make the machine work any better, and cost was an uppermost consideration. We see the same problem with hi-fi equipment. Also, the TRS-80 uses dynamic RAM for memory storage, and the "refresh cycle" makes the machine somewhat busier from the RFI point of view. Again, cost, but that is what makes it an attractive unit in the first place!

Fortunately, a well-designed unit incorporates a good ground plane on the pc boards, which is the first important step in minimizing RFI. Leads that are close to a good ground plane have a reduced radiation resistance, thereby minimizing the radiation from the leads. On this score the TRS-80 does quite well. Thanks to this, the machine, although very noisy, isn't hopeless.

Ideally, what should be done to optimize compatibility? Interference from any such device has two components — the radiation field and the induction field. The magnetic induction field is a real problem in that it requires a magnetic (ideally mu-metal) shield for containment. Ordinary aluminum enclosures have little effect. Fortunately, the induction field decays rapidly with distance, so generally a spacing of a few feet from the receiver is sufficient to minimize this problem. Nevertheless, induction must be considered in the ultimate case.

Assume that the machine has a well-designed ground plane on the pc boards, and is in a metal enclosure. Most microcomputers include a keyboard as a part of the basic unit. The usual keyboard uses plastic keys, and there is a big hole the size of the entire keyboard in the enclosure. This is a definite "no-no" from the RFI point of view. A better design would be one in which *each* key comes through an individual hole, resulting in much less leakage. Efforts to contain all rf radiation inside the enclosure are tough enough at best. As an example, in one case a cw keyboard became very "unhappy" when the linear amplifier was used. This keyboard was in a metal enclosure. In order to cure the problem, copper wires were strung horizontally below each row of keys and connected to the chassis. The vertical staggering of the keys prevents this from being done vertically, but in an extreme case a foil shield could be fabricated to fit below the keys.

Many enclosures fail to be effective shields because of the fabrication process in which things are painted and then assembled. The paint often prevents the elements of the enclosure from making a good electrical contact. Anyone who has examined a good "rf-tight" box with welded seams, bronze finger stock around removable panels and so forth, will realize the care that must be exercised. To ensure good metal-to-metal contact, clean paint off joints, use star washers under nuts and put in more bolts.

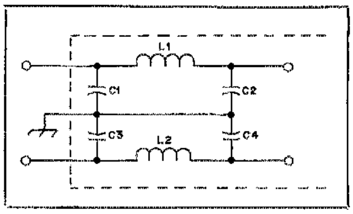


Fig. 1 — A "brute-force" type of filter suitable for bypassing the ac power line as it enters an enclosure. Filters of similar configuration may be used for dc lines.
C1-C4, incl. — 0.01 µF, disc ceramic.
L1, L2 — Approx. 13 µH; 3-inch winding length (75 mm) of no. 16 enam. wire closewound on 3/4-inch (20 mm) dia maple dowel.

Peripheral Connections

Now, assuming the enclosure is tight, what about the peripheral connections? These fall into two categories — those which carry signals completely outside the rf spectrum (60-Hz power, dc, and audio) and those which carry signals whose spectrum lies in, or overlaps, the rf range (video signals, pulse trains and so forth).

The first can be handled by "brute force" filters. The ac line, for example, can be isolated by the filter shown in Fig. 1. *Do not* depend on electrolytic capacitors for dc lines. Use a filter similar to that of Fig. 1 to decouple dc lines. Audio lines should also be decoupled for rf by a filter; there the inductance can of course be much more compact. Commercial feedthrough insulators are available with the entire filter self-contained.

For video or pulse signals and the like, decoupling cannot be used, so well-shielded leads to other shielded enclosures must be utilized. Use a good grade of shielded cable and good plugs and jacks. Every *peripheral* device which is connected must be debugged from an RFI standpoint. In some cases, a peripheral may not be necessary and can simply be unplugged. For example, after using the TRS-80 and a cassette unit for loading programs, *unplug the cassette unit* at the TRS-80 body (DIN plug). All effort at minimizing RFI can be undone by plugging in a peripheral that hasn't been debugged!

Any consideration of shielding and RFI always brings up the question of "grounding." There are two reasons for "common" grounds. First is the hazard of electrical shock, which has been covered repeatedly in various publications. *All* metallic conductors that the

[1] R. E. Barnwell, 1266 Sycamore Dr., Lilburn, GA 30247

human operator can touch should be solidly connected to what our British friends call an "earth." The best way to achieve this is by driving two or more ground rods into the ground as close as possible to the operating position and tying everything to these rods with heavy copper wire. Connecting to water pipes may not be sufficient — there is such a thing as an insulated union to reduce corrosion in pipes, so remember Murphy's Law!

The second reason for a common ground is to attempt to reference *all* signals to the same common reference potential. Herein lies the rub — the ground leads have a finite resistance, and even at low frequencies heavy currents in the ground connections may produce "ground loops" which cause hum difficulties. Most amateurs have encountered this type of problem at one time or another, especially in the era of heater currents with vacuum tubes. This problem can be eliminated by referencing signals, whenever possible, to a "local" ground point, and interconnecting in such a way as to minimize circulating currents.

At high frequencies we are faced with a more severe situation. As the wavelength becomes shorter, physical separation of units becomes comparable to a wavelength, and it is literally impossible to be sure that all "common grounds" are at the same potential. Therefore, each unit must reference its own "local" ground. These are then interconnected, and shielding must be as complete as possible. Even so, strong rf fields can produce such high circulating currents that occasionally the difficulty is handled more by "art" than science, since each specific case is different.

One final word. Ideally the station antenna should be at least 100 feet from the operating position, fed by a good-quality coaxial feed line into a quality balun at the antenna (assuming the antenna is of the balanced type). If properly connected, only signals received by the antenna enter the receiver. The computer interference also must reach the antenna in order to enter the receiver. Try your receiver with a well-shielded dummy load and see if the received signals are really down to zero. If not, you may have some work to do on your receiver!

Case History

The following case history of a TRS-80 illustrates the process and may serve to assist in similar situations. The stations started with a reasonably compact, well-grounded installation, adhering to usual good practice. The equipment complement is given in Table 1.

First-Stage Effort — The Macrotronics M-80 interface was used with the 16-K Level II TRS-80. No special efforts of any kind were made to reduce interference. The M-80 was exposed on the table in back of the computer. Shielded audio and keying leads about 8 feet long ran to the TS-820. The M-80 power module was plugged into a wall socket. This was the "let's plug it in and see what happens" stage.

Table 1

Equipment Used in Case-History Evaluations

Transceiver	Kenwood TS-820S
Linear amplifier	Drake L4B
Matching network	Drake MN 2000
Low-pass filter	Drake TV-3000
Antenna	Hy-Gain 18AVT vertical, 100 feet away, 16 feet above ground (Other antennas were available but this was used as a standard.)
RTTY afsk demodulator	Flesher TU-170
Cw processor	Homemade, variable bandwidth, pulse regeneration
Computer	Radio Shack TRS-80, 16-K level II TRS-80, 4-K Level I
Video monitors	Radio Shack, Sanyo
Cassette units	Radio Shack CTR-41, Superscope C-190
Teleprinter	Teletype model 19
Interfaces and Software	Macrotronics M-80 interface Macrotronics software for RTTY and cw K4TUZ Bit Byter interface K4ZUY software for RTTY

Many enclosures fail to be effective shields . . .

Results — RTTY reception was disappointing because of marginal performance of the RTTY demodulator on the M-80 board. Cw decoding was quite good. Interference (RFI) was very bad when the TS-820 was used on lower sideband for RTTY. Operation was much better on the fsk mode, because the TS-820 is fitted with a cw crystal filter which is automatically switched in for fsk. It became immediately apparent that using 170-Hz shift with the narrow filter made a big improvement on the RFI problem. But signals below about S5 were still marginal unless they fell in a noninterference "slot." There were spikes up to S8 or so on all bands, and a lot of background hash. Cw reception with the filter was much better, but RFI was still present to an objectionable degree. The keyboard was functional on both modes at low-power level, but exhibited very erratic behavior at higher power. In the process of trying different "fixes," it was found that unplugging the cassette unit after loading the program helped tremendously in the transmit mode. This procedure also made a definite improvement in the receive mode, although interference was still objectionable.

Second-Stage Effort — The same setup as described earlier was used, but with a Flesher TU-170 afsk decoder for RTTY and the homemade cw signal processor for cw.

Results — Much-improved performance was noted on RTTY and some improvement on cw. The cw processor on the M-80 actually works very well. The chief improvement on cw arose from the extra flexibility of the homemade processor. The major improvement was on RTTY. This configuration was considered to be a workable one when used with the crystal filter in both modes. Unfortunately, the TS-820 can only be used with fsk when using the crystal filter, and many amateurs would like to use afsk. Shifting to lower sideband to evaluate this mode with the ssb filter resulted in an interference level that was considered too high to be tolerable. The TS-820 can be modified to take care of this problem (I have since done so), but it is a bit involved. As an alternative, an active band-pass filter was constructed with approximately 400-Hz bandwidth, centered on the afsk tones. With this filter inserted in the audio channel ahead of the audio monitor and TU-170, usable performance was once more restored on RTTY. It should be noted that the software behaved perfectly and was a pleasure to use on both cw and RTTY. It supplies essentially unlimited buffer space and very clean keying. The cw decoder was found to be excellent, and did about as good a job on "sloppy" fists as could be expected. No cw decoder can decipher some fists, which are so nonuniform that even the most experienced human decoder is hard-pressed! Until there are more keyboard-sent cw signals on the air (please — I am something of a manual cw-nut myself!), the real value of automated cw decoding is doubtful. On machine-sent code, however, it works perfectly.

Third-Stage Effort — An Intra-Fab enclosure measuring 3 × 3 × 12 inches (76 × 76 × 305 mm) was obtained. The M-80 interface, the cw signal processor, a TRS-80 power-supply module, the M-80 power transformer and an accessory 12-volt dc supply were fitted into the enclosure. The front of the cabinet held the necessary switches for control functions, including control of the remote teleprinter and transmitter-distributor. The TU-170 was modified to include a buffered TTL-compatible output to drive the M-80 simultaneously with the loop driving the teleprinter. The printer motor could be turned on and off with dc relays operated from the panel. The connection from the M-80 to the TRS-80 was rewired into a shielded cable that passed through a grommet on the front of the control cabinet to the output port on the TRS-80. The ac line into the cabinet was decoupled with a brute-force filter. The power cord from the TRS-80 power module was passed through the front of the control cabinet and also shielded. All audio and keying signals, as well as relay controls and the teleprinter loop, were in shielded cables. Good-quality plugs and jacks were used at the back of the cabinet. This unit was placed in the operating console about three feet from the transceiver. The TRS-80 was connected in front of the unit on the operating table. The control unit was grounded to the rather heavy common ground bus, which was connected to all units in the console.

Results — Much-improved performance on all counts was obtained *in this case.* It should be obvious that all physical configurations may not behave the same way, but the general technique should be applicable. The arrangement of antennas, the feed system, TVI filters, station ground system, routing of ac lines in the walls, and so forth, all influence the outcome. In this case, the results were considered to be perfectly acceptable on all counts, although some spikes of about S2 still remained and background hash could still be heard on lower sideband without the filter. A considerable amount of on-the-air testing, both at 60- and 100-wpm RTTY, and lots of ragchewing on cw, were done to test the "livability" of this system. The testing led to the conclusion that, as far as this operator is concerned, it was completely satisfactory, although not perfect. About this time, the Bit Byter interface was obtained and promptly stuffed into the same box. No tests were made on the initial configuration of the unit, which is supplied in a shielded box. When placed in the control enclosure, including its own shield, it was found to perform essentially the same as the M-80. The software for this unit is for RTTY only, and produces a very attractive "split screen" presentation which allows composition of one's reply during reception, allows editing, has word wrap-around, and transmits line-feed/carriage-return (LF-CR) automatically at the proper time. It also ignores LF-CR on receive so that the 64-character line of the TRS-80 is always "packed." The software eliminates receiving RTTY pictures, but a printer is required for that anyway. This program was also checked on a 4-K Level I machine and was found to work fine — there is even plenty of buffer space!

At this time, some other "trial and

. . . a complete solution *is* possible.

error" schemes were tried. First, a "pan" of aluminum with 1-inch (25-mm) sides was fabricated, just large enough for the TRS-80 to fit in and still allow air circulation. Then a handful of leads from 6 to 18 inches long were made up with alligator clips on the ends. Next a lot of trial-and-error grounding was done between various units and in various combinations. The presence of the pan alone, as expected, gave some improvement. Then configurations were found that could reduce the S-meter readings to zero deflection at all points, although RFI could still be heard. Turning the agc off and setting the S meter for a reading of S2 by adjusting the manual gain control resulted in an apparently RFI-free situation. This really isn't a valid technique, however, because what is really being done is a form of "neutralization," where the magnitude and phase of the signals are being shifted to reduce the magnitude of the total, and this technique is frequency sensitive. It is mentioned, however, as one "port in a storm" if all else fails.

A comparison was made between the Sanyo monitor and the Radio Shack monitor. The Sanyo was found to be somewhat better, as might be expected, since it is in a metal enclosure. The Radio Shack monitor uses an opto-isolator, which undoubtedly improves things somewhat as far as this unit is concerned. No attempt was made to modify either monitor at this stage.

Fourth Stage Effort — Later an all-out attack on the problem was started. The returns are not yet all in, but the initial tests indicate that a complete solution *is* possible. This requires complete repackaging of the TRS-80 into a copper-plated steel enclosure, a copper-foil grid under the keys, some modifications to the TRS-80 electronics, improved interface isolation, better-shielded monitors, and so on. Shades of a HAL 3100! This approach is beyond the scope of the average amateur. It should be pointed out that this effort is mostly the result of outright stubbornness on the part of a retired professor of electrical engineering who doesn't seem to know when to let well enough alone. The second-stage effort was sufficient for the operator who likes to work occasional RTTY and cw in addition to his phone operation. This person will get a tremendous kick out of the operating ease provided by his computer, which he also uses for many other things. Stage three is for the dedicated RTTY and cw man, and the level of interference is easy to live with. All too often I found myself sweating, trying to eliminate interference that was still there when I turned off the computer! We have to live with the bands as they exist. When the "woodpecker" is on, you can't hear any interference! Stage four was undertaken just to prove that a solution is possible, and that a communication computer interface that is totally nonobtrusive can be constructed. One thing has resulted from these tests — once the operating ease and convenience of a flexible computer-based communication terminal is experienced, it is impossible to go back. Let's see now, how about automatic beam heading based on prefixes . . . QST

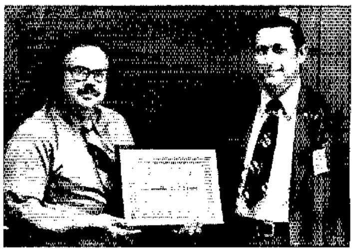
Strays

WORKED WA3ZRY LATELY?

☐ The start of the new decade was less-than-pleasant for one dedicated amateur, Arthur Shorey, WA3ZRY. A mid-January fire gutted his home, destroying his shack — and his extensive QSL card collection. In fact, Art, a sightless amateur from Dover, Deleware, had nearly qualified for 5-Band WAS. If you've worked WA3ZRY, please send another QSL card to Art Shorey, 8-B Bradys Ln., RFD 6, Dover, DE 19901.

HAM OF THE YEAR AWARD

☐ Do you know a ham who is worthy of recognition? The Dayton Hamvention awards chairman is soliciting nominees for Ham of the Year, to be honored at the Dayton Hamvention in April. Send nominations and correspondence to: Dayton Hamvention, P. O. Box 44, Dayton, OH 45401, Attention: Awards Chairman.



West Gulf Division Director Ray Wangler, W5EDZ (right), presents the ARRL Club Affiliation Certificate to Bill Dow, W5VRI, president of the Datapoint Amateurs and Technicians Association (DATA). The club's 30 members are all employees of Datapoint Corporation, a San Antonio, TX, computer manufacturer.

MANY MILES PER WATT

☐ C. J. Page, G4BUE, of West Sussex, England, had a 4400-mile, 28-MHz QSO with W4OO in West Palm Beach, FL. G4BUE used an input of 750 microwatts on the PA of his Argonaut for the contact, on December 9, during the ARRL 10-meter contest. — *Gene Sykes, W4OO*

QST congratulates . . .

☐ Julian R. Benjamin, W4RZN, who has been selected to the rank of Rear Admiral in the Judge Advocate General Group of the United States Naval Reserve.

• *Basic Amateur Radio*

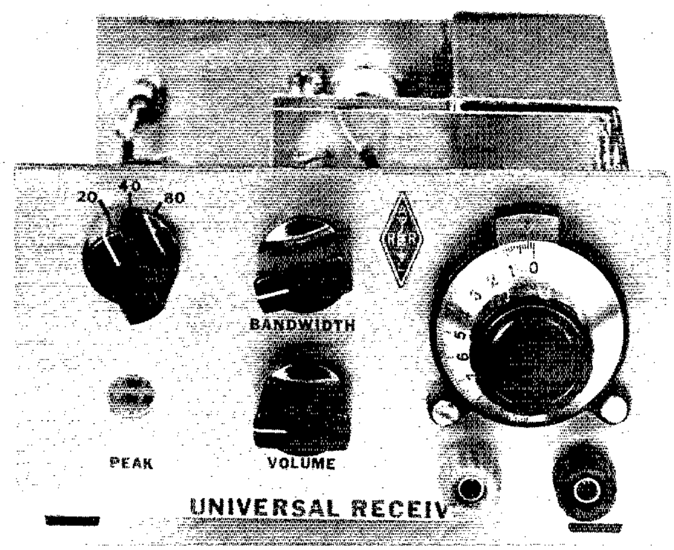
The Nitty-Gritty of Simple Receivers

Simple receivers are fascinating gadgets. This treatise on how they work can help make your experiments more successful.

By Doug DeMaw,* W1FB and Bob Shriner,** WAØUZO

Have you wanted to build your first solid-state receiver, but lacked the fortitude to try? Well, "learning by doing" is an excellent motto. We hope you'll apply that philosophy as you follow this continuing Basic Radio series.

This month we'll examine the roots of receiver circuitry and explain what each part of the circuit must do in order to provide acceptable performance. These ground rules can be applied to any direct-conversion type of receiver and need not be confined to the workshop project in this article.



This view of the direct-conversion receiver shows a band switch at the upper left. This and a peaking control (to be added at the lower left) will be used later in the circuit of an 80-, 40- and 20-meter down-converter.

The Simplest Receiver

As a new enthusiast in the art of radio experimenting you may have tried the circuit of Fig. 1. It is the most basic form of the "crystal set" or crystal detector. This type of radio is suitable for the reception of amplitude-modulated (a-m) signals, such as one finds in the commercial broadcast band between 550 and 1600 kHz. In the early days of Amateur Radio, a-m was the common voice mode, so a receiver of this kind could be used to monitor the quality of one's signal. If it were used today, and if a long piece of wire (50 feet — 15 m — or more) were used for an antenna, bc-band signals would be heard. However, only a jumble of stations would be present unless you lived very near one of the commercial stations. That being the case, the nearby one would predominate by virtue of sheer brute force.

The circuit of Fig. 1 routes rf energy from the antenna to D1, a small-signal rf type of diode. The diode acts as a half-wave rectifier to produce a dc voltage which pulsates in accordance with the modulated wave from the transmitted signal. These variations in dc voltage "excite" the earphone and cause its diaphragm to vibrate at an audio rate. The resultant sound is detectable by the human ear. The longer the antenna (and the better the earth ground) the greater will be the rf voltage applied to D1. This results in a higher dc output from D1, and therefore a louder response from the earphone.

A better circuit is seen at Fig. 2. The fundamental difference over that which is presented in Fig. 1 is the added selectivity provided by C1 and L2: They are tuned to the frequency of the desired station. This circuit permits a degree of separation between the wanted and unwanted signals. That is why this capability is called *selectivity* (it helps you to *select* the desired signal). The higher the Q of the tuned circuit the greater the selectivity or sharpness of response at the frequency to which the C1/L2 combination is tuned. Stations above and below this frequency are rejected in varying amounts, depending on how close their operating frequencies are

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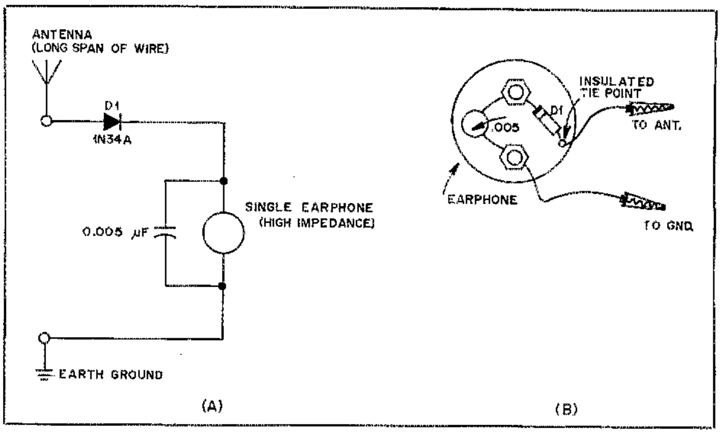


Fig. 1 — A diagram is provided at A for a very basic type of receiver. It is shown pictorially at B.

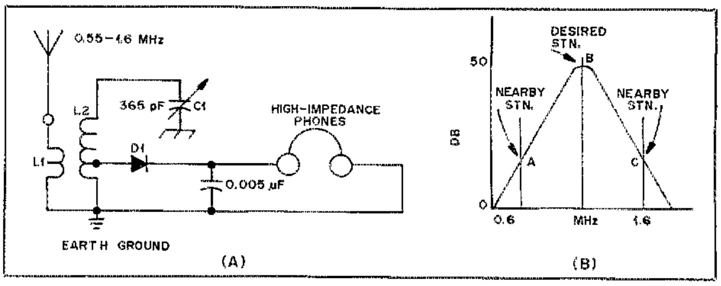


Fig. 2 — At A is a means by which to add rf selectivity to the simple circuit of Fig. 1A. The curve at B illustrates in relative terms the response of the tuned circuit at A.

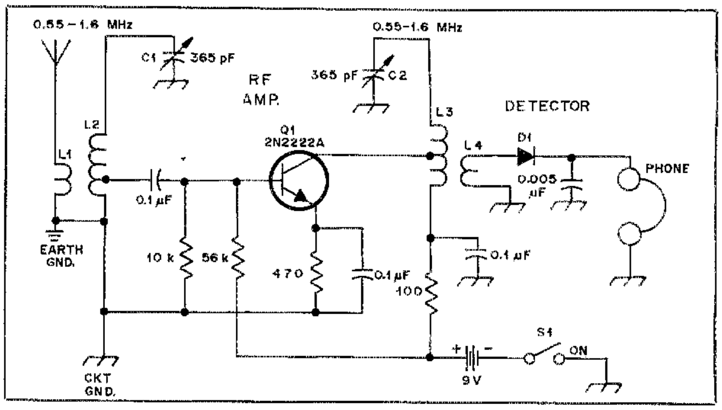


Fig. 3 — Greater receiver sensitivity can be obtained by adding an rf amplifier (Q1) ahead of the diode detector (D1), as shown here. The additional tuned circuit (C2/L3) aids the rf selectivity.

to the desired one. The farther away the greater the rejection. This can be envisioned by examining the curve in Fig. 2 at B. The station we wish to hear (B) has been tuned in by adjusting C1 so that it forms a resonant circuit with L2. This gives maximum signal response to station B and places stations A and C quite far down on the response curve of the tuned circuit, thereby rejecting them by many decibels (dBs). There can be no such rejection of the unwanted stations when using the circuit of Fig. 1. The steeper the sides of the curve (resulting from higher values of Q, or by using additional tuned circuits ahead of D1) the greater the rejection of the unwanted stations, A and C. Tuned circuits of this general variety, when used in the early stages of a receiver, provide what is known as *front-end selectivity*.

An elaboration of front-end selectivity is demonstrated in Fig. 3. Here we continue to employ a simple diode detector (D1), but to make the receiver more sensitive we have added an rf amplifier between the antenna and the detector. As shown, Q1 will boost the incoming signal some 10 to 15 dB. This will make all signals louder in the earphones — a distinct advantage when listening to the weaker bc-band stations. But of equal or greater significance is the extra tuned circuit (C2 and L3). This coil and capacitor form a tuned circuit which is resonant at exactly the same frequency as C1 and L1, assuming they have each been tuned to the desired listening frequency. The resultant response curve will be much narrower (bottom edges pulled closer in toward the center) than that of Fig. 2B. This will provide even greater rejection of signals which fall above or below the one we have tuned in. We encourage the readers of this article to experiment with the circuits of Figs. 1, 2 and 3. The performance traits we have just discussed will become readily apparent when using these circuits for reception of the standard bc band.

The overall sensitivity of the three circuits can be improved by adding a bipolar-transistor audio amplifier between D1 and the earphones. This will provide another 10 dB of volume. A sample circuit is given in Fig. 4. Almost any audio type of npn transistor will work at Q1 with the values shown.

What About CW and SSB Reception?

We've already admitted that the circuits just discussed are suitable for a-m reception only. So, how can we change them to permit cw and ssb reception? Well, first let's understand why the simple receivers of Fig. 1, 2 and 3 aren't satisfactory for cw and ssb use. They depend upon the carrier being transmitted along with the desired audio intelligence (modulation). In the case of an ssb signal the carrier is suppressed by some 50 dB within the transmitter. Therefore, the carrier must be reintroduced *in* the receiver. This provides the equivalent of an a-m signal during detection. This steady carrier is mixed with the pulsating rf signal to produce a modulated carrier. The detector used for this function is called a *product detector*, since what comes out of it is the product of the internally generated carrier or *beat-frequency oscillator* (BFO) and the voice-rate rf energy (minus a carrier) that is received on the antenna and amplified within the receiver.

When receiving cw signals with one of

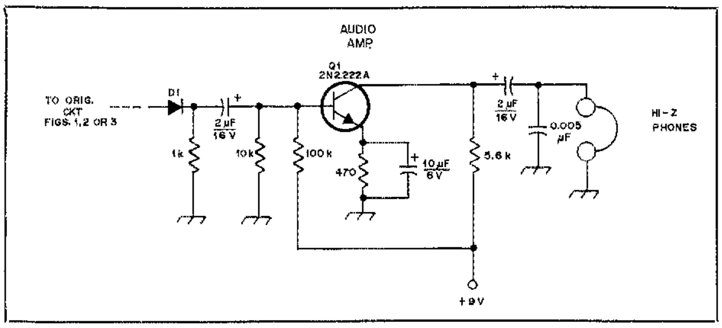
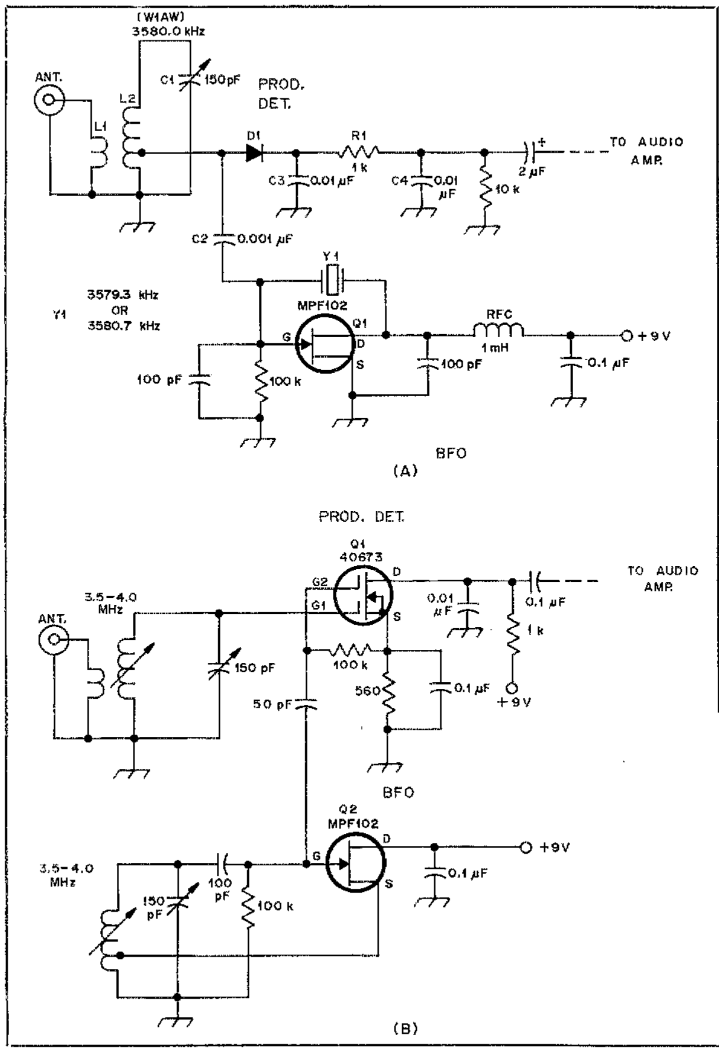


Fig. 4 — An audio amplifier can be used after D1 to improve the overall sensitivity of a simple receiver, such as that of Fig. 3.

the circuits discussed earlier, all that we'd hear in the earphones would be thumps each time a code character was sent. Although this kind of signal could be copied with difficulty, it is much better to have a tone between 200 and 1000 Hz (depending on individual preference) present in the earphones or speaker. This is also accomplished by using a product detector. The BFO carrier is mixed with the cw signal in the detector. The two frequencies are separated by whatever difference the operator prefers (200 to 1000 Hz). The resulting output from the detector is a note at that frequency each time a code character is sent.

Diodes can be used as detectors, or we can use active devices (components that require an operating voltage), such as bipolar transistors, FETs or ICs. The diode detector introduces a loss (conversion loss) in signal level, where an active detector can produce some gain (conversion gain) while acting as a detector. The BFO can be thought of as a small transmitter which generates a steady carrier at some specified frequency. In a superheterodyne type of receiver the BFO operates at the receiver intermediate frequency (i-f). In a direct-conversion receiver (more on that later), the BFO operates at approximately the incoming-signal frequency. There is a slight frequency offset to provide a *difference frequency* for copying upper sideband, lower sideband or cw. We can, for the purpose of this discussion, regard a product detector as a mixer. In both examples two frequencies are mixed to produce a third frequency. The resultant *mixer* frequency (intermediate frequency) is at rf, whereas the *product-detector* output is at audio. Fig. 5A shows how a BFO can be applied to a simple diode mixer. If the BFO is crystal controlled, only *single-frequency* reception will result in this circuit. If the BFO is made tunable — making it a *VFO* (variable-frequency oscillator) — coverage of a wide frequency range is possible.



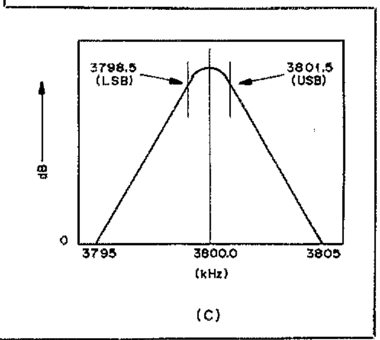


Fig. 5 — Diagram A shows a basic form of the direct-conversion (synchrodyne) receiver. It is set up in this example to receive W1AW on 80 meters as a fixed-frequency receiver. The circuit at B shows how a variable-frequency beat oscillator (VFBO) can be used to give broad coverage of an amateur band. An active detector is shown in this example (Q1). The curve at C shows the frequency relationships between the incoming signal and the two choices of VFBO injection voltage.

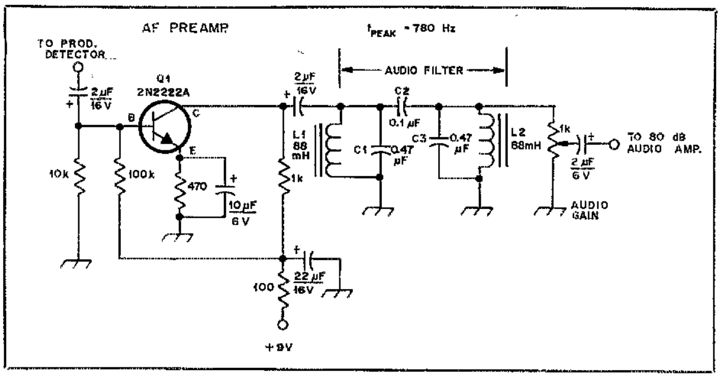


Fig. 6 — An LC audio filter can be used to develop satisfactory selectivity for cw and ssb reception. L1, L2 and the related capacitors comprise such a filter.

Fig. 5B shows such an arrangement in which an active product detector is employed. If we were to label the BFO with a truly meaningful name (when it is tunable) we might call it a "variable frequency beat oscillator," or "VFBO." For the remainder of this article, at least, we'll refer to it as such.

Fig. 5A shows an FET BFO supplying a steady carrier to the detector, D1. Upper- or lower-sideband reception is possible with this direct-conversion receiver by selecting the appropriate crystal frequency at Y1. Since W1AW can't legally operate ssb on 3580 kHz, we have shown crystal frequencies which will provide a 700-Hz cw beat note when C1 and L1 are tuned to W1AW at 3580.0 kHz. In other words, the BFO can be placed 700 Hz above or below 3580.0 kHz to obtain the desired cw audio tone. For ssb reception the crystals would be cut for 3578.5 kHz (lsb) or 3581.5 kHz (usb). This kind of receiver is called a "direct-conversion" one because the signal from the antenna is converted to audio immediately or *directly* after the antenna. In some parts of the world this kind of circuit is called a "synchrodyne." When working with a conventional superheterodyne receiver, the signal is converted to an intermediate frequency (single conversion), and sometimes to a second (double conversion) or even third intermediate frequency (triple conversion) before it is changed to audio frequency. Therefore, a superheterodyne receiver is anything but a direct-conversion type!

The simple circuit of Fig. 5A is not recommended for use with a resonant antenna. This is because the BFO signal will be radiated by the antenna and may cause QRM to amateurs nearby. An rf amplifier stage between the antenna and D1 would greatly reduce the radiation probability. This is true of most direct-conversion receivers. R1, C3 and C4 of Fig. 5A comprise an rf filter which prevents the BFO energy from reaching the audio-amplifier stages.

A direct-conversion receiver which uses an active product detector and a VFBO is shown at B of Fig. 5. With the proper inductance value at L1 and L2 (both the same value) all of the 75/80-meter band can be covered. Radiation of the VFBO via the antenna will not be as severe with this circuit as when using the one at A. This is because the dual-gate MOSFET (Q1) provides several dB of isolation between gates 1 and 2. (We must assume that the physical layout of the circuit is arranged to prevent unwanted stray coupling between the components and conductors relating to the gates of Q1.) The VFBO is tuned slightly above the desired ssb signal for usb reception or slightly below it for lsb reception. A cw beat note can be effected by the same means — above or below the desired signal. The greater the separation between the desired signal and the VFBO frequency the higher will be the cw-note pitch. We can learn from this discussion that a direct-conversion receiver does not provide "single-signal reception." Rather, there is a response *either side* of zero beat. A superheterodyne receiver with a selective i-f system (tuned circuits or filters) will provide single-signal reception, thereby rejecting QRM which may be present on the opposite side of zero beat.

Fig. 5C shows a front end response curve with relation to VFBO output placement. The VFBO offset is 1.5 kHz above or below the desired ssb signal to provide upper- or lower-sideband reception. For cw reception we would move the VFBO frequency closer to the desired signal to avoid having an excessively high-pitched beat note.

Shortcomings of Direct-Conversion Receivers

The principal failing of receivers which use the direct-conversion scheme has already been discussed: They do not provide single-signal reception. This means that under conditions of heavy QRM it is possible to experience twice as much QRM as when using a selective superheterodyne receiver. This is because there is no rejection of unwanted signals which may appear on the unused side of zero beat.

Another problem is that the overall gain of a receiver should be on the order of 80 to 100 dB (antenna to audio output). In a superheterodyne circuit a large part of the required gain is obtained at the rf and i-f sections of the receiver. All, or nearly all, of the gain must be provided by the audio channel in a direct-conversion receiver. This means that for good headphone volume the audio-amplifier section should produce 80 to 100 dB of gain: Care must be exercised to design an audio amplifier that will not break into self-oscillation or pick up hum and amplify it. For the purpose of experimentation, the circuits of Fig. 3 and 5 could be fed directly into a hi-fi amplifier. That would provide plenty of audio!

Another difficulty we must contend with when using direct-conversion receivers is the inherent lack of overall selectivity. Since there is no i-f at radio frequency (the i-f is at audio), we can't add a crystal or mechanical filter to obtain the desired selectivity. The usual practice is to employ an *audio* filter after the product detector. This type of filter can be made from toroid coils or pot-core inductors. It should be designed for a cw or ssb bandwidth, although an ssb audio filter will permit good reception of cw signals if we're willing to sacrifice some selectivity. Many amateurs prefer to use an RC (resistance/capacitance) active audio filter which uses ICs. This type of filter can produce some gain, whereas the coil/capacitor type of filter causes some loss in the audio level. Fig. 6 shows an ssb type of audio filter which contains two surplus 88-mH toroid coils.[1] It will work satisfactorily during cw reception also. The filter can be installed immediately after the first audio amplifier in the manner shown. This style of filter is known as an LC (inductance/capacitance) bandpass filter. It will reject unwanted signal energy above and below the frequency of interest.

Circuit Comparison

Two block diagrams are presented in Fig. 7 to illustrate the fundamental differences between a direct-conversion receiver and a "superhet" type. The circuit at A has a VFBO which is tunable over the range of the desired incoming signals (3.5 to 4.0 MHz). The remainder of the receiver (all after Q1) operates at audio frequency.

A basic type of superheterodyne receiver is depicted at B of Fig. 7. In this

[1] References appear on page 28.

example the local oscillator (VFO) is not on the same frequency as the incoming signal. Rather, it is tunable from 5.0 to 5.5 MHz. This frequency, when added to that of the incoming signal, results in a *sum* frequency of 9 MHz, which is the intermediate frequency (i-f) at the mixer output. Thus, for reception of a 3.6-MHz cw signal, the VFO would be tuned to 5.4 MHz (3.6 + 5.4 = 9 MHz). The 9-MHz mixer output is routed through a selective crystal filter (FL1) to sharpen the receiver selectivity, then amplified at 9 MHz by means of Q3. Q4 and Q5 in this circuit function in a manner similar to Q1 and Q2 of Fig. 7A. The output from Q4 is at audio frequency. The BFO (Q5) uses two crystals. They are offset from 9 MHz to provide usb and lsb reception.

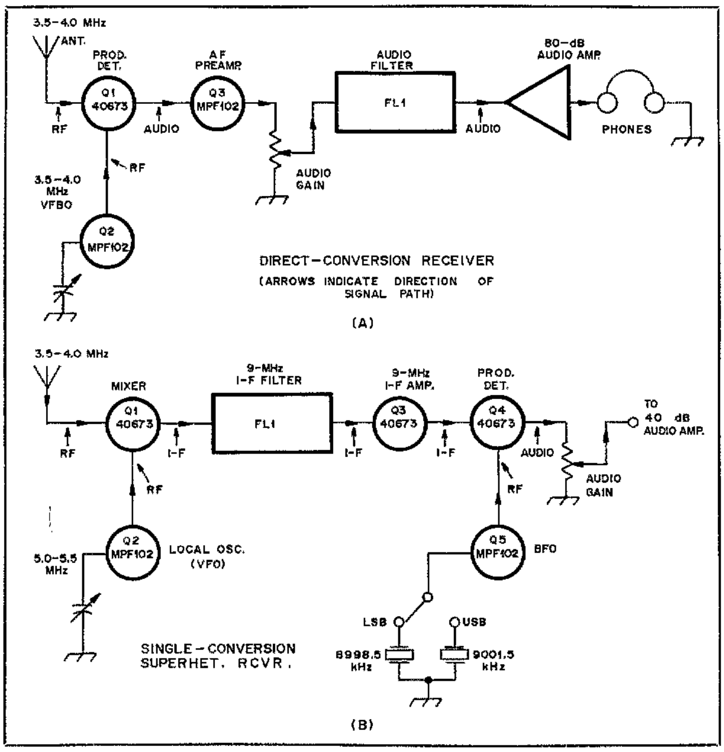


Fig. 7 — The block diagrams at A and B show the fundamental differences between a direct-conversion and a superheterodyne receiver. See text.

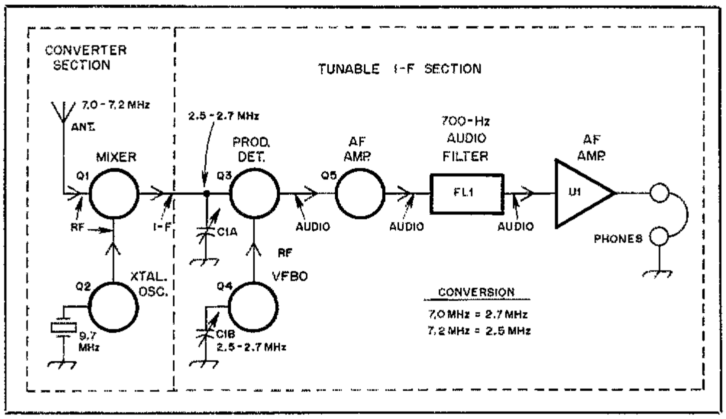


Fig. 8 — Block diagram of our tunable i-f receiver, showing how the down-converter (Q1/Q2) will be connected to it for reception on 80, 40 and 20 meters. The example is for reception on 40 meters.

This Month's Project

The performance of a direct-conversion receiver can be improved by designing it as a double-conversion type of unit. This can be done by making the main part of the receiver function as a tunable i-f system over a frequency range below the amateur bands of interest. The early stages of the receiver comprise a crystal-controlled converter, the output from which is at the tunable intermediate frequency. Fig. 8 shows a block diagram of such a receiver. Q3, Q4, Q5, FL1 and U1 can be thought of as a separate direct-conversion receiver which tunes from 2.5 to 2.7 MHz. In other words, we could attach an antenna to the input of Q3 and actually hear commercial signals in the 2.5- to 2.7-MHz range.

In order to receive the amateur bands (40 meters in this example) we must place a converter between the antenna and the 2.5- to 2.7-MHz receiver. In Fig. 8 we have specified Q1 and Q2 as the converter section. The 7-MHz signals are fed into a mixer (Q1) which also receives an injection frequency at 9.7 MHz (from Q2). The *difference frequency* is 2.7 MHz (9.7 minus 7.0 = 2.7 MHz). If we were to tune in a signal at 7.2 MHz, the difference frequency (i-f) would be 2.5 MHz. This is the range the tunable i-f accommodates. In essence, we have "married" a superheterodyne receiver to a direct-conversion receiver. However, we still won't have single-signal reception: There will be a response either side of zero beat, just as with the receivers we discussed earlier in this article.

The advantages of this circuit are increased gain at rf and better frequency stability. It is much easier to obtain good VFO frequency stability at 2.5 MHz than it is at, say, 14 MHz. The stability of the crystals used at Q2 of Fig. 7 will be excellent, however. Some commercial products contain receivers of this general variety (Heath HW7, HW8 and the Ten Tec Century 21).

The tunable i-f receiver we shall construct is shown schematically in Fig. 9. A dual-section 365-pF variable capacitor (C1A/C1B) tunes the input of the product detector (Q1) and the VFBO (Q3). The slugs in L2 and L4 are adjusted so that both tuned circuits *track* (are on the same frequency when C1 is adjusted). Audio output from Q1 is amplified by means of Q2.

A simple high-Q audio tuned circuit (L3 and C2) is used between Q2 and Q4 to provide variable cw and ssb selectivity. A Q control (R1) is included in the circuit:

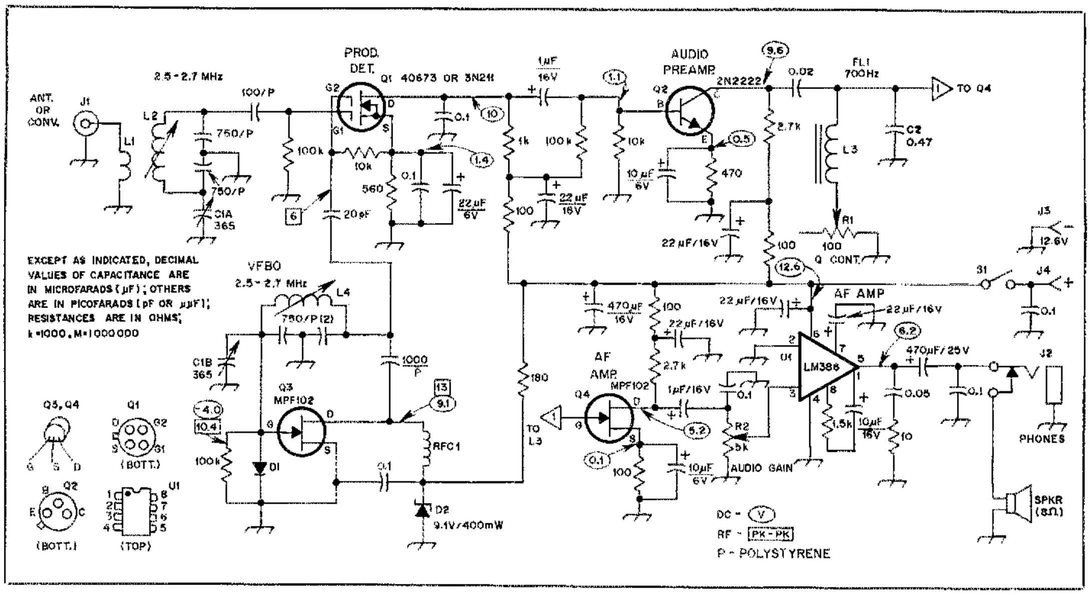


Fig. 9 — Schematic diagram of the 2.5- to 2.7-MHz receiver. Fixed-value capacitors are disc ceramic unless otherwise indicated. Fixed-value resistors are 1/4- or 1/2-watt composition types. Polarized capacitors can be electrolytic or tantalum units.

C1 — Miniature two-section transistor-radio variable, 365 pF per section. (Circuit Board Specialists part used in this model.)
C2 — Mylar or other high-quality capacitor, 0.47 µF.
D1 — High-frequency silicon diode, 1N914 or equiv.
D2 — Zener diode, 9.1 V at 400 mW or 1 W.
J1 — RCA phono jack, single-hole mount.
J2 — Miniature closed-circuit phone jack.
J3, J4 — Insulated binding post. Use red for + and black for −.
L1 — 4 turns of no. 24 enam. wire over the center part of the L2 winding.
L2 — Slug-tuned inductor, 9 µH nominal. J. W. Miller Co. no. 42A826CBI or equiv. (19070 Reyes Ave., Box 5825, Compton, CA 90224, catalog avail.)
L3 — Pot-core inductor. 153 turns no. 28 enam. wire on bobbin of Amidon Assoc. PC-2616-77 pot core. (12033 Otsego St., N. Hollywood, CA 91607, catalog avail.)
L4 — Same as L2.
R1 — Linear-taper, 100-Ω composition control.
R2 — Audio- or linear-taper, 5000-Ω composition control with spdt switch.
RFC1 — Miniature 1-mH rf choke. J. W. Miller 70F103AI or equiv.
S1 — Spst, part of R2.

The higher the resistance in series with L3 (R1), the lower the tuned-circuit Q and the wider the tuned-circuit response. Therefore, we will obtain the narrowest response (best selectivity) when R1 is effectively out of the circuit and the bottom end of L3 is grounded directly. Our peak frequency for this circuit is 700 Hz, as determined by the 110-mH inductor (L3) in parallel with the 0.47-µF capacitor (C2).

Additional audio amplification is provided by Q4. U1 increases the audio level so that it is sufficient for operating headphones or a speaker.

Assembly Data

Double-sided pc board (copper on both sides) is used for the receiver panels and partitions. Two Universal Breadboards are employed in order to leave sufficient space for the hf-band down-converter we will add later in the series. This open space is along one side of the receiver.

The VFBO is located in a compartment at the right-rear of the receiver. The compartment is 2-1/4 × 1-1/4 × 2-1/2 inches (57 × 32 × 63 mm) HWD. A press-fit metal cover is made from a scrap of aluminum, flashing copper or tin can. It is U shaped.

A miniature 8-Ω speaker is located just

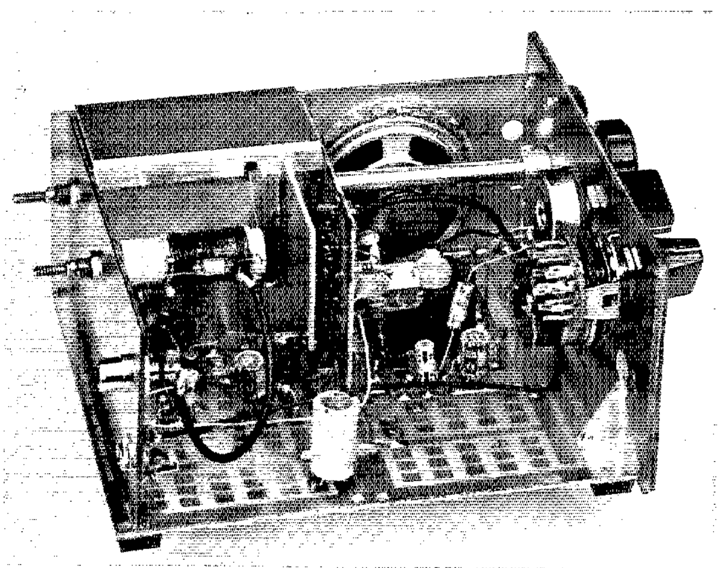


Fig. 10 — Interior view of the assembled receiver with one side panel removed. C1 is located inside the VFBO compartment, as is L4. A press-fit metal cover (see text) encloses the top of the VFBO compartment during operation. Miniature RG-174/U coax cable is used between L1 and J1. It is used also between R2 and the input to U1. Be sure to ground the shield braid at each end of each cable. Miniature shielded audio cable can be used in place of the RG-174/U.

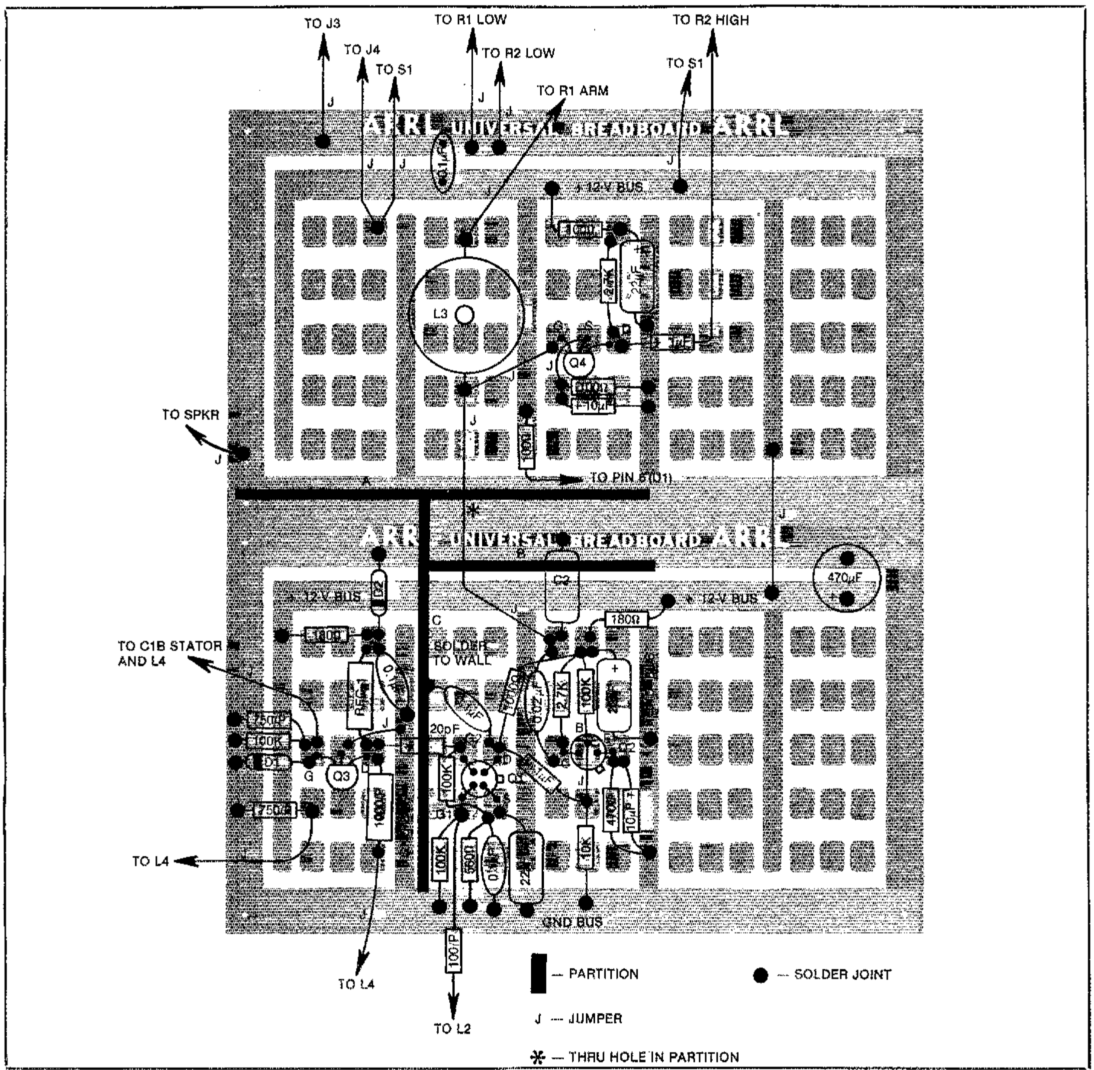


Fig. 11 — Parts-placement guide for the main circuit board. The unused area at the right is reserved for the 80-, 40- and 20-meter converter which we will build later in the series. The black dots indicate solder joints. The scale black-and-white pattern for this board was presented in Basic Radio, September 1979 *QST*.

ahead of the VFBO compartment on the side wall of the receiver. A perforated metal protective screen is glued over the speaker opening in the side wall (epoxy glue), then the speaker is cemented in place on the screen. Be careful to avoid letting the glue get on the speaker cone. Use just a light coating around the outer perimeter of the speaker face.

A 2-3/4 × 1/4-inch (70 × 6.3 mm) length of hobby-style brass tubing (thin wall) is used as a coupler between C1 (in the VFBO compartment) and the vernier drive on the front panel. Epoxy cement is used to affix the tubing to the shaft on C1.

U1 and the associated components are installed on a small pc board (partition A) which is soldered to the front of the VFBO box and the ground foil on the Universal Breadboard. The U1 assembly is mounted vertically, as shown in the photograph. A shield made from double-sided pc board (1-1/2 × 1-1/2 inches — 38 × 38 mm) is installed between the back side of the U1 pc board and the end of L2. The lead from L2 is passed through a small hole in partition C (on the Q1 side of partition B), then into the VFBO compartment. This shield prevents rf energy from being coupled into the U1 board from L1/L2 (VFBO energy from L4 which can be radiated via L2).

Fig. 10 shows the interior of the assembled receiver with one side wall removed. The unused rotary switch will be employed for band switching when we build the converters. The U-shaped metal cover for the VFBO compartment has been removed for this photograph.

The parts-placement guide is provided in Fig. 11. The components which are mounted on the front and rear panels are not shown, but the leads which join them to the circuit are clearly identified. Partition A contains the printed circuit for the audio output stage while serving as a shield baffle. Partition B has sufficient space below it to allow clearance for C2.

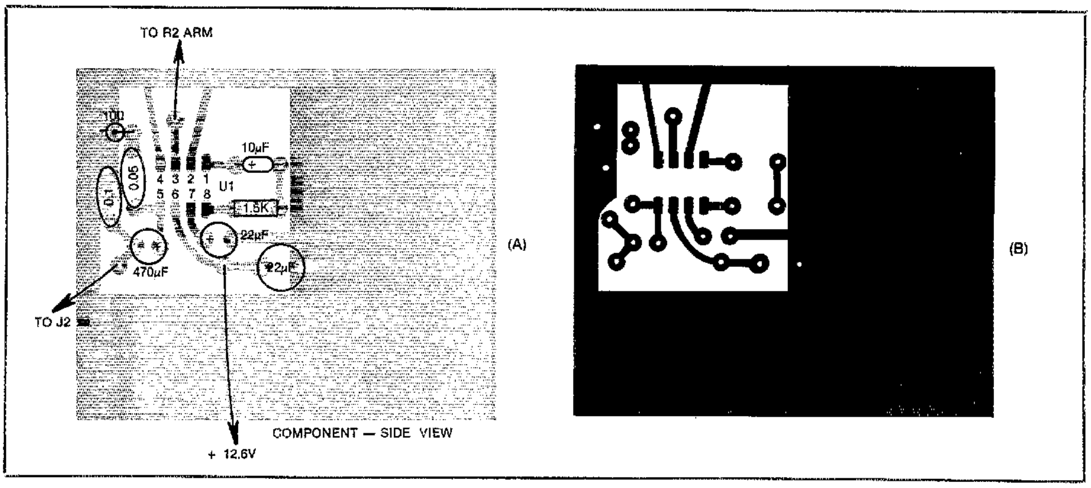


Fig. 12 — Parts-placement guide for the U1 audio circuit. Part of this board serves as a shield for the VFBO compartment. The scale black-and-white pattern for this board is presented at B.

A small notch is cut in partion C so it can "straddle" the 20-pF capacitor between Q1 and Q3. We suggest that you install the partitions after most of the components are soldered to the main circuit board. They are held in place by means of solder, joining them to the side panel, rear panel and circuit board, as appropriate.

Although two Universal Breadboards can be joined to form the large main board used in this project, a single circuit board containing the two grids can be purchased.[2] Epoxy cement can be used to join two individual boards if they are already on hand.

A parts-placement guide for the audio amplifier pc board/baffle plate is provided in Fig. 12A. It is shown from the components side.

Coils L2 and L4 are mounted on the rear panel of the receiver. A generous coating of Polystyrene Q Dope or similar low-loss coil cement should be applied to the winding of L4. This will help to ensure good VFBO stability. J1 and J2 are also located on the rear panel.

Checkout and Alignment

Our first obligation before applying operating voltage to the completed circuit is to conduct a visual inspection. We must be certain that no unwanted short circuits exist (solder bridges between pads, component leads shorting together, etc.). Make certain that all electrolytic capacitors are installed in accordance with the polarity markings (+) shown in Fig. 11. Similarly, be absolutely sure that the transistors and U1 are oriented properly on the circuit board.

Connect a signal generator (set at 2.5 MHz) to J1. Apply 12 volts to J3 and J4 (observe polarity!) and advance the audio-gain control to maximum (fully clockwise). Set C1 so the plates are fully meshed (maximum capacitance). Next, set the vernier dial so that it reads zero (0), then tighten the shaft set screw. The slug in L4 is adjusted next until a 2.5-MHz signal is heard in the phones or speaker. Turn the generator output down until the signal is weak (noisy sounding), then adjust the slug in L2 for maximum signal. There will be some interaction between L2 and L4, so the foregoing procedures will have to be repeated two or three times in order to get optimum results. Now, when C1 is set at minimum capacitance (10 on the vernier dial), the receiver should be tuned to approximately 2.7 MHz. Later on, after we build the 80-, 40- and 20-meter down-converter, we will be able to tune 200 kHz of each of those bands — cw or ssb segments, depending upon the settings of L2 and L4.

Adjustment of the Q control (R1) will sharpen or broaden the received signal. The narrowest response will be had when R1 is set for finite (zero) resistance.

If a signal generator is not available the receiver can be aligned (at night) by connecting an antenna to J1 and adusting L2 and L4 for optimum reception of WWV at 2.5 MHz. It is for this reason that a tuning range of 2.5 to 2.7 MHz was chosen.

If the receiver is working properly the antenna noise (QRN) should be louder than the receiver noise. This can be checked by attaching and detaching the antenna lead at J1 after the alignment is completed. Don't expect this receiver to send signals blasting out of the speaker. Ample gain exists, but until the down-converters are built and installed there will not be high volume from the speaker during weak-signal reception: Headphones will be more suitable for weak-signal listening.

Those who wish to listen to the 160-meter band while waiting to build the hf-band converter can do so by adjusting L2 and L4 for 1.8 MHz with C1 at maximum capacitance. If the receiver won't tune low enough in frequency, simply add some additional fixed-value capacitance across each coil (L2 and L4). Two 100-pF capacitors should suffice for this purpose. The one used on L4 should be a silver-mica or polystyrene type, but a disc ceramic unit will be satisfactory across L2.

In Summary

This receiver is suitable for reception of a-m, cw and ssb signals. The Q control (bandwidth) should be set at approximately midrange for voice reception. It will provide excellent cw reception when adjusted for the narrowest bandwidth. The sensitivity of the circuit in Fig. 9 is such that a 0.5-µV signal (from a signal generator) is plainly discernible.

Best on-the-air results will be had when the antenna is resonant at the receive frequency. This means a dipole, end-fed wire or vertical antenna which is tuned and matched for 50-ohm transmission line (coax) is recommended. Those who have 80- or 40-meter antennas may wish to tie the feeders together and secure a match to 50 ohms (using a Transmatch) if the receiver is to be tuned to the 160-meter band, as discussed earlier.

The 80-, 40- and 20-meter converter will be described in April *QST* for 1980. Keep your soldering iron hot, for we're sure you'll want to build that circuit into your direct-conversion receiver.

References

[1]Toroid coils of the type mentioned are sold as surplus material. Check the *QST* Ham Ads for suppliers.

[2]Circuit boards, negatives and parts kits for this and other League projects are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.

A Simple and Sensitive Impedance Bridge

Spring is coming soon! That's antenna-project time. Be prepared with this easy-to-build impedance bridge.

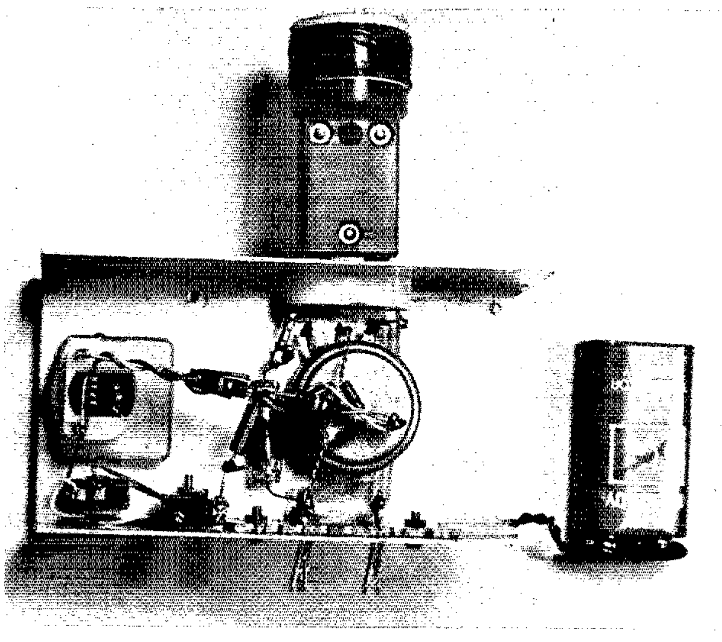
By Frank M. Thompson,* WØOD

The ideas presented here are aimed at those of you who like to tinker with antennas. Up 'til now, many amateurs never really felt the need for an impedance bridge. But if the interest shown today in antenna-matching networks and VSWR indicators may be used as a guideline, perhaps you're ready for an impedance bridge as well.

The Basic Circuit

For years, this writer used a homebuilt impedance bridge that employed a differential capacitor and was built along the lines of one shown in earlier ARRL Handbooks.[1] This old standby worked long and well when used within the frequency range it was designed for. Its usefulness is evidenced by the hand-worn sheen of the aluminum case. Since the first bridge was built, several attempts have been made to produce a bridge that would work well over a wider range of frequencies. But nothing really "clicked" until recently.

The desire was to develop a simple, sensitive circuit capable of being used over a wide spectrum of frequencies and exhibiting minimal stray reactances. The basic circuit used in the development of this bridge is shown in Fig. 1. Mechanically, the unit can be packaged in a small box



The construction of the balanced impedance bridge. The null potentiometer may be seen behind the four diodes. The meter-zeroing potentiometer is the small object at the bottom left of the photo. In this unit, the signal source is coupled to the bridge by means of a homemade coil assembly. The coil consists of 16 turns of no. 24 enameled wire close-wound on a 1-inch plastic form (a sawed-off pill bottle). This is bolted to an FT-243 crystal holder. For use above 30 MHz, two turns of no. 14 wire (self-supporting) will work well.

*Rte. 1, Box 226C, Baudette, MN 56623

[1]Notes appear on page 31.

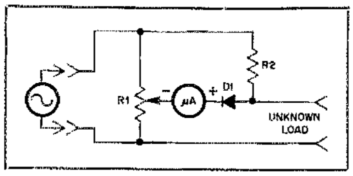


Fig. 1 — Diagram of the basic bridge circuit used during development. As explained in the text, the circuit does not perform well with low signal input levels.

with very short leads between components. Unfortunately, such a basic circuit does not work very well at low signal levels. The resultant null is so broad that the bridge is useless as a practical device. The cause of this broad null will be explained shortly.

Components

It was found that at the impedance levels involved here, an Allen-Bradley type J 250-ohm potentiometer introduces negligible strays — even when mounted in the metal enclosure. Other satisfactory potentiometers are no doubt available. The use of good carbon-film resistors at R2 contribute no difficulties. The meter, too, may be eliminated as a source of trouble. It is typical of many miniature meters available on the market. Measuring about an inch (25.4 mm) square, it has a full-scale deflection of 150 microamperes and an internal resistance of 1 kΩ. What's left? The diode . . .

D1 is a germanium diode. These diodes conduct at low levels of forward bias but the dynamic forward resistance of these devices increases with diminishing forward current. This may be seen in the plot shown in Fig. 2. At the extremely low current levels present when searching for the bottom of a null, the diode resistance is very high. The resultant indicated null is therefore quite broad.

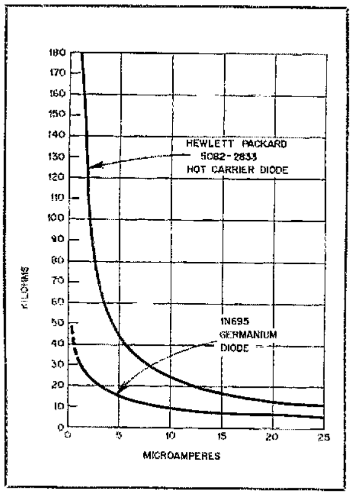


Fig. 2 — It may be inferred from this graph that at zero current the forward resistance of the diode becomes infinite. Inasmuch as a search for a null is really a search for zero current, a dilemma is evident. The advantage of using a "keep-alive" current through the detector is explained in the text.

In an effort to obtain a sharper and more easily discernable null indication, a fixed forward current was provided through the diode. This current forward-biases the diode, placing it at a lower resistance region of its forward-resistance characteristic. The resulting down-scale meter defection ("bias") is compensated for by using an equal and opposite voltage drop across a fixed resistor. The circuits just described are shown in Fig. 3A and 3B as the bridge and detector, respectively.

The circuitry is housed in an enclosure measuring 2-1/4 × 1-1/2 × 4-1/4 inches (57 × 38 × 108 mm). Note that no electrical connection was made to the enclosure. The entire circuit "floats" above ground. The unknown impedance is connected to two insulated terminals. This facilitates measuring balanced loads such as the input of a balanced line. In addition to fixing approximately 45 μA of bias current through the diode, R3, R6 and R7 effectively isolate the battery from the rf circuit of the bridge. R4 provides a means of adjusting and matching the voltage drop across the diode bridge to that across R5, allowing a no-signal zero adjustment.

The performance of this impedance bridge satisfies the design targets. Nulls are readable with the drive available from a grid-dipper. Sample resistors show consistent readings from dc through the 250-MHz upper limit of the signal source used.

A Second Bridge

Another bridge was assembled for checking unbalanced loads such as those presented by coaxial lines. This bridge,

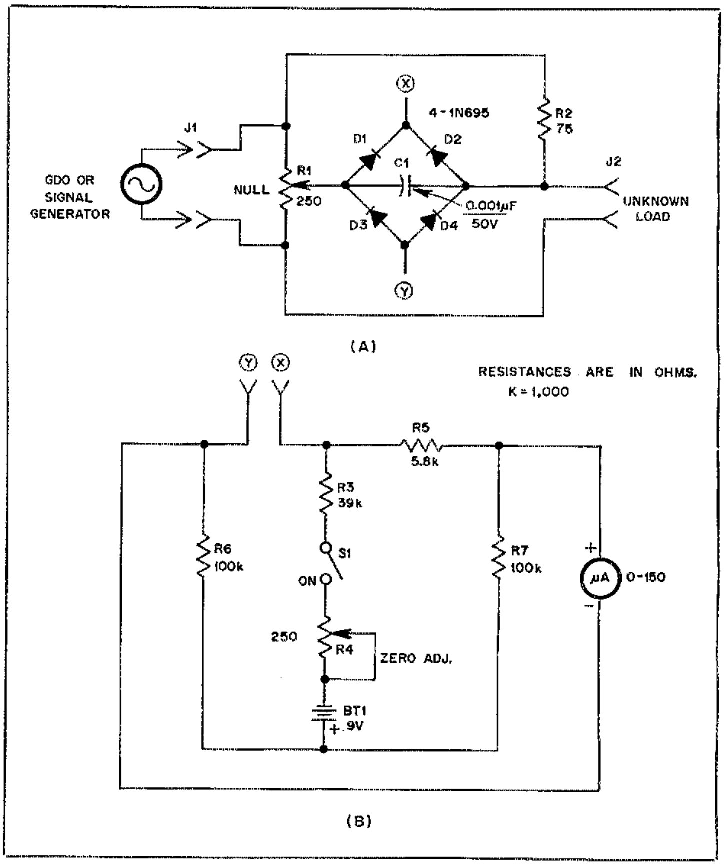
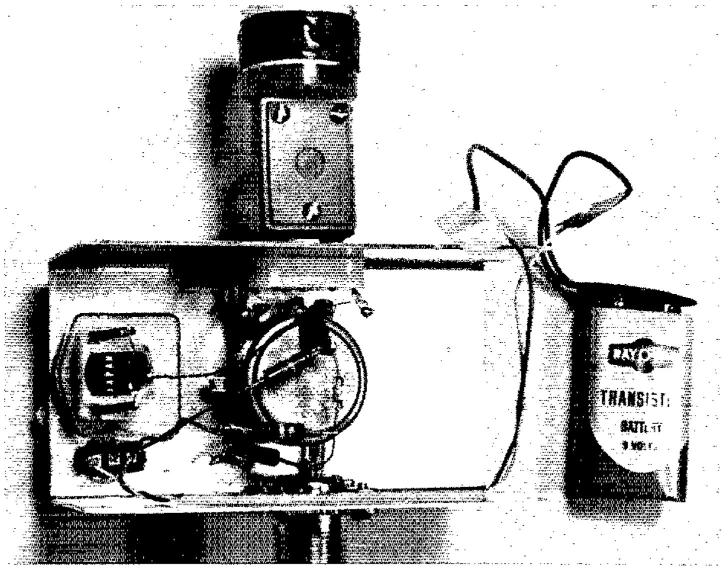
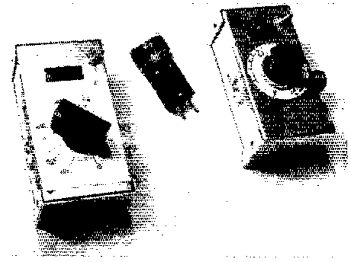


Fig. 3 — At A, the diagram of the first satisfactory bridge circuit built by the author. The circuit is capable of operating over a frequency range from dc to 250 MHz. The metering circuit is shown at B. R1 is discussed in the text. Note that no portion of the circuit of Fig. 3 is connected to the metal enclosure. J1 is an FT-243 crystal socket. J2 may be any type of insulated jack.



A bridge for use with unbalanced lines. Note the relatively small number of parts required. A single germanium diode is used in this model. An FT-243 crystal socket is used as the input coil jack, J1, in both bridges.



The two completed impedance bridges. The one used for balanced loads is at the left. Dial calibration is performed using resistors of known value across the load terminals and coupling a signal source to the input.

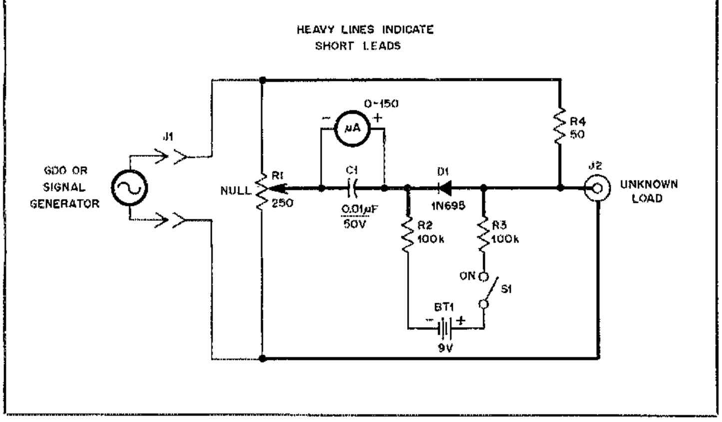


Fig. 4 — The second bridge described in the text was designed for use with unbalanced loads. Refer to the text for the method used to set the meter zero point. R1 should be mounted with the terminals next to the load side (J2) of the bridge to avoid significant measuring errors at high frequencies. J1 is an FT-243 crystal holder while J2 in this instance is a standard SO-239 coaxial connector. Resistances are in ohms; k = 1000.

shown in Fig. 4, is contained in an aluminum box measuring 2-1/8 × 1-5/8 × 4 inches (28 × 42 × 102 mm). In this bridge, resistors R5 and R7 were eliminated and a single germanium diode was used in the detector. Upscale "bias" for the meter was provided by adjusting the meter movement zero-adjusting spring for approximately a 45 μA reading on the meter scale in the absence of any current through the meter. The voltage drop across the diode when the bias current is present returns the needle to zero. This bridge worked well at all frequencies up to approximately 200 MHz where the resistance readings began to drift. Initially, the cause for this error was not known. Later it was discovered that the potentiometer had been mounted with its terminals adjacent to the input side of the bridge. This resulted in the leads on the "unknown" arm of the bridge being about an inch longer than they should have been. Better results will be obtainez if the terminals of the potentiometer are mounted adjacent to the load side. Additionally, good readings were obtained when measuring voice-coil impedances while using an audio-frequency generator as the signal source.

There are possibilities for improving the circuits described. If others are prompted to seek such improvements, this discussion will have served its purpose.

[1] *The Radio Amateur's Handbook*, 48th edition (1972), p. 562.

Strays

MOVING? UPGRADING?

☐ When you change your address or call sign, be sure to notify the Circulation Department at ARRL hq. Enclose a recent address label from a *QST* wrapper if at all possible. Address your letter to Circulation Department, ARRL, 225 Main St., Newington, CT 06111. Please allow six weeks for the change to take effect. Once we have the information, we'll make sure your records are kept up-to-date so you'll be sure to receive *QST* without interruption. If you're writing to Hq. about something else, please use a separate piece of paper for each separate request.

Walking Your Tower Up? Can You Do It Safely?

Have any idea how much force you'll have to exert to walk up a 60-foot tower? Better find out before you start. The load can be more dangerous than you think!

By P. B. Mathewson,* W9IR

Have you ever attempted to "walk" a tilt-over tower up to the vertical position, only to discover that about half-way up the tower is too heavy to handle? This article provides a simple formula for calculating the maximum force a person must exert for such a task. For those of you who have programmable calculators, the exercise in math becomes a matter of fun.

You have probably noticed that when you initially pick up a tilt-over tower, you are surprised to find how light it seems. Nevertheless, as you attempt to walk it up, it feels heavier and heavier until a point is reached where it begins to feel lighter again. Finally, when it is in the vertical position, the weight, as far as you are concerned, is zero. Even the lightest tower can be deceiving because the apparent weight can become many times the actual weight as it is being walked up. Many people have been injured and towers have been damaged in an attempt to erect a mast in this manner. Amateurs planning such an operation are therefore advised to calculate the maximum apparent weight first. If raising the tower will be too much for you to handle, get one or more of your friends to give you a hand.

Calculating Tower Weight

Consider Fig. 1. The weight of the tower can be assumed to be concentrated in the center if the tower weight is distributed uniformly over the entire length. By summing the moments (ΣM) at the base of the tower, we can eliminate any forces at the base from our calculations.

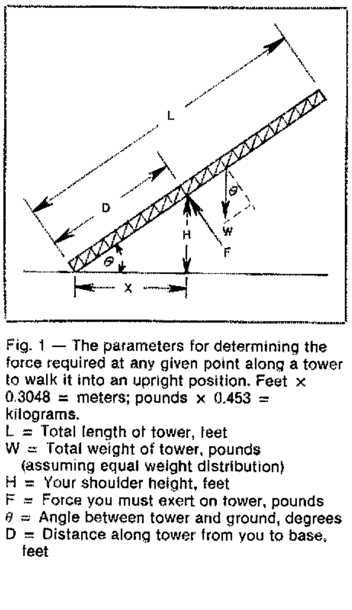


Fig. 1 — The parameters for determining the force required at any given point along a tower to walk it into an upright position. Feet × 0.3048 = meters; pounds × 0.453 = kilograms.
L = Total length of tower, feet
W = Total weight of tower, pounds (assuming equal weight distribution)
H = Your shoulder height, feet
F = Force you must exert on tower, pounds
θ = Angle between tower and ground, degrees
D = Distance along tower from you to base, feet

ΣM_{BASE}:

$$FD - W\cos\theta \, \frac{L}{2} = 0$$

$$\text{Or } F = \frac{LW\cos\theta}{2D}$$

$$\text{But } D = \frac{H}{\sin\theta}$$

$$\text{Therefore } F = \frac{LW\cos\theta\sin\theta}{2H}$$

By using this formula, you can calculate the force (F) you must exert on the tower at any angle (θ). The quantity $\sin\theta\cos\theta$ maximizes at 45 and is equal to 0.5. Therefore, the force exerted (F) reaches maximum when the tower is at an angle of 45° above ground. The maximum force can then be expressed as:

$$F_{MAX} = \frac{LW(0.5)}{2H}$$

$$F_{MAX} = \frac{LW}{4H} \qquad \text{(Eq. 1)}$$

Let's use an example of a tower 60 feet long and weighing 120 lb. Let us also presume that your shoulder height is 5 feet. Therefore, L = 60, W = 120 and H = 5.

$$F_{MAX} = \frac{60\,(120)}{4\,(5)} = 360 \text{ lb!}$$

To walk up a 60-foot tower, you would have to exert 360 lb of force. The question then arises: Can you do it? Of course, if you had a shoulder height of 6 feet, you would have to exert only 300 lb of force. So you shorter guys had better get some help with your tower!

*5860 Glen Ora Dr., Bethel Park, PA 15102

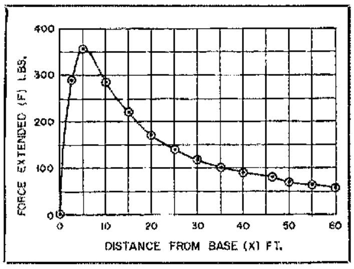


Fig. 2 — A graph of the exerted force (F) versus distance from the tower base (X). (See text.) The tower is 60 ft long and weighs 120 lbs. A shoulder height of 5 ft is assumed.

You'll find it interesting to calculate, by means of a programmable calculator, the amount of force required as a function of distance from the base of the tower. The distance X in Fig. 1 can be expressed as:

$$X = \frac{H}{\tan \theta}$$

To find the angle θ at a distance X, simply take the arc tangent of H/X.

$$\theta = \tan^{-1} \frac{H}{X}$$

Then substitute this angle into the formula:

$$F = \frac{LW \cos \theta \sin \theta}{2H}$$

Thus:

$$F = \frac{LW \cos\left(\tan^{-1} \frac{H}{X}\right) \sin\left(\tan^{-1} \frac{H}{X}\right)}{2H} \quad \text{(Eq. 2)}$$

Fig. 2 shows a graph of exerted force (F) versus distance from the base of the tower (X) for the previous example. This curve shows that the maximum force occurs after you have walked almost 60 feet! At this point, if the load seems unbearable, you are faced with a long walk back should you decide you can't handle the tower. Here is where most accidents occur. Even if you can lift 360 lb, you must remember that you have already walked quite a distance supporting over 100 lb.

In conclusion, therefore, I strongly suggest that you use Eq. 1 to calculate the force necessary to raise your tower. Do not overlook the additional weight of an antenna if you installed one on the tower, as it will add considerably to the force required. Indeed, by carefully planning your installation, you can avoid the potential hazards of such work and provide yourself with a tower that will render years of trouble-free use. QST

Strays

FLORIDA BEACON BACK ON THE AIR

☐ For several years, Bob Davis, N4RD, of Englewood, FL, operated a beacon transmitter on 28.207.5 MHz. The beacon's operation was coordinated with the IARU 10-Meter Beacon Project and, in conjunction with the other beacons that operate just above 28.2 MHz, provided a very useful propagation indicator.

Bob became a Silent Key in November, and the beacon went off the air. Knowing how much the beacon meant to Bob, and how useful it had been to amateurs the world over, members of the Tamiami Radio Club took on the project of returning it to the air as a memorial to N4RD. A committee of three — WD4MSN, WB4AGT and WA4IWL — was appointed to oversee its operation. The Florida Beacon was reactivated at 0025 UTC on January 16 under the call sign WD4MSN. The FCC no longer issues *in memoriam* calls to club stations, but this does not make the Florida Beacon any less a memorial to an amateur who deserves to be remembered, N4RD. — *David Sumner, K1ZZ*

ARRL INTERNATIONAL DX CONTEST AWARDS PROGRAM

☐ The South Florida DX Association's donation of a plaque for the top European single-band score on 3.5-MHz cw was inadvertently left out of last month's listing on page 32. In addition, several more sponsors have donated plaques.

DX Phone

Single Operator

7 MHz	K6OYE Contest Machine

Multiop-Single Transmitter

Oceania	Carl Smith, WØBWJ

Multiop-Multi Transmitter

Europe	Grosse Pointe Farms DXA

DX CW

Single Operator

3.5 MHz	Earl D. Merry Memorial (donated by W8KI)
28 MHz	West Jersey Radio Amateurs

Multiop-Single Transmitter

Oceania	K6OYE Contest Machine
Europe	Martti Laine, OH2BH

Multiop-Multi Transmitter

North America	Ventura County ARC., K6MEP

W/VE CW

Single Operator

QRP	Hollywood ARC (Florida)

Special

Single Operator

Canada (cw)	CANADX
Japan (phone)	Western Washington DX Club
Japan (cw)	Randy Thompson, K5ZD
W/VE Operator (combined)	National Contest Journal

ATTENTION INSTRUCTORS

☐ This is a reminder that we ask you to send $1.50 with your order to help cover expenses on the Novice, General and Advanced/Extra Instructor Guides. This amount should accompany your order or it can be charged to your VISA, Master Charge or BankAmericard account. The Novice Student Workbook is available as part of *Tune in the World with Ham Radio.* — *Maureen Thompson, KA1DYZ, ARRL Club and Training Department*

MICHIGAN HAMS TURN TABLES

☐ Steve Gabridge, WB8AHJ; Ron Pal, WD8NNM; and Dave Tokarski, WD8QVA, recently did a good deed *for* Boy Scouts in the Macomb District of the Clinton Valley (MI) Council, Boy Scouts of America. These hams set up an Amateur Radio station at the home of Scout Commissioner Joe Waltzer for the Jamboree-on-the-Air. Under the direction of the three amateurs, over 50 scouts and leaders made contacts from Michigan to as far away as Germany. Special certificates were prepared for the event and awarded to each scout who made a contact. QSL cards are arriving daily, and arrangements are underway for the next Jamboree-on-the-Air. — *Joe Waltzer, Scout Commissioner*

Clinton Valley (MI) Boy Scouts take some time out for instruction. The scouts made contacts as far away as Germany. *(photo courtesy Joe Waltzer)*

QST congratulates . . .

☐ Robert L. Wendt, W2JAN, who has been named president of the Sperry division of the Sperry Corporation.

☐ ARRL Central Division Director Don C. Miller, W9NTP, recipient of the Indianapolis Radio Club outstanding amateur plaque.

A Universal Touch-Tone Decoder

Hold it! You don't need repeater control? Well, these novel circuits can be used for other functions as well.

By Robert D. Shriner,* WAØUZO

Since fm repeater systems throughout the country are becoming mighty sophisticated, there's a need for a good, reliable method of controlling their various functions. The control unit described here is extremely reliable, flexible and immune to false signals. Any number of control functions can be built into this modular unit. Starting with a simple, single-digit, on/off control, it may be expanded to provide up to 45 different control functions, including a three-digit on/off command. The application of the decoder system described here is not limited to repeater use. With a little ingenuity one might adapt the simpler systems to turn on house lights or open garage doors.[1] And there's a neat little voltage-to-frequency converter, too. More about that later.

The heart of the system is the NE567 tone decoder. Note the unique method of interconnection as shown in Fig. 1.[2] In other systems, seven ICs are used to provide all the decoding functions. These decoders may respond to false signals and are critical of input tone levels, however. In this unit 24 ICs are used, two for each digit (0 to 9) and two each for the asterisk (*) and pound (#) signs. This may at first seem to be a waste of ICs, but the selectivity of the decoders is greatly enhanced and this arrangement allows the use of other capabilities of the IC.

Circuit Description

Refer to Fig. 1. U1 is used to decode the

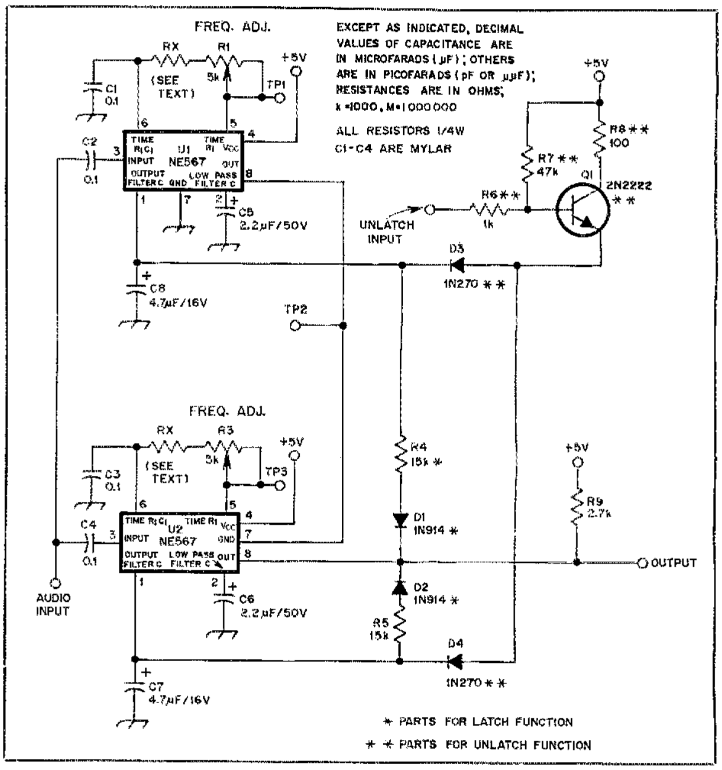
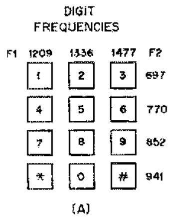


Fig. 1 — The circuit diagram of the Universal Touch-Tone Decoder. A pair of ICs is used to provide better reliability and immunity to "falsing." If desired, the capacitor at pin 1 of each IC may be increased to 100 μF to provide a two-second decoding delay.

*1740 E. 15th St., Pueblo, CO 81001

[1]Notes appear on page 40.

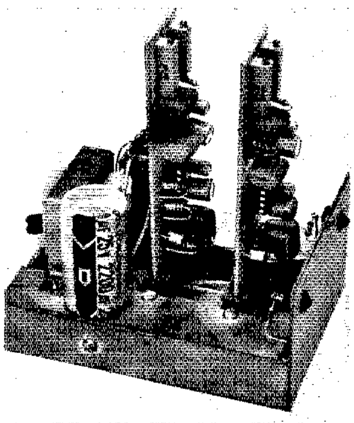


VALUE OF RX

FREQ.	VALUE
1209	6.8k
1336	5.6k
1477	5.1k
697	13k
770	12k
852	10k
941	9.1k

(B)

Fig. 2 — The layout of the 12-key pad and the frequencies associated with each line and row are shown at A. Fig. 2B gives the values required for RX for the various frequencies to which the decoders of Fig. 1 are tuned.



With a little ingenuity, this simple version of the decoder can find many uses.

higher frequency (f1) of the Touch-Tone pair (see Fig. 2A). When U1 receives the correct tone, the output (pin 8) will supply a low to U2, pin 7, enabling it to decode the lower frequency of the pair (f2). Upon reception of the frequency pair, the output of U2 will go low. This low will be used in several different ways in this system.

The first way this low is used is to "latch" the digit into the system. D1, D2, R4 and R5 are used for this purpose. If the latch feature is not desired, omit these components. To "unlatch" the unit, Q1 will be used. When the base of Q1 is low (grounded), the latch is enabled. If the base is high (ungrounded) the system will unlatch.

Note that the decoders may be built one at a time on a small board or in groups of four on a larger board. Both boards can be plugged into a standard 0.156-in. (4.0-mm) card socket. A 6-pin socket is used for the single-digit model and a

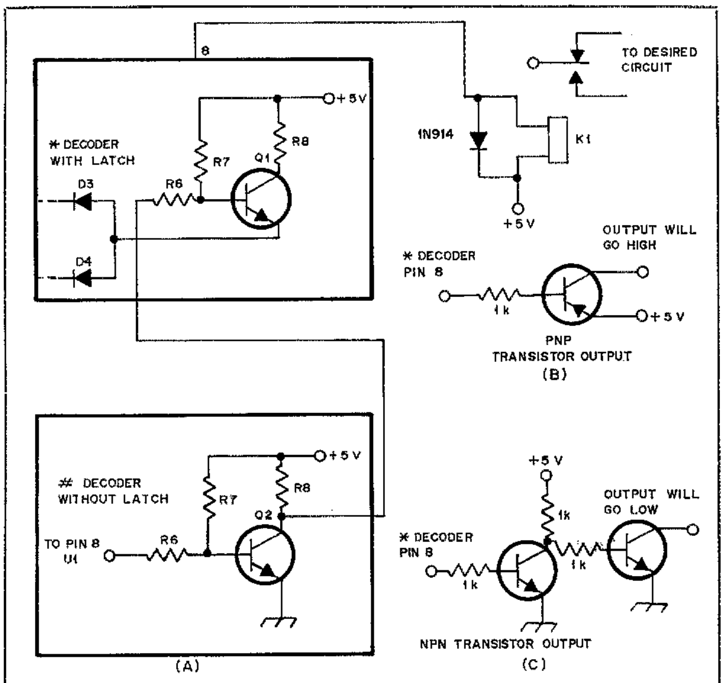


Fig. 3 — A simple two-button, on/off decoder. A relay is shown at A, but transistor switches may be substituted as at B and C.

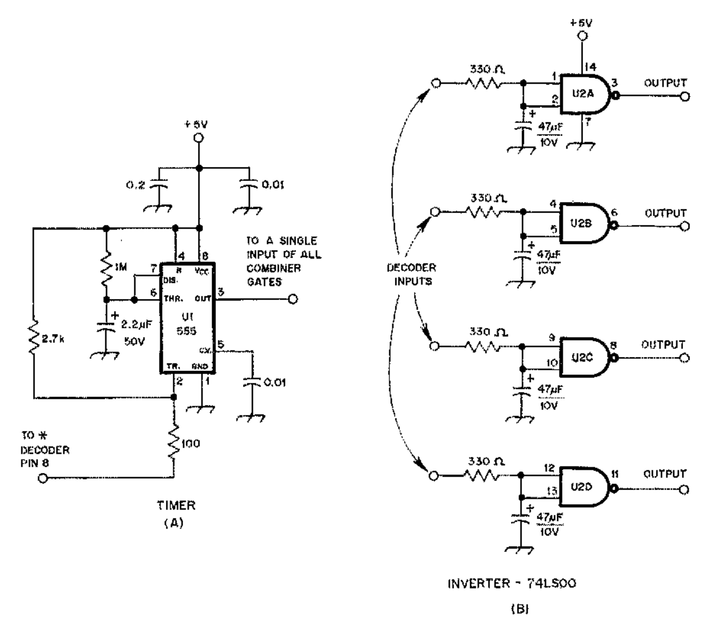


Fig. 4 — The diagram of the TIMER-INVERTER board. The timer is used to provide a "window" through which the control data must be passed. Only one inverter IC is shown, but there are actually three on the board. The 47-μF capacitors at the input to the gates slow down the action of the inverters and prevent system "falsing" due to voltage "spikes."

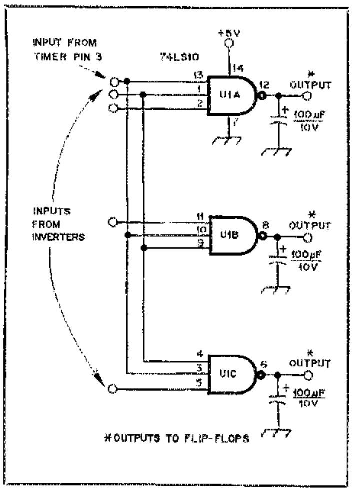


Fig. 5 — There are three 74LS10 ICs on each COMBINER board although only one is shown.

28-pin socket for the four digit board.[3]

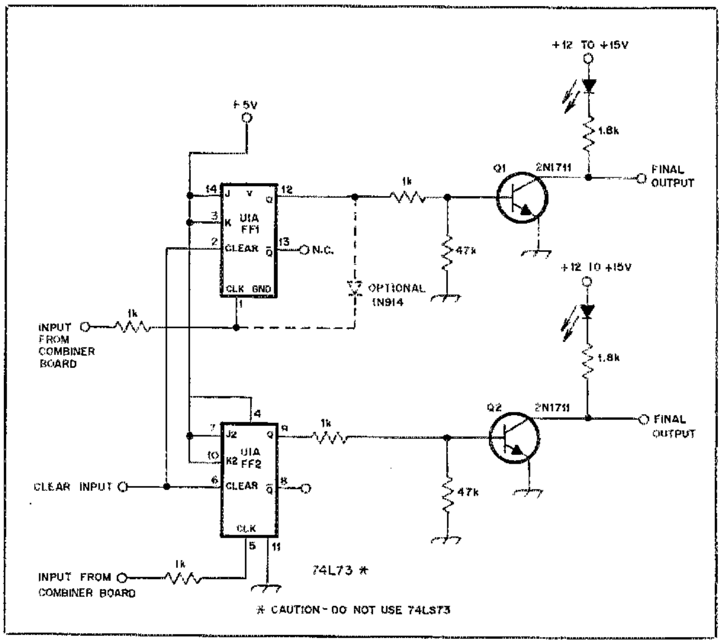


Fig. 6 — A diagram of one section of the FINAL board. FF1 and FF2 are both part of the same IC, a dual J-K flip-flop. Four of these dual flip-flops and eight of their accompanying output transistors are mounted on each board. See Fig. 8D and the text concerning the installation of the optional diode shown in dotted lines.

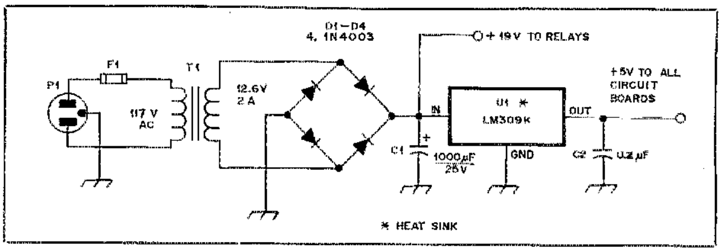


Fig. 7 — A diagram of a representative power supply which may be used to power the Universal Touch-Tone Decoder.
C1 — 1000-µF, 25-V electrolytic.
C2 — 0.2-µF, 35-V Mylar.
D1-D4, incl. — 1N4003 or equivalent.
F1 — 1-A, 125-V fuse.
P1 — 3-circuit ac plug.
T1 — 12.6-V, 2-A transformer.
U1 — LM309K voltage regulator.

Construction

As a start, a single-tone decoder will be constructed and its operation examined. Select a frequency pair from Fig. 2A. Choose the appropriate resistor value for RX from Fig. 2B. Mount the components on the board with the exception of those required for the latch/unlatch circuitry. Install short wires at TP1, TP2 and TP3 for attaching test leads. Apply power to the circuit and connect a frequency counter to TP1. Use a low-value capacitor (approximately 300 pF) between the counter and TP1 to prevent the counter from loading the IC. Adjust R1 to provide the correct chosen frequency.

To adjust U2, a signal source at f1 is required. A Touch-Tone pad may be connected to the audio-input point of Fig. 1. The pad will generate a single-frequency tone (f1) when two buttons in a vertical row are pressed simultaneously. Any two coincidentally pressed buttons in a horizontal line will generate f2. Feed f1 into the decoder and adjust the amplitude of the tone so that TP2 goes low. With the counter at TP3, adjust R3 for f2 with f1 still applied. Now, when the digit corresponding to the frequency pair (f1/f2) is pressed with the output of the pad applied to the decoder, the output of U2 (pin 8) will go low. When the tones are removed, pin 8 will return to a high.

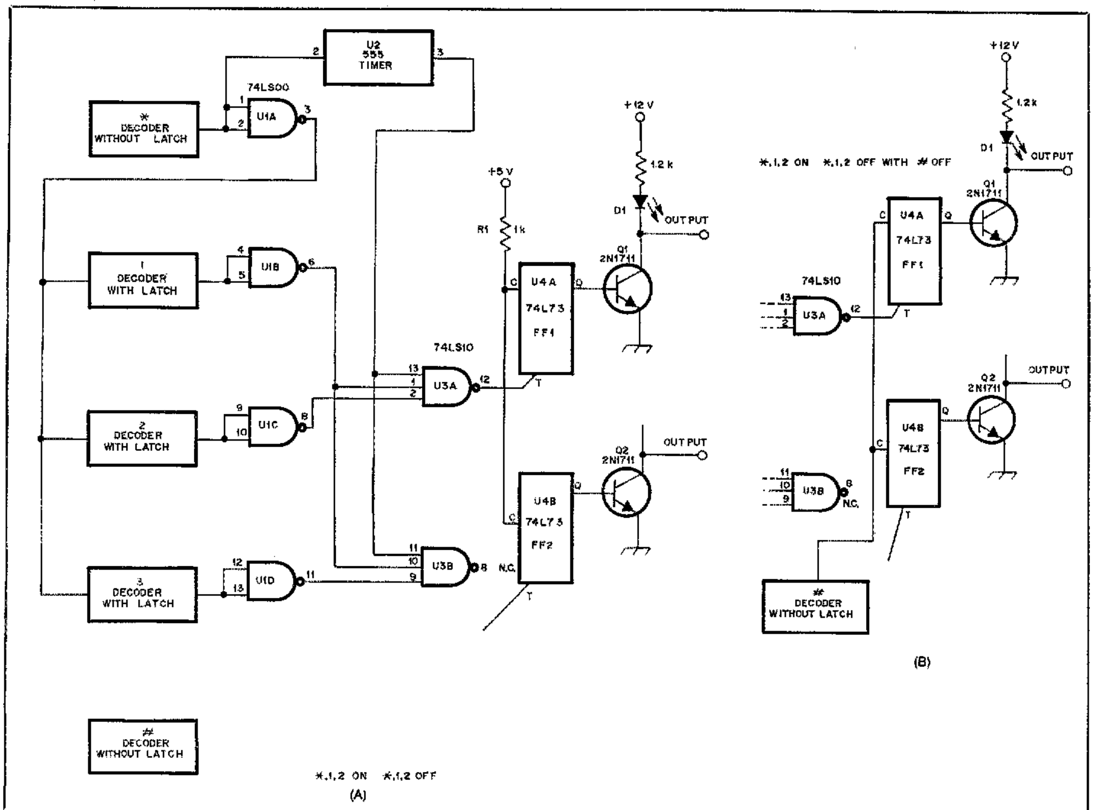
Install the components associated with the latch function. Now, when the frequency pair is recognized by the decoder, the output of U2 will go low and remain low after the tones are removed. Mount the unlatch function components and ground the base of Q1. You should note that pin 8 will go low when the tones are received and remain low until the base of Q1 is ungrounded or taken high.

To become even more familiar with the circuitry, a simple * (on) and # (off) decoder will be constructed. Build the * decoder with the latch function and the # decoder without the latch. Connect the transistors (Q1, Q2) as shown in Fig. 3. A relay is shown at the output although either a relay or transistor may be employed. When the * is received, the relay will close and remain closed (latched) until a # signal is received.

Topsy Grows

Let's proceed to construct a complete system offering up to 45 different control functions and using a three-digit entry. Use of either the * or # sign as the first entry for a control function is recommended, especially if the repeater is equipped with an autopatch. In this manner, numbers alone cannot initiate a control function. Personal preference is to use the * symbol to initiate the command and the # sign as an "all clear"; this also permits system reset.

To carry the logic required for the larger system, other circuit boards will be needed. All are of the 28-pin plug-in variety. A timer is also needed; an NE555 serves nicely. The timer, activated by the *



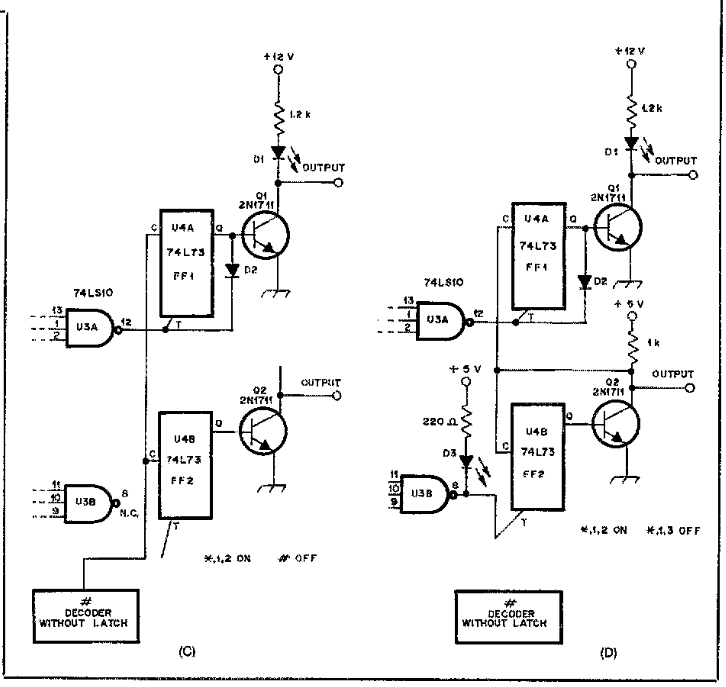


Fig. 8 — The four circuits diagrammed here are discussed in the text. The most simple circuit (A) does have a weak point, while that at D is the most reliable.

decoder, (constructed without a latch) will open a "window" through which the other two digits must be passed. This "window" will remain open for only two seconds. The * is also used to reset all other decoders. This was done so that if any of the decoders have been accidently activated, no command function will be carried out.

It will also be necessary to invert all the lows supplied by the decoders. This operation is performed by SN74LS00 quad, two-input NAND gates. The input pins of the gates are tied together, thereby creating inverters. The timer and inverter diagram is shown in Fig. 4. Only one TIMER-INVERTER board is required for any system of up to 45 functions.

To combine the three digits and generate one output, a COMBINER board is used. Each board contains three SN74LS10 ICs. Fig. 5 shows the make-up of a single 74LS10 which incorporates three triple-input NAND gates. Each board furnishes nine functions; five boards are used in a 45-function decoding system.

The last board required is (appropriately) the FINAL board, which contains the latches for the desired functions and the transistor drivers. Four SN74L73 dual J-K flip-flops and eight 2N1711 transistors are mounted on each

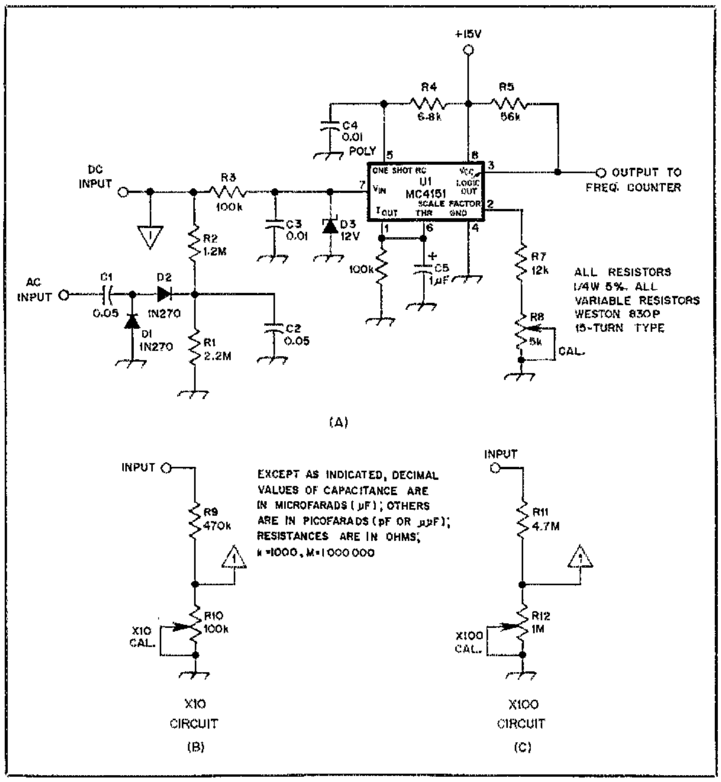
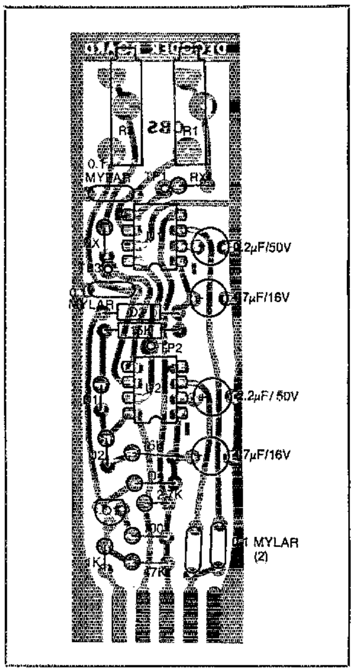
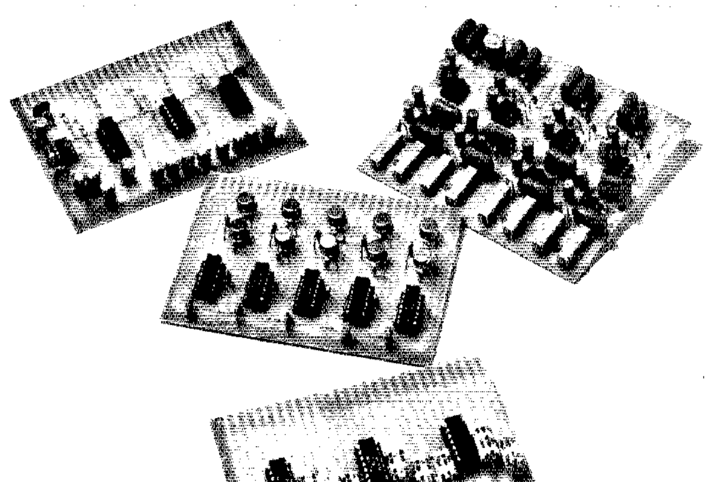


Fig. 9 — The voltage-to-frequency converter is shown at A. Both dc and ac voltage amplitudes may be read out on a frequency counter at the output of the IC. The circuits at B and C may be used as X 10 and X 100 multipliers at the input to the converter.



The component placement for the smaller DECODER board is shown here. The same arrangement is used on the larger board which houses four decoders.



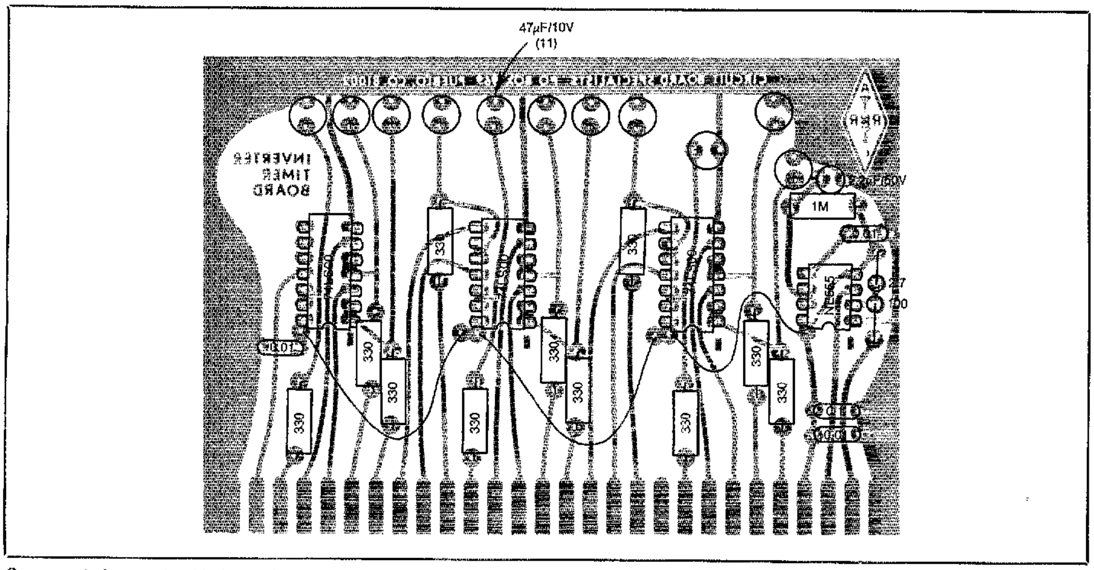
The four printed-circuit boards used in the decoder. At the upper left, the INVERTER-TIMER; upper right, the DECODER; center, the FINAL and at the bottom of the photograph, the COMBINER board. See note 3, page 40, about etching patterns.

board. Five boards are used in the 45-function system with 5 functions left open for possible use later. A single SN74L73 is shown in Fig. 6.

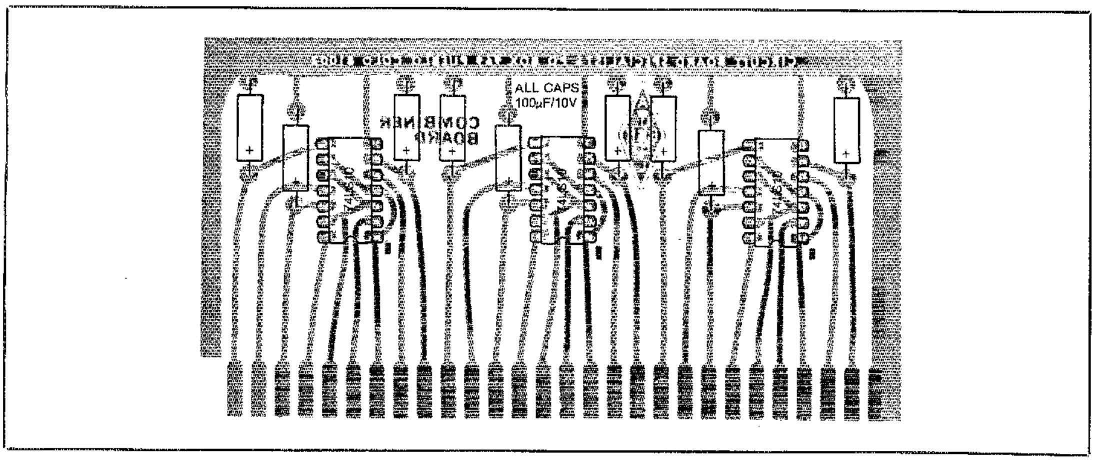
To power the described circuits, a supply similar to the one shown in Fig. 7 will be needed. The supply chosen should be capable of delivering approximately 750 mA to the decoder system and sufficient current for the operation of any relays that will be used.

Construction of a *,1,2, ON function will be described next. Then, several options will be discussed to reverse the state ending with the use of a *,1,3 OFF command. The diagrams shown in Fig. 8 illustrate the various options available. The * and # decoders should be built without the latching feature; all the other decoders will use the latch function. An INVERTER-TIMER board, at least one COMBINER board and one FINAL board will be needed as well.

To contain the system, a card cage or "shoe box" was made out of double-sided, printed-circuit-board material. The function-control outputs are brought out to card sockets mounted on the rear of the case. This allows everything to be disconnected easily for servicing. LEDs are mounted on the front panel of the enclosure to provide an indication of the status of all of the functions. A Touch-



Component placement guide for the INVERTER-TIMER board. Only one of these boards is required for any system employing up to 45 functions.



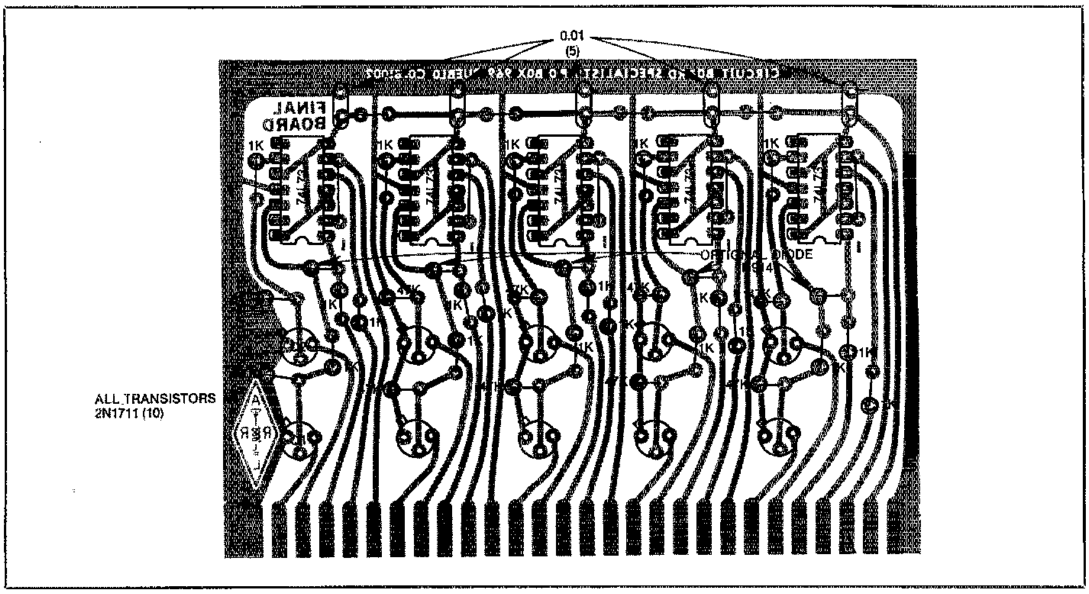
The COMBINER board component placement is shown above.

Tone pad was also installed on the front panel. This pad may be switched into the system for local checks of the unit.

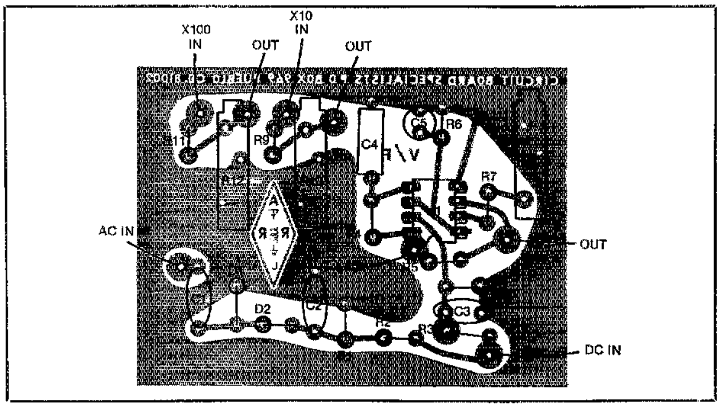
Refer to Fig. 8A. Note that the output of the * decoder is used to start the timer and reset all the decoders. The output of U2 is applied to one input of the three-input gate, U3A. The second input of the gate is satisfied by the output of the "1" decoder and the third input by the "2" decoder. This forces the output of U3A low. This low toggles the J-K flip-flop U4A (note that the clear or C input of U4A is held high through R1). The Q output of U4A will go high and remain high. This causes transistor Q1 (the output transistor) to conduct. The corresponding LED will glow, indicating that the function has been carried out. If desired, a relay could be used at the output of Q1. With this simple system, one must use the same codes (*,1,2) to turn off the function. This is not a sound idea since one cannot tell (from a remote point) whether the function was being keyed on or off. A better method is shown in Fig. 8B. The clear (C) input of U4 is connected to the # decoder. The basic action of the decoder will be the same as before, but now, use of the # key will ensure the function is in its off state. An extra bit of insurance may be obtained through the addition of D2 as shown in Fig. 8C. This will prevent the same code (*,1,2) from turning the function off; now the *only* way this may be done is with the # key.

In Fig. 8D, a system is shown which uses an ON code of *,1,2 and OFF code of *,1,3. Remove the # decoder output from the clear input of U4 and connect that input to the collector of Q2, the output transistor of the *,1,3 decoder. Add the LED, D3, as shown.

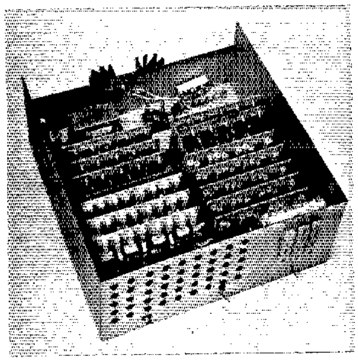
It is best to use a number of decoder chips and separate inputs to each chip for a couple of reasons. Some of the decoder audio inputs can be connected to the repeater receiver so that a number of users



Component positions for the FINAL board. Five boards are needed for a 45-function system.



This is the voltage-to-frequency converter component arrangement.



The completed 45-function Touch-Tone decoder. Double-sided printed-circuit board soldered along the seams makes a sturdy enclosure.

can key them up, as in autopatch use. Other decoders can be used with a 450-MHz control receiver and still others properly coupled to the telephone line for other uses.

A highly accurate voltage-to-frequency converter circuit is presented in Fig. 9A. Calibration is straightforward. Couple a frequency counter to the output of the converter and connect a +12V source to the input. Adjust the calibrate potentiometer for a reading of 12 kHz, as read on the frequency counter. A +1.5-V source should provide a reading of 1.5 kHz, and so on. Provisions have been made on the printed circuit board for inclusion of a X 10 and X 100 multiplier circuit. These additions are shown in Fig. 9B and C, respectively. The ac-to-dc converter permits measurement of ac voltage and will be read as an RMS voltage on the frequency counter. This novel voltage-to-frequency converter circuit can be utilized in many ways such as providing a digital readout of signal levels. Or, if your repeater is equipped for telemetry, you could use this circuit to provide signal level readouts. The circuits presented here should provide many hours of building and learning enjoyment and find both practical and fun applications.

Notes

[1]If such operation is intended, one should pay particular attention to sections 19.34(b), 19.35 (c), 97.61, 97.89 and 97.99 of the Communications Act of 1934. See *The Radio Amateur's License Manual*, ARRL, $4.

[2]*FM and Repeaters for the Radio Amateur*, first edition, p. 119.

[3]Circuit boards and parts kits are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002. Printed circuit board etching patterns are available from the ARRL for 50 cents and an s.a.s.e.

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu FT-7B Mobile/Base HF Transceiver and YC-7 Frequency Display

Are you thinking about doing some mobile or portable operating? If so, you should take a look at the FT-7B, Yaesu's new hf transceiver. If not, you should look at it anyway, because it's also suitable for fixed service. An improved version of the FT-7, intended for the market generated by the Japanese no-code license, the B model features 100-W PEP input on ssb, a-m and cw. The transceiver covers 80 through 10 meters. The bandswitch has four 10-meter positions, each covering a 500-kHz segment. A crystal for 28.5-29.0 MHz is standard equipment; the others are optional. Other features of the FT-7B include a noise blanker, an rf attenuator, a crystal calibrator, concentric rf and af gain controls, a clarifier (RIT) and one fixed channel per band (crystals not supplied).

Circuitry and Performance

The unit is completely solid-state. It contains 54 transistors, 78 diodes and 8 ICs. The usual premixing arrangement is employed to produce an i-f centered on 9 MHz. A 6-pole crystal filter having a shape factor of 1.67 (6 dB/60 dB) establishes the selectivity under all conditions except a-m transmitting. In the receive mode, a monolithic filter precedes the noise blanking gate to provide "roofing" against strong signals outside the crystal filter passband.

The VFO operates at 5 MHz and uses a bipolar transistor. The transceiver performs within its stability specification, but I would expect better performance from an FET. At room temperature the unit stabilized after one hour of operation, during which time it drifted 1 kilohertz. This performance is acceptable for home station environments, but the mobile operator trying to have a QSO during his half-hour drive to work may have trouble on a cold morning. The tuning mechanism operates smoothly and features anti-backlash gears.

The noise blanker is worth looking into because it appears to lack the ills characteristic of other units. This circuit contains seven transistors, six of which are FETs. One of these is used in an 8545-kHz crystal oscillator that establishes a 455-kHz i-f for the blanker. The significant feature of the FT-7B noise blanker is that it doesn't appear to degrade the receiver's dynamic range. Yaesu achieved this improvement at the expense of a slightly higher blanking threshold. Noise pulses must be somewhat more offensive than usual before they are blanked.

In the cw mode, a two-pole RC active audio filter follows the product detector. This filter has a 6-dB bandwidth of 80 Hz, but as would be expected from the simple design, the skirts

*Assistant Technical Editor, ARRL

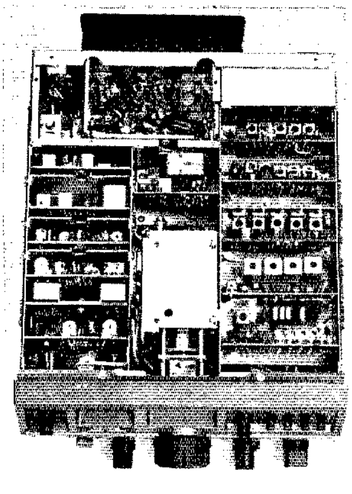
The FT-7B transceiver with optional YC-7 remote frequency display. The microphone and mobile mounting bracket are supplied with the transceiver.

Table 1

FT-7B Mobile/Base HF Transceiver

Frequency Coverage: 500 kHz of 80-15 meters, four 500-kHz segments of 10 meters (crystal for 28.5-29.0 MHz supplied).
Operating modes: lsb, usb, a-m, cw
Power requirements: 13.5 V dc ± 10 percent at 10 A transmit, 0.6 A receive.
Dimensions (HWD): 9- × 3-1/8- × 12-9/16-inches (230- × 80- × 320-mm) including heat sink.
Weight: 12 lbs (5.5 kg)

Claimed Specifications	*Measured in ARRL Lab*
Input power: 100 W PEP ssb, a-m 100 watts dc cw	50-55 watts rf output over frequency range
Carrier suppression: >50 dB below rated PEP output	>50 dB
Unwanted sideband suppression: >50 dB at 1000 Hz	>50 dB
Spurious emission: >40 dB below fundamental	>50 dB below fundamental
Distortion products: 31 dB below PEP output	31 dB below PEP
Frequency stability: <100 Hz per half-hour after warm-up	90 Hz per half-hour after one hour
Microphone input impedance: 500 ohms, nominal	
Antenna output impedance: 50 ohms, nominal	
Sensitivity: 0.5 μV for 10 dB S + N/N	0.25-0.5μV over frequency range
Image rejection: 50 dB	50-60 dB over frequency range
I-f rejection: 50 dB	50 dB over frequency range
Selectivity: 2.4 kHz (−6 dB), 4.0 kHz (−60 dB) cw audio	
Peak filter: 80 Hz (−6 dB)	
Audio output power: 3 watts at 10 percent THD	
Audio output impedance: 4 ohms	
Price class: $675	
Manufacturer: Yaesu Musen Co., Ltd., Tokyo, Japan	



Inside view of the FT-7B. The top cover of the PA module has been removed. A tan bracket could be made from the plate attached to the heat sink. The loudspeaker is on the underside.

aren't very steep. The receiver agc bandwidth is 2.4 kHz in all modes, so the audio filter isn't the lifesaver it could be.

It would be nice to have cw selectivity at the i-f, but I don't know of a simple way to get it. On 80 meters, the sense (usb/lsb) of the signal is inverted, causing it to be located in a different part of the i-f passband than on the other bands. The cw offset frequency is 800 Hz on 40 through 10 meters and 1200 Hz on 80. If you peak the received signal on the nose of the audio filter, you can't transceive on frequency in the 80-meter band unless you shift the clarifier 400 Hz. The clarifier has plus or minus 3 kHz of range, which was enough to allow me to contact a DX station who was operating on split frequencies.

On ssb, the receiver audio sounds clean and the agc action is smooth. A diode envelope detector is used in the a-m mode. The 2.4-kHz filter is used in both voice modes, so only one sideband reaches the a-m detector, resulting in a poorer signal-to-noise ratio in the detector. Additional i-f and af amplification is used with the a-m detector in an apparent attempt to equalize the a-m and ssb sensitivities, but the result is a somewhat noisier receiver on a-m.

The manual states that the transceiver is spurious-free. With the antenna input terminated by a 50-ohm resistor, I found internally generated responses at 14.001, 21.201 and 28.801 MHz. All of these spurs were weak (below 1 μV equivalent antenna input), but I found the one at 14.001 MHz to be offensive, the futility of competing on that frequency with 50 watts into a vertical antenna notwithstanding.

The overall performance of the receiver is good. We didn't perform the Hayward dynamic-range measurements because the cw-selectivity characteristics aren't the same as those of other transceivers. The numbers derived from the tests wouldn't be directly comparable to previously published results. However, the real test for receivers in Newington is how closely you can tune to W1AW while copying weak signals. My house is one mile from W1AW. So long as I tuned W1AW out of the i-f passband, I couldn't tell it was on the air. This was *without the attenuator activated.*

The transmitter works well on ssb. Using the hand-held microphone supplied with the transceiver, I received a good audio-quality report from N1FB during a 10-meter ground-wave contact. He reported high voice recognizability, even though my signal was too weak to move his S-meter (our stations are 10 miles apart and our antennas are cross-polarized). When I switched to a-m, he couldn't hear me at all. Suspecting a malfunction, I made some a-m measurements, and found the FT-7B to be working perfectly well. Why couldn't N1FB hear me? A-m simply isn't as efficient as ssb for weak-signal work. The FT-7B has considerable circuitry devoted exclusively to the a-m function. Rather than merely unbalancing the modulator and transmitting an "a-m compatible" signal through the filter, Yaesu chose to modulate the control gate of a dual-gate MOSFET amplifier following the cw carrier oscillator. The crystal filter is bypassed, resulting in a genuine dsb a-m emission. As can be seen in the a-m envelope photograph, Fig. 3, the modulation linearity is adequate for voice work. The waveform is similar to that obtained with screen modulation (remember screen modulation?). When I applied nearly 100 percent sinusoidal modulation, the average power increased from 12 watts to about 16 watts. A separate a-m alc circuit prevents the final amplifier from being overdriven on positive modulation peaks, but it's still possible to generate plenty of splatter from the negative excursions. If the mic gain and drive controls are adjusted as prescribed by the manual, the unit modulates cleanly.

I'm a cw operator, so I looked forward to using the FT-7B on the mode where its 50 watts of output would be most effective. I made several contacts using the hand key, and all of the receiving operators said the rig sounded good. Then I called a station who was sending faster (about 25 wpm), and he asked me to reduce the weighting on my keyer. This puzzled me, because I was sending with a bug! The next day I arranged tests with W1VD and N1FB, who recorded my signal. When he played the tape for me, I couldn't copy it! The dual-trace oscilloscope photo of the keying signal and the resultant rf envelope, Fig. 4, documents the problem. After the keying pulse has ended, the rf output continues for at least 20 milliseconds before it even begins to decay. I tore into the circuit and didn't stop until the unit produced the waveform shown in Fig. 5. My modification is radical, but it allows independent control of the attack and decay slopes. The details of the modification appear in the "Hints and Kinks" section of this issue. Realizing that my approach was somewhat of an overkill, I asked Yaesu for a simpler solution. The engineers reported that R1015 and C1012 have been changed to 47 kΩ and 0.33 μF in current production models. I restored the circuit to its original configuration and changed the two components. The third keying photo, Fig. 6, shows the results of Yaesu's fix. The performance is superior to that of the original circuit, but is somewhat sensitive to temperature variations and component tolerances. Yaesu also suggested changing C1012 to 0.047 μF and placing it between collector and base of the keying transistor in a Miller integrator fashion. If you plan to operate cw with the FT-7B, listen to it critically on a local ham's receiver.

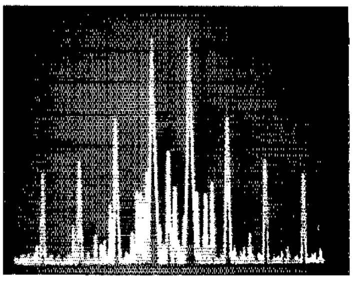


Fig. 1 — IMD spectrum of the FT-7B. Each tone is 6 dB below the rated PEP output. The test tones were 700 Hz and 1900 Hz. Vertical scale: 10 dB per division. Horizontal scale: 1 kHz per division. Test frequency is 14 MHz.

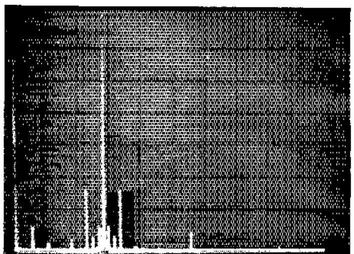


Fig. 2 — Worst-case harmonic and spurious spectrum (28 MHz). At full power input, all spurious outputs are more than 50 dB down. Vertical scale: 10 dB per division. Horizontal scale: 10 MHz per division. The tall pip at the extreme left of the photo is generated within the spectrum analyzer. The FT-7B complies with current FCC spectral purity requirements.

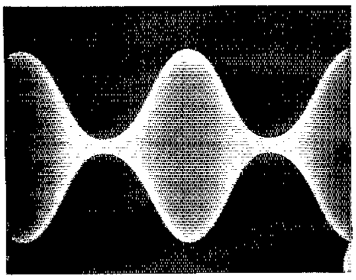


Fig. 3 — When was the last time you saw an a-m envelope? The FT-7B is capable of reasonably good linearity at high modulation percentages. For this test, the carrier frequency was 28.5 MHz and the modulation frequency was 1000 Hz.

A phase-shift oscillator generates the cw sidetone. The nearly pure sine wave is a pleasant departure from the raucous notes produced by the multivibrators in some other rigs. The sidetone output is rectified and used to activate the T-R relay for "semi-break-in" cw. The relay hang time is adjustable.

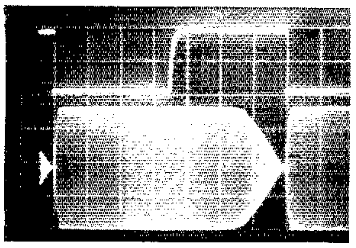


Fig. 4 — Rf envelope vs. keying waveform of the unit as received. The upper trace is the switching waveform at the FT-7B key jack and the lower trace is the output envelope. The horizontal scale is 10 msec per division.

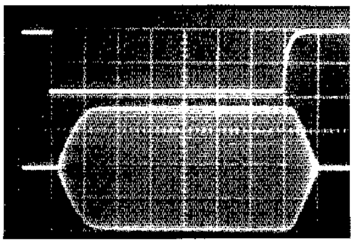


Fig. 5 — After radical surgery, the keying looked like this. In this photo, the horizontal scale is 5 msec per division. The modification information is printed in "Hints and Kinks."

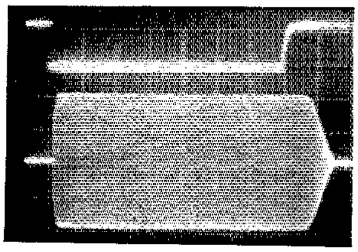


Fig. 6 — Here's the keying resulting from Yaesu's suggested modification (see text). Horizontal scale is 5 ms per division.

The YC-7B Frequency Display

Mobile operators must be able to determine their frequency quickly, with no more than a glance away from the road. The YC-7B remote digital display fills this need. The unit is an optional accessory that plugs into a rear-panel socket of the FT-7B. Stick-on Velcro strips allow the display to be mounted anywhere within reach of the umbilical cable.

The YC-7B counts the final mixer injection frequency. Preset commands from the FT-7B ensure proper carrier frequency readout on all modes. On 80 meters, an 18-MHz crystal oscillator heterodynes the LO signal to the proper range for the counter. The time-base frequency is 655.36 kHz. No special temperature compensation is used, but the overall stability should be at least an order of magnitude better than that of the FT-7B VFO. The readout resolution is 100 Hz, but the instrument counts down to 10 Hz, with a 0.1-second gate time. This unit does not add any spurious responses to the receiver.

Construction

Most of the FT-7B circuitry is assembled on a dozen phenolic pc cards which plug into three mother boards. The card sockets are individual gold-plated spring pins soldered into the mother boards. The mobile operator needn't worry about the reliability of the sockets — the cards are held firmly in place by the top cover. Two wired-in pc boards and the VFO and PA modules complete the electronics. The VFO and PA are shielded, of course. Most of the tuned circuits are on the mother boards, so you can repeatedly remove and reinstall the plug-in cards without upsetting the alignment. The PA heat sink protrudes from the rear panel. The sink is adequate for voice and cw duty cycles. The a-m rating applies to RTTY and SSTV service. Two screws secure a flat plate to the heat sink fins. A small fan could be mounted to this plate very conveniently.

Aesthetics and Impressions

The unit certainly is compact. That's not surprising, considering the cars it was designed to be installed in. At a time when the styling of Amateur Radio equipment is diverging toward the "military" and "hi-fi/furniture" looks, the FT-7B represents a refreshing alternative to these extremes. The cabinet is painted a businesslike metallic blue that won't look out-of-place in your car or on your kitchen table. The four-color dial and meter are highly visible, yet not at all garish. For fixed service, the analog dial is easy to read, and with its 1-kHz resolution and good linearity, you really don't need the optional digital readout. It's handy, though, for precise clarifier tuning and keeping track of the VFO. All of the controls are conveniently located.

Table 2

YC-7B Remote Digital Frequency Display

Specifications

Resolution: 100 Hz
Clock frequency: 655.36 kHz
Gate time: 0.1 sec.
Operating temperature: 0-40° C
Power connections: from FT-7B
Dimensions (HWD): 1-5/8 × 3-5/8 × 5-3/8 inches (40 × 93 × 135 mm)
Weight: 12-1/2 oz (360 g)
Price class: $110
Manufacturer: Yaesu Musen Co., Ltd., Tokyo, Japan

I experienced a small amount of TVI while operating the rig into a dummy load on the same table with my plastic-encased television set. You may have to scrape some paint off the mating metallic surfaces of the FT-7B enclosure if you live in a weak TV signal area.

A *QST* advertisement for the FT-7B reads: "Enough power to drive those linears!" The manual makes no mention of using the transceiver with an external amplifier, but if you dig into the schematic diagram, you'll find that the alc line and the 13.8-volt transmit line (to control a relay) are brought out to the power connector. There's an unused set of contacts on the T-R relay, but they aren't accessible from outside the transceiver.

The attention Yaesu paid to the a-m mode is perplexing. If the intent was to make the transceiver compatible with converted CB rigs, a better solution is to install BFOs in the CB rigs. If you want to participate in the second genesis of a-m, you'll never compete with those plate-modulated Valiants and DX-100s! I would much prefer to see the a-m mode scrapped in favor of some advanced ssb/cw features, such as sharp i-f selectivity, full break-in, VOX and even (bite my tongue) speech processing.

Tinkerers will love this rig, for one can remove most of the cards without unsoldering any wires. If you like, you can fabricate a completely new set of cards. Serious experimenters will undoubtedly conceive numerous worthwhile modifications. With a little ingenuity, a remote VFO could be plugged into one of the fixed-channel crystal sockets. Another possible improvement would be a VFO drift correction circuit using feedback from the YC-7B. If you apply the correction voltage to the wiper of the dial calibration potentiometer, you won't have to violate the VFO compartment.

The FT-7B offers something for everybody. You can have plenty of fun with it just like it is. And if you're ambitious, you can turn it into a truly deluxe station. The equipment is covered by a three-month limited warranty. — *George Woodward, W1RN*

HEATH SB-221 LINEAR AMPLIFIER KIT

How does the SB-221 differ from the earlier SB-220[1] amplifier? The major difference, electrically, is an unfortunate by-product of FCC action to prevent amateur-equipment manufacturers from including our 10-meter band in linear amplifiers: The SB-221 does not operate on 10 meters! The band-switch panel markings read only "80, 40, 20 and 15" (meters).

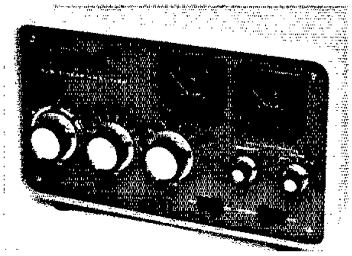
Heath Company and other commercial manufacturers of hf-band amateur amplifiers are required to ensure that all amplifiers require at least 50 watts of driving power and that they must be incapable of operation at 27 MHz. They can't, therefore, operate at 28 MHz without elaborate and highly expensive circuitry which is beyond manufacturing reason. All of this came to pass because of widespread illegal operation by CBers who purchased amateur-band linear amplifiers and employed them at 27 MHz. The FCC's inability to enforce the CB regulations imposed a severe economic and marketing hardship on the amateur-equipment manufacturers as well as the amateurs. These regulations, fortunately, do not apply to vhf and uhf types of amplifiers.

SB-221 Features

The popular and reasonably priced amplifier can be made to work satisfactorily on 10 meters by converting it back to an SB-220. More on that later. But, let's examine the circuit and features for the benefit of those who are contemplating the purchase of a "pair of shoes" for that presently "barefoot" exciter.

In its present form, the SB-221 operates in the 80, 40, 20 and 15-meter bands. The required driving power is 100 watts maximum. Rf power amplification is accomplished by means of two 3-500Z triode tubes which are forced-air cooled. These well-proven tubes

[1]"Recent Equipment," *QST*, August 1970, p. 45.



The Heath SB-221 linear amplifier. Though it may appear to be "stock," this '221 operates in five bands. Modification information is given in the text.

Table 4

Results of SB-221 Tests Performed in ARRL Laboratory

Band	$P_{IN(watts)}$	$P_{OUT(watts)}$	Input VSWR	Drive Power (watts)	Efficiency (%)
80	1000	560	1.53:1	70	56
80	1900	1150	1.42:1	100+	60
40	1000	600	1.41:1	70	60
40	1900	1200	—	100+	63
20	1000	580	1.6:1	75	58
20	1900	1100	—	100+	58
15	1000	560	1.79:1	75	56
15	1900	1050	—	100+	55
10	1000	500	1.42:1	67	50
10	1900	1000	—	100+	53

offer reliable service and good efficiency. They are the instant-heating-filament type. Hence, operation is permissible the moment the amplifier power switch is turned on.

Maximum dc power input is 2-kW PEP on ssb, 1 kW on cw and 1 kW on RTTY. This amplifier is rated, in terms of its duty cycle, for continuous voice modulation on ssb. For cw use the maximum key-down (steady carrier) time is 10 minutes. When operating the RTTY mode the manufacturer specifies a 50 percent duty cycle, or a *maximum* transmit time of 10 minutes.

The metering system enables the operator to monitor the plate current at all times by means of a 0- to 1-ampere dc meter. A second meter and related switch permits the monitoring of grid current, relative output power or dc plate voltage. There is a two-level plate-voltage setup which is programmed from the front panel by means of a rocker switch. One position provides the proper operating voltage for tune-up and cw. The alternate switch position is for ssb operation. In the latter position the plate voltage and current are elevated to provide the 2-kW PEP power input level while keeping the plate impedance the same as it is in the tune position. Therefore, no readjustment is needed when going from tune to the ssb mode.

Driving power is supplied to the grounded-grid 3-500Zs through switched, broadband pi-section matching networks. The amplifier input impedance is approximately 50 ohms. Hash noise is prevented during the standby period by automatic application of beyond-cutoff bias to the tubes. The proper idling current for the tubes during transmit is established with Zener-diode-regulated bias.

Table 3

SB-221 Specifications

Size (HWD): 8-1/4 × 14-7/8 × 14-1/2 inches (210 × 378 × 368 mm).
Weight: 50 pounds (22.7 kg).
Color: Two-tone light and dark green.
Power requirements: 117 V ac at 50/60 Hz (20 A max.), or 240 V ac at 50/60 Hz (10 A max.).
Driving power: 100 W max.
Dc input power: 2-kW PEP for ssb and 1 kW for cw and RTTY.
Key-down maximum at full power: 10 minutes.
Frequency range: 3.5 through 21 MHz.
Price class: $620.
Manufacturer: Heath Company, Benton Harbor, MI 49022.

During transmit, an automatic limiting control (alc) circuit in the amplifier develops negative voltage which can be routed to the exciter to reduce its gain when the exciter output is sufficient to overdrive the amplifier. A phono jack is provided on the rear apron of the amplifier for alc takeoff. Another jack is located on the rear of the amplifier for a control line from the exciter which actuates the amplifier changeover relay. When this line is shorted, the relay closes. Fig. 7 shows the amplifier third- and fifth-order distortion product levels. Fig. 8 is a spectrum display of the amplifier spurious products. The harmonic levels are well within FCC limits. Additional TVI protection is offered by the double-shielding technique used in the SB-221: The rf deck has a perforated metal enclosure. The amplifier cabinet serves as the second shield. Rf bypassing is employed at the power-supply primary, the alc jack and the relay-control jack.

What About 10-Meter Operation?

This reviewer couldn't make an ounce of sense out of having this fine amplifier on the operating desk without being able to use it on 10 meters. So, a check was made between the schematic diagrams of the earlier SB-220 and the SB-221. Most of the circuit remained the same. The new version contained a sealed filter in the excitation line to prevent 27- or 28-MHz operation. The band switch lacked the necessary contacts for 5-band use. There was no 10/15-meter plate coil and the 10/15-meter input coil was missing. There were other differences (slight), but none that couldn't be resolved easily.

The lineup of required components was obtained from Heath. Here is the list needed for conversion back to the SB-220 format: 63-561 rotary switch, 63-562 wafer switch, 20-99 22-pF mica (2), 20-120 220-pF mica, 20-113 470-pF mica (2), 20-103 150-pF mica, 20-124 115-pF mica (2), 40-966 40-meter input coil, 40-964 10/15 meter input coil (2), 40-968 10/15 meter plate coil, 595-1122 SB-220 manual. The cost of the foregoing parts at the time of this writing is $31.50. Heath has agreed to sell these parts to SB-221 owners if a photocopy of the purchaser's valid amateur license accompanies the order. The filter in the SB-221 must be removed by drilling out the rivets which hold it to the main chassis. There is no 10-meter marking on the front-panel band switch. A white press-on decal can be added if that band position needs to be identified.

Converting an already-built SB-221 to the SB-220 format will require a certain amount of "unbuilding" first. Fortunately, the reviewer started from scratch with the amplifier kit and wired it as an SB-220. Everything went smoothly by working from the SB-220 manual. Now, the 10-meter band is situated in the "nothing" position on the panel, respective to band-switch indexing. Assembly time for an experienced amateur builder should be on the order of 20 hours. Neophytes should plan to spend up to 35 hours for a project of this nature. — *Doug DeMaw, W1FB*

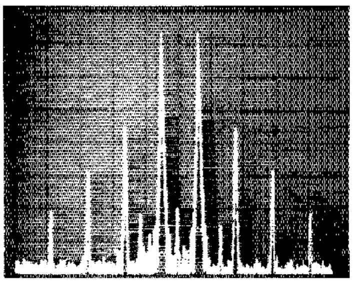


Fig. 7 — Spectral display of the SB-221 IMD characteristics at 3.5 MHz during a two-tone test. Vertical divisions are 10 dB; horizontal divisions are 1 kHz. Third-order distortion products are down approximately 35 dB from the PEP output. The individual tones are 6 dB down from the PEP output. All measurements were taken in the ARRL lab.

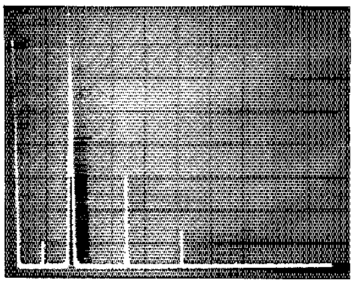


Fig. 8 — Spectral display of the SB-221 amplifier on 3.5 MHz. Vertical divisions are 10 dB; horizontal divisions are 2 MHz. The full-scale pip is the 3.5 MHz carrier with a low-level spur off to its left. The signal immediately to the right of the carrier is the second harmonic at approximately 50 dB below peak power. The third harmonic is 66 dB below peak power.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

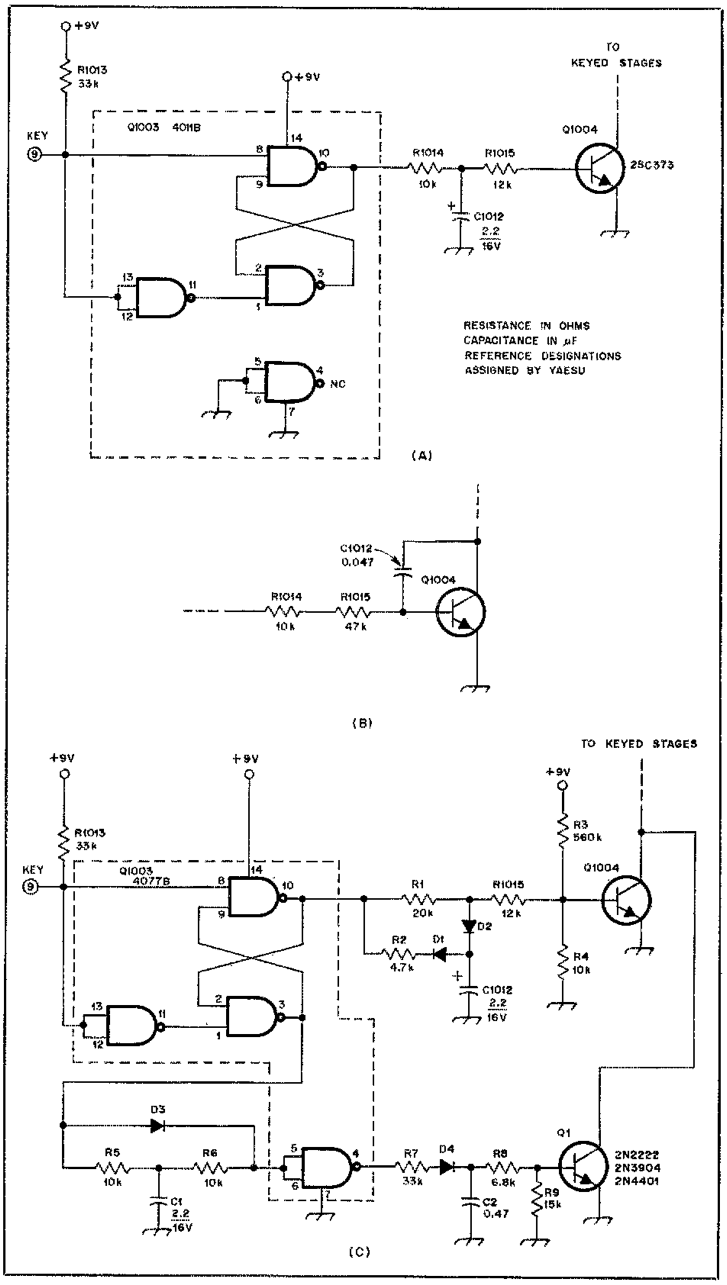
IMPROVED KEYING FOR THE FT-7B

Early production units of the Yaesu FT-7B transceiver exhibit less-than-ideal keying characteristics. At speeds over about 20 wpm, the dits run together. If you intend to do any serious cw work, listen to your signal critically on an external receiver. Don't depend on the sidetone to give you the true story, because it's keyed independently. The keying circuit is located on the predriver card (PB-1632). Drawing A shows the original circuit. The problem is that C1012 must discharge almost completely before Q1004 comes out of saturation. In the second-generation transceiver, Yaesu changed C1012 and R1015 to 0.33 µF and 47 kΩ, respectively. Recently, the circuit has been updated to the Miller integrator configuration illustrated in Drawing B.

If you're still not satisfied with the keying after trying these fixes, reach for an X-acto knife and rework the circuit as shown in Drawing C. C1012 now has independent charge and discharge paths. Because of the 0.6-volt conduction threshold of D2 and the Q1004 base bias supplied by R3 and R4, the time-constant network doesn't come into play until Q1004 begins to conduct. After the rf envelope has attained maximum amplitude, Q1 is switched on in parallel with Q1004. The turn-on delay for Q1 is governed by R5, R6 and C1. When the key is opened, Q1004 is turned off immediately, and the envelope decay is controlled by C2 discharging into the base of Q1. D3 defeats the Q1 delay network during the key-up interval.

The "Product Review" section contains an oscillograph of the keying waveform produced by this circuit. The rise and decay times are controlled independently by C1012 and C2. Some operators prefer a somewhat harder "make," but I suggest a minimum rise time of 3 ms to avoid key clicks. The resistance values were chosen in consideration of the transistor betas, conduction thresholds, and the current source and sink capabilities of the gates, as well as the RC time constants. In designing the circuit, a few decade boxes got as much work as my calculator!

To preserve your warranty, you may wish to start with a new predriver card. There are a lot of extra parts in this modification, but you can squeeze them in. If you build the circuit like a space truss, with short component leads, it will be rigid enough for mobile service. When working on the pc card, give due respect to the CMOS IC. — *George Woodward, W1RN*

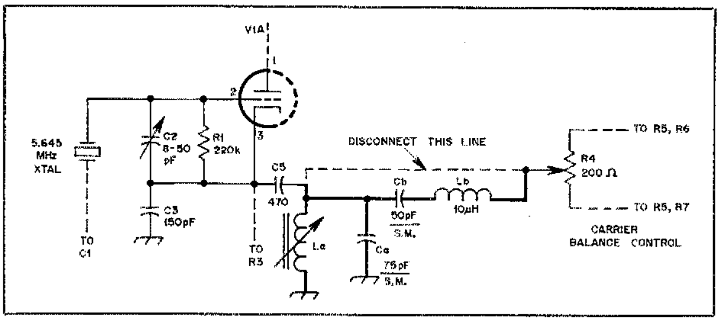


Original keying circuit for the FT-7B. Changing C1012 and R1015 to 0.33 µF and 47 kΩ will improve the high-speed performance (A). Current production models of the FT-7B have this shaping circuit (B). FT-7B modification for the perfectionist. The rf envelope can be shaped to taste by the DXer or QRQ enthusiast (C).

ANTI-TVI MODIFICATION FOR THE T-4XB

In the "Hints and Kinks" section of June 1979 *QST*, J. H. Mehaffey described a TVI problem with his TR-4 very similar to one that had plagued me for some time. I have a Drake T-4XB. His simple and successful modification of the TR-4 to clear up the harmonic output of the 9-MHz carrier oscillator clearly pointed the way for me.

*Assistant Technical Editor, *QST*



The W6HB anti-TVI modification for the Drake T-4XB. Heavy lines show added circuitry.
C_a — 75 pF silver mica, 5 %.
C_b — 50 pF silver mica, 5 %.
L_a — 24 turns, no. 24 enameled wire, close spaced on open end of Miller coil form no. 4400-2.
L_b — 10-μH Miller coil no. 4612.

Unlike the TR-4 with a 9-MHz oscillator, the T-4XB carrier oscillator is at 5.645 MHz, so different values of components are required to make the fix. In my case, those used were "junk box" values, ones at hand close enough to what seemed to be needed. The diagram is drawn in a manner to match that of the Drake manual.

There is sufficient chassis room for the few required parts under and around R4, the carrier-balance potentiometer of the T-4XB. L_a, the slug-tuned coil, is easily mounted in the extra hole of the left-rear chassis apron. With the adjustment screw on the outside, access to it is easy, although this is a seldom-needed tuning adjustment. L_b and the two capacitors are supported by a small double tiepoint and the respective leads. The short ground connections are made to the socket frame of V1.

I also took Mr. Mehaffey's suggestion regarding linearizing the final by disconnecting C53 and C58, the 470-pF cathode bypass capacitors of the 6JB6 output tubes. L_a can be peaked with a grid-dip meter. Touch-up tuning for maximum drive, as shown by increased final-amplifier plate current, should follow. To complete the adjustment, realignment of the carrier oscillator ought to be carried out using the procedure in the Drake manual.

Lacking the proper test equipment to measure harmonic attenuation, I cannot tell you how much those obnoxious harmonics were reduced. I'd guess reduction is comparable to the amounts shown in Mr. Mehaffey's report. I do know, however, that the TVI problem is cured. — *Hank Brown, W6HB, Los Osos, CA*

PREVENTING ICE BUILDUP ON ANTENNAS

Every year *QST* prints photos of otherwise solid antenna installations that have come crashing down because of ice buildup on the antenna. A quarter-inch of radial ice on a tribander can add 20 pounds or more to the weight of the antenna, as well as additional windloading. What's more, a quarter-inch of ice is nothing compared to what a real ice storm can dump on your antenna. An inch of ice would not be unusual — that is, if your antenna stays up long enough for an inch to collect.

There is a very simple yet remarkably effective way of preventing any ice build up: apply that no-stick, space-age material, Teflon, to the antenna elements. Water will bead up on the Teflon, and when the droplet is heavy enough it simply slides around to the bottom of the element and falls off. If any ice does form, it too will quickly slide off. Because Teflon has excellent rf properties, it will not affect the normal operation of the antenna.

The simplest way to apply Teflon to a ham beam antenna is to wrap the elements and boom with self-adhesive Teflon tape. I used Connecticut Hard Rubber Company[1] Temp R Tape, type T, which comes in rolls 1 inch (25 mm) wide by 18 yards (15.5 m) long, obtainable at a local industrial distributor. The antenna is spiral-wrapped, mummy style. The Teflon tape has a lot of stretch, which makes for a very tight and long-lasting installation. An fm broadcast antenna so treated has been in use through four severe winters and several ice storms without noticeable icing.

For quads, wrap the spreaders with the tape. This will have the additional benefit of prolonging the life of the spreaders, especially if they are the bamboo variety. Unfortunately, ice can and will build up on the wire quad elements. To combat this, I suggest trying Teflon insulated hookup wire for the quad elements. I haven't tried this yet, but expect to on my next quad. Of course, the same idea would apply to any wire type antenna.

One last comment. Teflon is expensive. Yet it is still a lot cheaper than a new antenna to replace that twisted mass of metal gracing your back yard. — *Jacob Z. Schanker, W2TSM, Rochester, NY*

[1]Connecticut Hard Rubber Co., 407 East St., New Haven, CT 06509.

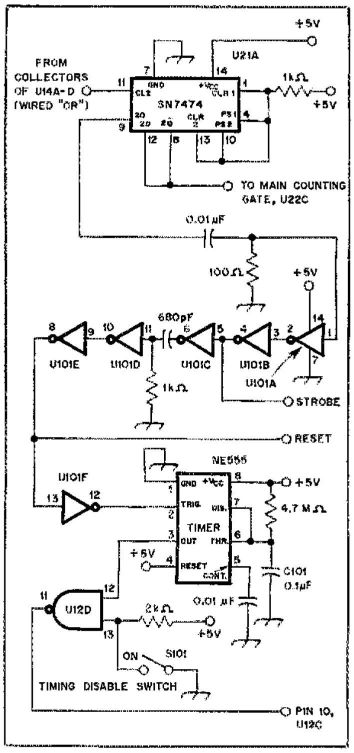
COMPETITION-GRADE RECEIVER MODIFICATIONS

I would like to pass along two modifications of Wes Hayward's "Competition-Grade CW Receiver" described in April 1974 *QST* and the ARRL publication *Solid State Design*. Both modifications replace discrete components with MSI circuits, reduce the number of parts used and, in my experience, result in more reliable operation.

The first revision is to the differentiation network which generates strobe and reset pulses from the time base. I replaced the two 2N3904 transistors and their associated biasing networks with an SN7404 hex inverter and two one-pole RC networks. The input of this new circuit is taken from the Q output of U21A, the SN7474 flip-flop. I used a 10-MHz time-base crystal. Only one flip-flop is required to derive a 1-ms to 0.1-s positive pulse from the $\overline{Q}$ output of the SN7474 to open the main counting gate, U22C. The complementary Q output provides a positive going signal as the main counting gate is closed. Two inverters (U101A and U101B) function as a differentiator and a level shifter to provide a short duration, sharp, positive strobe pulse immediately after the main counting gate is closed (pin 13 of U22C becomes low).

Three additional inverters (U101C, U101D and U101E) provide a positive reset pulse by differentiating the negative going edge of the strobe pulse. Hayward adds a cautionary word that the TTL ICs are "Out-of-spec" when the inputs are taken negative, but should work without problem. I found this circuit results in a cleaner pulse signal than the original circuit.

Furthermore, I used the popular NE555 timer as the one-shot in place of the relaxation oscillator circuit. Upon a negative trigger pulse, derived from the reset pulse by inverter U101F, the NE555 flip-flop is set. The NE555 output is high, which is inverted through U12D and closes the clock oscillator gate, U12C. The NE555 timing capacitor, C101, charges until the impressed voltage reaches 2/3 Vcc. Then the NE555 output is driven low, driving the output of U12D high and allowing the clock-



WB6NCJ provides this modification for Wes Hayward's "Competition Grade CW Receiver." Reduction of the number of parts for the set and improved performance is reported. Part numbers greater than 100 represent new parts not included in Hayward's original design.

oscillator signal to be applied to the main dividing chain. Consequently, the main dividing chain is only operative intermittently and reduces the amount of digital noise generated. When closed, S101 will disable the timing circuit and permit continuous operation of the counter, a useful feature for trouble-shooting the circuitry.

The original impetus for the new design was the low price and easy availability of the NE555, along with my desire to experiment with this device. The parts count was reduced from the original circuit. Nevertheless, I find that the modification works well. No doubt the MSI circuits of the original project may soon be supplanted by LSI chips. Until then, however, the price, availability and reliability of TTL chips will undoubtedly make them attractive to amateur builders. — *Douglas Blayney, M.D., WB6NCJ, San Diego, CA*

OVERVOLTAGE PROTECTION FOR FIELD-DAY EQUIPMENT

Part of my assignment for the last Field Day was to provide a means of protecting the station rig from generator overvoltage. I became more concerned when we decided to use my TS-820S as the station rig. My overvoltage-protection circuit, made for this purpose, helped me breathe easier. It should help you, too, if you find your rig "on the line."

The core of the circuit is an LM111 voltage comparator. The line voltage is divided, rectified and filtered. This input to the comparator is compared to a Zener reference diode. Normally the reference voltage is higher than the divided line voltage and a high level is present on the comparator output. Should the line voltage rise, the comparator will switch to a low output state.

The latching relay, K1, proved to be too slow to kick out. Therefore, a CMOS latch was added. This latch is initially in an unknown state. The reset switch sets it to a known state and if the line voltage is below the switching level of the comparator, it will turn on Q1 and illuminate the LED. This indicates that it is all right to turn on the output relay, K2.

The enable switch, S2, applies power to relay K1, and if Q1 is turned on the relay will close. Doing so applies power to the relay, K2. Lamps DS1 and DS2 indicate an open-circuit condition or on-line, respectively.

An overvoltage condition results in the CMOS latch being set, turning Q1 off. This opens K1, which in turn opens K2. The response of the circuit is tailored so that small spikes which can be filtered easily by the transceiver power supply do not trip the circuit, but an overvoltage condition existing for a few cycles will trigger it.

The circuit can be calibrated to trip out at 130-V ac by using a Variac. With the input voltage at 120 V ac, adjust R4 so that the reset button will reset the CMOS latch. Then further adjust R4 so that 130 V ac on the input causes the circuit to trip.

Once calibrated, circuit operation is simple. First depress the reset button, S1. If the voltage is safe, the LED will come on. (The open-circuit lamp, DS1, will be on when the unit is plugged in.) Next, depress the enable button, S2. This will close the line relay, K2. The on-line lamp, DS2, will come on and the open-circuit lamp, DS1, will go out.

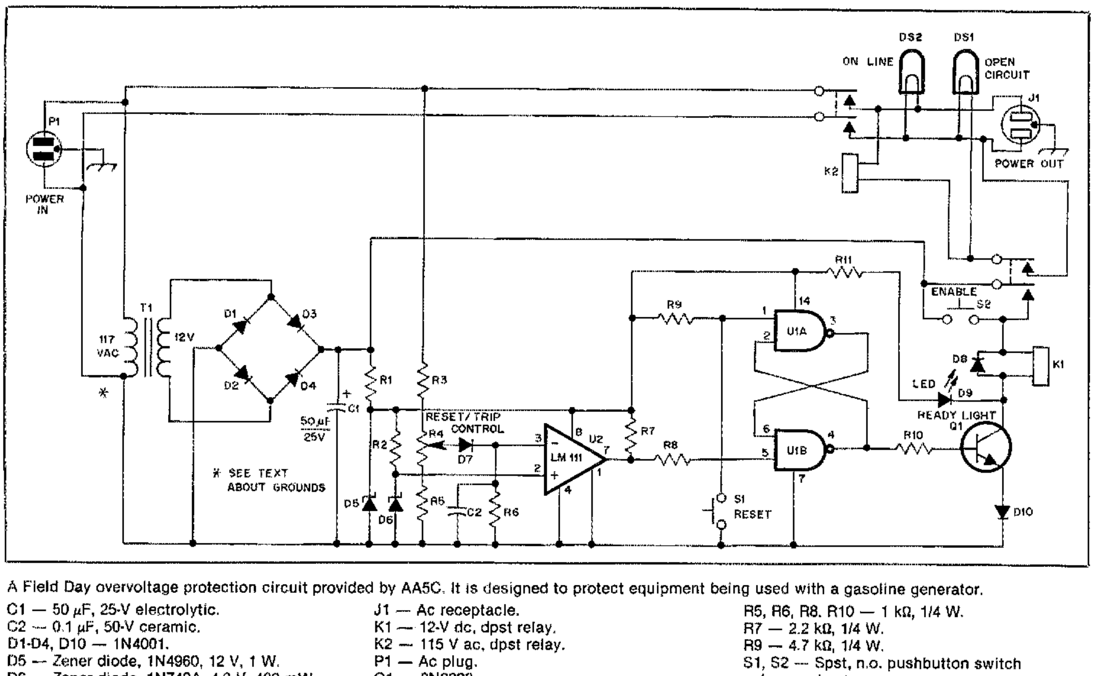
A word of caution: Be sure to completely isolate the circuit from the chassis on which it is installed. The line neutral is not isolated from the circuit ground. My thanks to Otis Hanby, W5TKK, for his advice and comments on the circuit design. — *Greg McIntire, AA5C, Lewisville, TX*

INSULATOR CLEANING SOLVES MLA-2500 FUSE-BLOWING PROBLEM

My Dentron MLA-2500 amplifier (no. 29) was shipped to my new home here in Montserrat this past spring. After it arrived, I unpacked it, then gave it a trial run that proved that the amplifier was in good working order.

Other MLA-2500 owners may be interested in one minor problem that did concern my unit. After operating for years in a dusty basement, the amplifier began blowing the fuse resistors in the final amplifier. I tried to find a short, but the problem lasted only a fraction of a second, with the amplifier immediately returning to normal operation (as it did most of the time) or giving way to blown fuse resistors.

In desperation, I completely cleaned every component in the final box. Finally, I spotted the Teflon insulator between the rf choke and the chassis. It had a thin film of dust on it which would break down, causing a short circuit to the chassis. Cleaning the insulator completely eliminated the difficulty. To avoid a similar breakdown, it looks like a regular cleaning of the final area is in order for heavy uses of the amplifier. — *Chod Harris, VP2ML, Spanish Points, Montserrat*



A Field Day overvoltage protection circuit provided by AA5C. It is designed to protect equipment being used with a gasoline generator.

C1 — 50 µF, 25-V electrolytic.
C2 — 0.1 µF, 50-V ceramic.
D1-D4, D10 — 1N4001.
D5 — Zener diode, 1N4960, 12 V, 1 W.
D6 — Zener diode, 1N749A, 4.3 V, 400 mW.
D7 — 1N914.
D8 — 1N645 or 1N4001.
D9 — LED.
DS1, DS2 — 117-V pilot lamps.
J1 — Ac receptacle.
K1 — 12-V dc, dpst relay.
K2 — 115 V ac, dpst relay.
P1 — Ac plug.
Q1 — 2N2222.
R1 — 270 Ω, 1/2 W.
R2, R11 — 470 Ω, 1/2 W.
R3 — 30 kΩ, 1/2 W.
R4 — 5-kΩ Trimpot.
R5, R6, R8, R10 — 1 kΩ, 1/4 W.
R7 — 2.2 kΩ, 1/4 W.
R9 — 4.7 kΩ, 1/4 W.
S1, S2 — Spst, n.o. pushbutton switch (momentary).
T1 — Power transformer, 117 V ac pri., 12 V ac, 300 mA sec.
U1 — CMOS quad 2-input NAND gate.
U2 — Differential comparator LM-111.

Technical Correspondence

Conducted By
Doug DeMaw,* W1FB

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VHF RECEIVER DYNAMIC RANGE

☐ For some time now I have been following the joint efforts of W1FB and W7ZOI on strong-signal performance of receivers through the pages of *QST*, and would like to comment on the Technical Correspondence by W7ZOI in the November 1979 issue. My interest in strong-signal performance of receivers is mainly related to vhf, where (I submit) the requirements for high dynamic range are even greater than at hf, for the following reasons.

1) With the advent of widespread high-power operation on vhf (at least at the low ends of the bands), with high-gain antennas, strong local signals can be very big indeed; and of course you want to work the DX most badly when the band is open and all the locals are on!

2) There is much less scope on vhf than on hf for trading-off NF (noise figure) against dynamic range, for the low background noise levels allow one to work routinely with signals of tens of *nano*volts. For example, in DX work on 144 MHz, experience suggests that 3 dB is the acceptable upper limit of NF (i.e., MDS = −147 dBm in 500 Hz). Most commercial transceivers are significantly "deafer" than the 3-dB limit, so we see many users fitting preamplifiers which, while achieving an acceptable system NF, further degrade an already mediocre dynamic range.

3) Because background noise levels are so low, great demands are placed on in-band spectral purity of amateur vhf transmissions. These demands *can* be met with the aid of constructive and friendly criticism of one's signal by other band users; but only if their receivers have a high enough dynamic range to render their comments valid and useful.

As a contribution to solving some of the problems of strong-signal handling on vhf, I have been developing a ring-mixer front-end board for the FT221 transceiver. I wrote up the design recently for a European vhf magazine.

When measured with ham-shack equipment, using the "Hayward methods" as far as possible, the front end gives very good performance. You probably won't be surprised to learn that reciprocal mixing proves to be the limiting factor on strong-signal handling (the FT221 has a very noisy PLL), or that I had a lot of trouble in measuring the blocking performance. I tried to do so at a frequency corresponding to a dip in the LO noise spectrum, but subsequent laboratory measurements by G4DGU suggest that the dynamic range with respect to blocking is probably about 120 dB. However, he did confirm all the other "ham-shack" measurements, which was comforting.

Experiments continue (of course!), particularly with respect to reducing the noise sidebands of the LO and increasing the dynamic range of the post-mixer i-f stage. G4DGU's small electronics company has also production-engineered the FT221 board for those who would rather buy than build from a circuit.

Having introduced myself and explained my interest in your own work, may I now comment on the W7ZOI Technical Correspondence and the W1FB reply which followed it? I fully agree with your criticisms of the IMD-intercept concept. Its usefulness and technical validity are limited by the preconceptions that IM is of practical importance (which is not usually the case unless the front-end is very susceptible to strong signals), and that two-tone IM behavior follows a strictly third-order law (promises, promises!). But the most important criticism of the use of IMD-intercept in evaluating amateur receivers is the abstract nature of the concept: It is not directly related to *any* observable aspect of performance on the air, so it has little chance of being readily accepted or understood by amateurs.

W1FB implies that the greatest problem in expressing dynamic range(s) by the Hayward method in *QST* reviews is that a comparison of two receivers which overload at the same strong-signal level will spuriously favor the unit with the narrower i-f bandwidth, since its MDS will be lower and its dynamic range thus appears the greater. But in practice this error will rarely exceed 6-7 dB. Is this significant in comparison with the wide variations in dynamic range encountered among different commercial receivers? I hardly think the discrepancy will influence the consumer habits of the readers of *QST* reviews, or place the League in an embarrassing position with respect to equipment manufacturers. At least, it won't if you explain (again) the basis of the tests.

The greatest strength of the Hayward method of receiver evaluation is that it measures the effects of practical importance on the air, under realistic conditions. For this reason it should not be abandoned lightly in favor of a more abstract concept which offers only a spurious promise of greater technical rigor. Although you're evidently experiencing some difficulty in conveying the meaning of your present test methods to all your readers, *please* keep faith with your original ideas. They are sound and useful.

Finally, may I again thank you both for sharing the results of your continued work with the rest of the world through the pages of *QST*. — *Ian White, G3SEK, 83 Portway, Didcot, Oxfordshire OX11-OBA, England*

CORRECTIONS FOR A SIMPLE RF SNIFFER FROM OCTOBER 1979 *QST*

☐ In order to function as intended as a voltage doubler, the circuit in Fig. 1 requires an additional capacitor, C_0 = 0.01 μF, as shown. Perhaps you'd like to make this correction in an upcoming issue of *QST*.

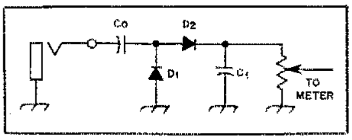


Fig. 1 — Diode detector shown correctly as a voltage doubler. C_0 is required for doubler action. It was omitted from the original *QST* presentation through error.

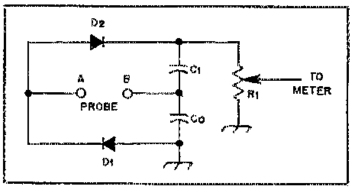


Fig. 2 — Suggested circuit presentation for more obvious voltage-doubler function.

I personally think many beginning hams would have difficulty understanding how this circuit "works." A more obvious voltage doubler with the same components is, in my opinion, that of Fig. 2. C1 charges through D2 when V_{AB} positive and C_0 charges through D1 when V_{AB} negative. — *Dr. Gethro Meek, DJØTT, Brahmsallee 33, XI, 2000 Hamburg 13, Germany.*

QUAD CORRECTION

☐ I recently received a letter from WD4GRI, who built the October 1979 "Hints and Kinks" quad. He found he could not get the SWR down below 2.0. He rightly points out that the feed impedance of a quad with 0.2-wavelength reflector spacing should be 110 ohms, which would explain his results.

In rechecking my SWR measurements I found that the 1.3 SWR figure was evidently caused by a faulty SWR above 2.0. My apologies for this goof.

The quad can be matched easily to 50 ohms if the choke balun is replaced with a quarter-wave matching section of RG-187/U (75 ohms) rather than RG-175/U (50 ohms). The length works out to be 13.36 inches (339 mm). My SWR is now below 1.5 across the entire 2-meter band. RG-187/U is flexible enough to be formed into a 2-1/2 turn coil, as specified. This small-diameter coax may be hard to find, although it is listed in the Allied Electronics catalog. If RG-59/U is substituted the choke-balun/matching-section will have to be only 1-1/2 turns, as RG-59 is too stiff to make 2-1/2 turns. The word "jacket" in the drawing should read "bracket." This was a drafting error. — *Fred Brown, W6HPH, 1169 Los Coderos, Lake San Marcos, CA 92069*

THE MONTGOMERY WARD DISH FOR WEFAX

☐ Recently I needed a 4-foot dish for 1691-MHz WEFAX (Western Electric Facsimile) reception — a rather scarce item in most parts. N5US saw a 44-inch (1.1-m) uhf TV dish in the Montgomery Ward catalog and wondered if it might solve the problem. In desperation one was ordered, and lo, on delivery, a full 4-foot job it was, and sturdily

*Senior Technical Editor, ARRL.

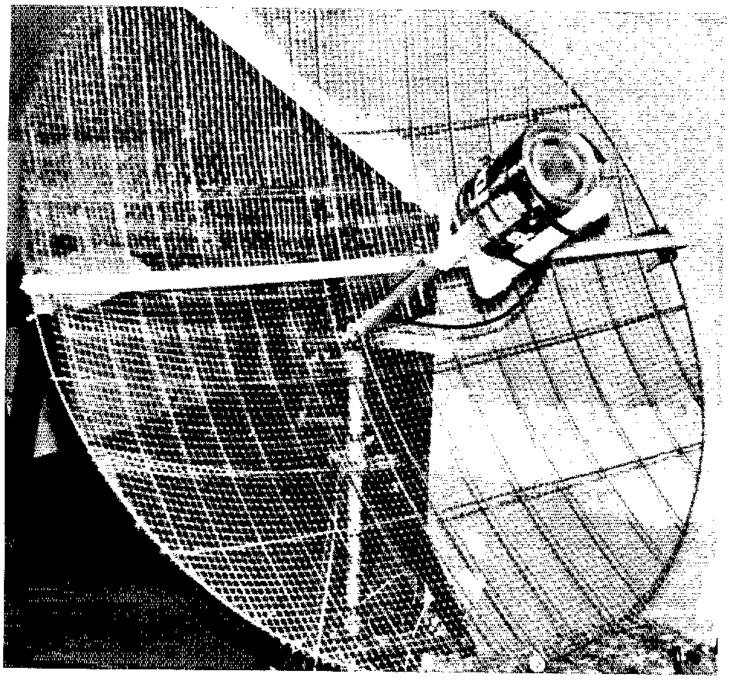


Fig. 3 — Photograph of the Montgomery Ward uhf TV antenna after the W7AVE modification for use as a 1691-MHz WEFAX receiving antenna.

constructed of welding rod, too!

It was found that the original construction with two horizontal halves worked out better for satellite purposes if the whole construction was rotated 90°. In this manner the original mast became a horizontal bar which was used only for lateral stabilization of the dish and for support of the feed-can supporting rod. The original folded dipole/splasher and supporting unit were replaced with a new contraption to enable use of a more efficient feed-horn system, as shown in Fig. 4. This item was compounded from a 15-inch (381-mm) length of 3/4-inch (19-mm) electrical conduit. It was silver-soldered into a 3/4-inch plumber's tee after having been flattened somewhat, 10 inches (254 mm) from the far end until it was the exact thickness of the discarded assembly unit. The original unit may be used as a model for the appropriate drilling and orientation. The now-horizontal "mast-substitute" I used was cut from a piece of one-inch (25 mm) wooden dowelling covered with heat-shrinkable tubing, originally sold as a shower-curtain rod.

A 3/4-inch, inside-threader pipe-to-PVC coupler makes the transition to the PVC can support. The threaded end is cemented onto the end of the conduit with Weldwood brand epoxy (advantage: it does not run). Two elbows and stray lengths of 3/4-inch PVC pipe complete the assembly. The feed-horn is held in place by means of two large hose clamps obtained from an auto parts supply house.

The feed horn is the WA7MOV design used extensively in the West. Briefly, it is a 2-lb coffee can with the 44-mm probe located 3 inches (76 mm) from the closed end of the can and with the focal point of the dish at about an inch inside the mouth of the can.

The dish must be recovered with a screen. The writer used the more-expensive 1/2-inch (13-mm) mesh hardware cloth; a 4-foot (1.2-m) square is sufficient. It is cut in strips and fastened firmly between the horizontal rods of the dish. Some piecing is necessary. These strips are fastened firmly in place with short loops of no. 18 iron which are twisted firmly in place with pliers.

Some who have duplicated this dish have used window screen in place of the hardware cloth. It is less expensive and easier to put on, but has more wind resistance. But the heavier hardware cloth, if firmly applied, helps to strengthen the dish assembly. A final spray job with polyurethane varnish (to further firm up the joints and prevent tarnish) is envisioned before it is moved outside.

The dish is supported by a 3/4-inch elbow, and is threaded into the side of the aforementioned tee. Its movement provides for the elevation of the dish. The new supporting mast is 3/4-inch water pipe, supported in a Radio Shack 3-foot (0.9-m) tripod. Maintenance of elevation is still "Mickey Moused" in place by an appropriately located box and a pile of books!

Vital statistics of the original dish are: diameter — 48 inches (1.2 m); depth — 8 inches (203 mm); focus — 18 inches (457 mm) and f/d ratio — 0.375. Montgomery Ward lists the unit as no. 63A19293R and calls it a "44-inch Parabolic-Screen UHF Antenna." The price is in the $25 range.

The dish serves well in my set-up inside the absorptive layers of the house. Duplicators report performance that is similar to that of commercial dishes. The conversion has the advantage that nothing is modified from the original antenna and it can be easily replaced in uhf TV service, should one so desire. — *Lindsay R. Winkler, W7AVE, Rte. 1, Box 209, Walla Walla, WA 99362*

Feedback

☐ In "Adding Receiver Incremental Tuning to the HW-104 or SB-104 Transceiver" (January *QST*, page 18, Fig. 2), the identification of the base and collector leads of Q2 are reversed.

☐ In "Bug Box QSK," February *QST*, page 31, the polarity of C12 is wrong. The positive terminal of C12 should connect to the junction of R5 and R6.

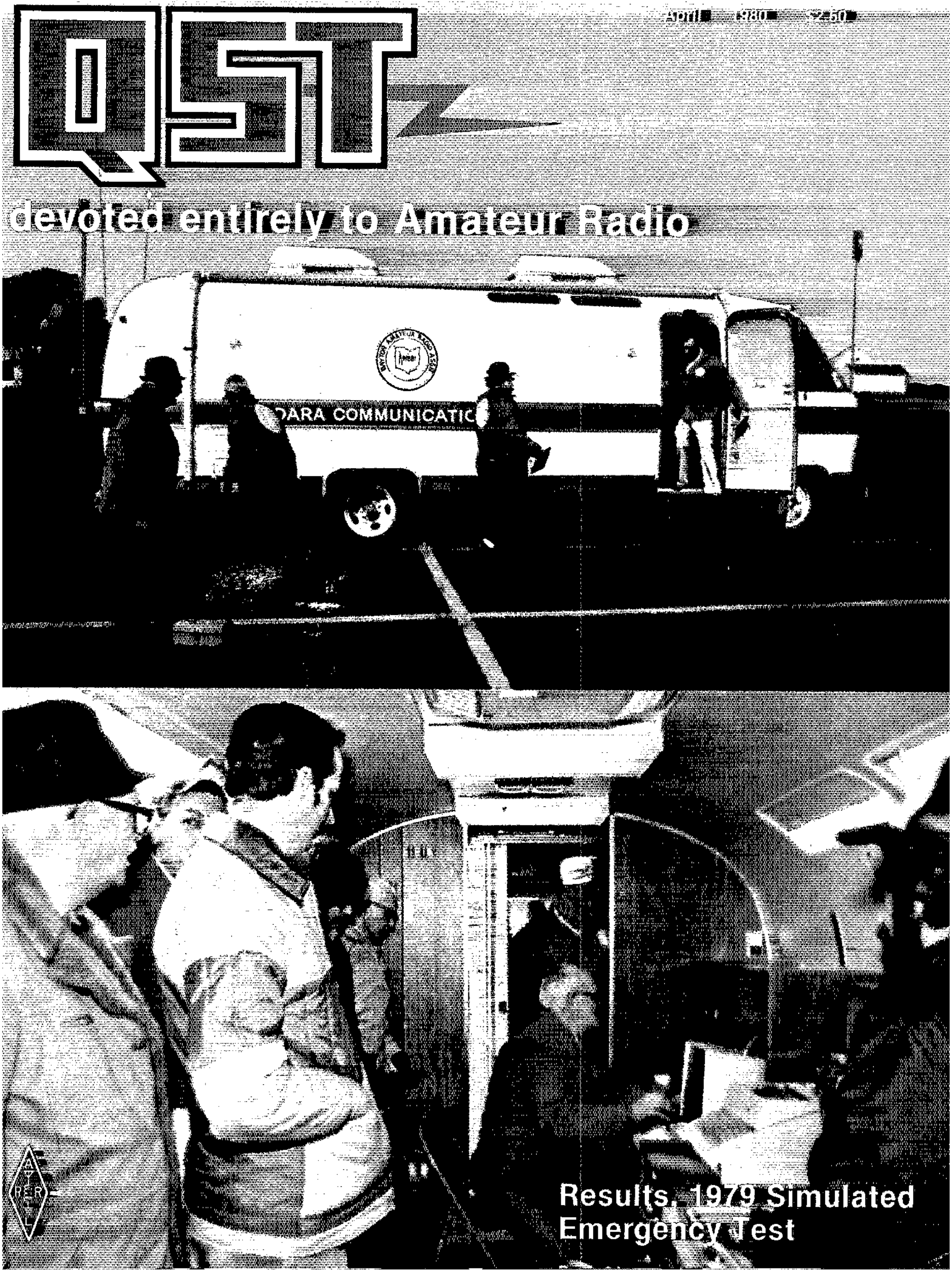
☐ An error occurred in "Improving the SB-104A/SB-644A" (August 1979 *QST*). On page 31, at the bottom of the middle column, step 2 should read: "Disconnect the jumper wired from lug 3 of the TUNE switch to lug 2 of the CW switch."

☐ Two errors appeared in the December 1979 *QST* article, "Simple, Band-Switching Receiver Design" (page 20, Fig. 5). Author Baber points out the omission of a connection dot between the +12-V input line and the vertical line immediately to the left that connects to Q5, Q6 and the 16-kΩ resistor at the base of Q12. Also, at S1A there should be no connection at the 80-meter position of the switch. C5 and the associated padding capacitor are connected to the 40-meter switch position.

☐ There is an error in Table 1 of "The Geneva Story" (February *QST*, page 53). For the amateur-satellite service, 5650-5670 MHz is restricted to *uplink* only and 5830-5850 is restricted to *downlink* only.

☐ The photograph of the *DaVinci Trans America Balloon* ("Stray," January *QST*, page 29), was taken from a light plane piloted by John C. Shildeler II, WAØNEV.

☐ With apologies to all RTTY stations, please change suggested "YL Activity Day" cw frequencies to 14,058, 21,058 and 28,058 kHz.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THE COVER

The Dayton Amateur Radio Association's nifty communications van was active during the fall edition of the Simulated Emergency Test. See page 91.

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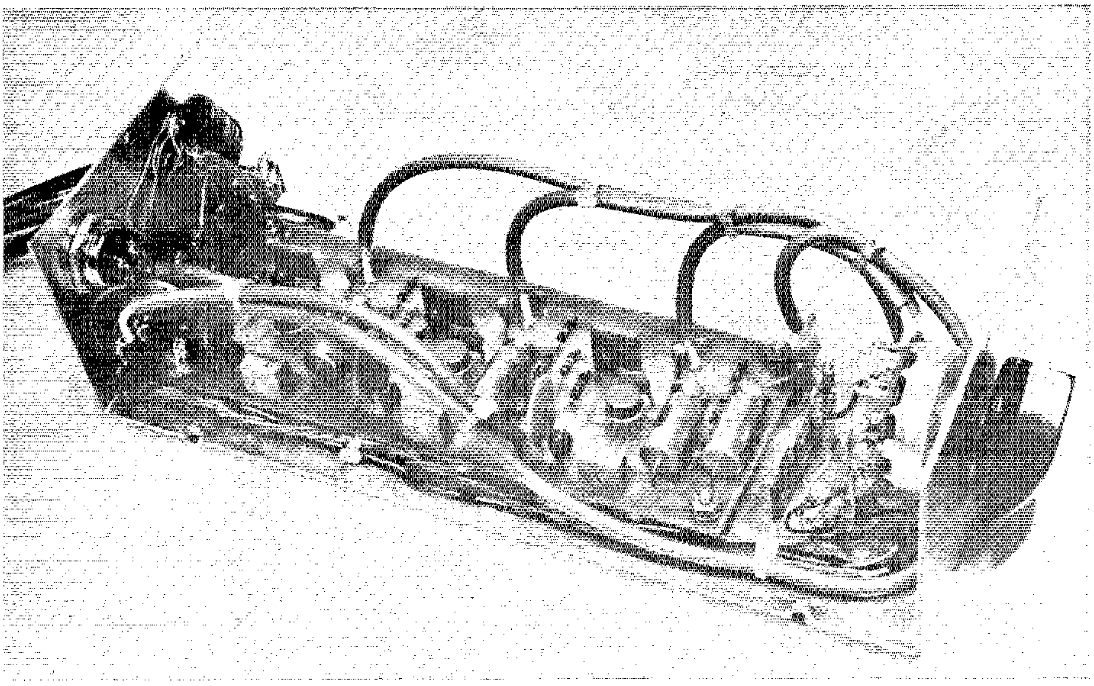
An Adjustable-Gain Microphone Amplifier

Here's a useful station accessory that's just right for a first project.

By Glen Thome,* N8AKS



Completed 3-channel microphone amplifier with cover removed. A 4-pin input connector is used in this model.

How often has this situation occurred? A desk-stand microphone sits unused because its output is too low to modulate a transmitter adequately. To further compound the problem, the rig transmits very well when using a hand-held microphone, and the same rig is used for both mobile and fixed service. Obviously, the internal microphone-gain potentiometer cannot be readjusted in this case since overmodulation or overdeviation would surely result when using the hand-held microphone, even though the rig may transmit well with the desk-stand unit.

The most practical solution to this dilemma is to amplify the output of the desk-stand microphone, but certain restrictions apply to this plan of attack: (1) The amplifier should be simple and compact; a solid-state design is immediately indicated; (2) the power should be obtainable from the rig or a small battery; power consumption should be minimal; (3) audio bandwidth should be fairly wide, with a flat response from 300 to 3000 Hz; (4) circuit gain should be adjustable over a wide range to adapt the amplifier to any combination of microphone and transmitter; and (5) the amplifier input should accept either high- or low-impedance microphones and

*917 Delaware Ave., Elyria, OH 44035

feature both high- and low-impedance outputs so either one could be used as required.

Theory of Operation

As shown in Fig. 1, the microphone amplifier consists of an adjustable-gain operational amplifier circuit. The signal from the microphone is applied to the non-inverting input of U1 through coupling capacitor C1. The circuit input impedance is determined by R1, or by the parallel combination of R3 and R4. Connecting R1 matches the input circuit to a low-impedance microphone; with R1 removed, R3 and R4 determine the input impedance, which, in this case, allows use of a high-impedance microphone. R3 and R4 also serve to bias the noninverting input of U1. Since U1 is operated from a single-ended power supply, the bias voltage is necessary to linearize the amplifier output and avoid clipping one side of the input waveform. To help ensure that power supply noise does not disturb the input, R2 and C3 are included as a ripple filter. C2 provides low-reactance bypassing of the power bus.

The gain is determined by the setting of R5, and is adjustable from approximately 0 to 40 dB. During testing of this circuit with a 1-kHz sine wave, no distortion was evident on the output waveform

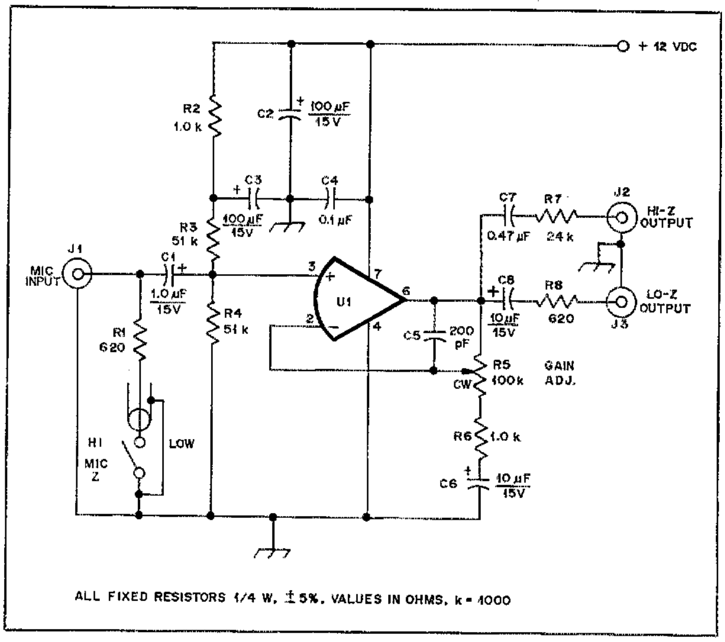


Fig. 1 — Schematic diagram of the microphone amplifier. C1, C6 and C8 are tantalum electrolytics; C2 and C3 are aluminum electrolytics. All other capacitors are tubular or disc ceramic. R5 is a pc-mount potentiometer (Helitrim 72XWR100K or equivalent). U1 is a 741 op amp IC or high-performance equivalent having an 8-pin package.

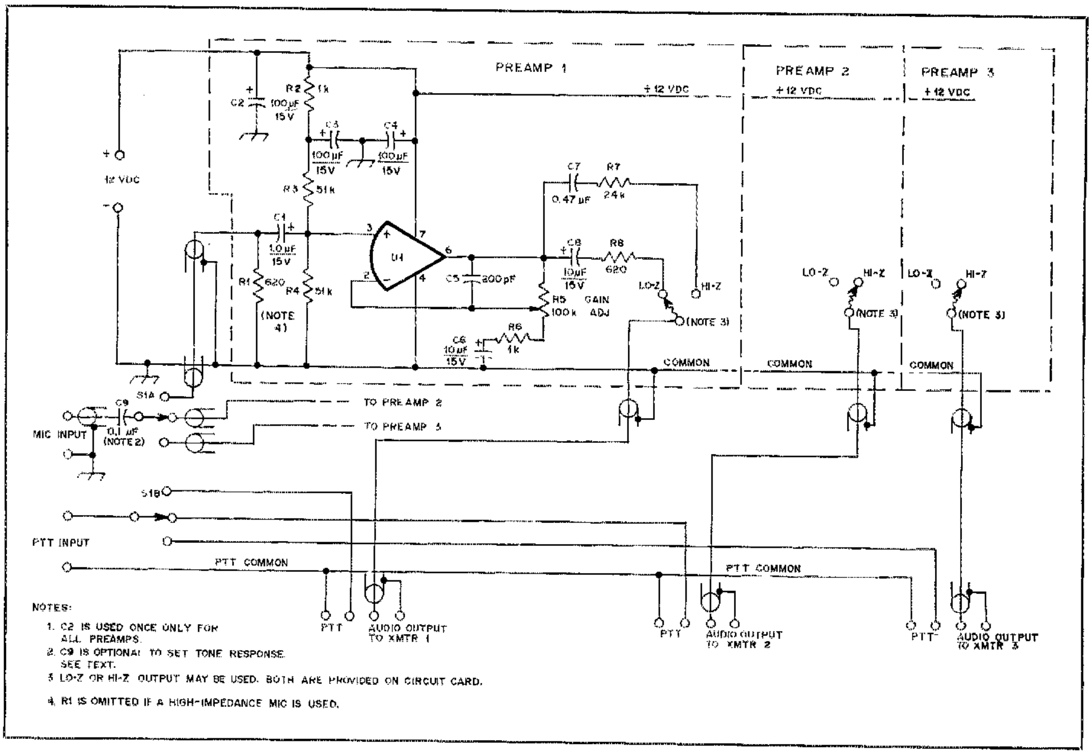


Fig. 2 — Schematic diagram of a multi-channel microphone amplifier featuring PTT switching.

throughout the gain adjustment range of the amplifier.

The output from the amplifier is available at either low or high impedance, selectable to match the characteristics of the audio input circuit of the transmitter to be used. Since the output impedance of an ideal operational amplifier is zero, the desired output impedance can be obtained by means of a series resistor. This amplifier offers output impedances of approximately 600 Ω and 24 kΩ.

A common 741 op amp is used at U1 in the author's unit and it performs adequately. The purist may elect to use one of the more modern low-noise, wide-bandwidth devices, such as the MC1741SCP, MC1456, CA3140, NE5534, or LF356.

Construction

The amplifier is constructed on a circuit card designed for chassis mounting. Any number of amplifiers can be built on one circuit card to match the needs of individual stations. The author constructed a three-channel amplifier and mounted all components in an aluminum Minibox. The schematic diagram for the three-channel amplifier, shown in Fig. 2, indicates the method used for switching the microphone to any one of the amplifiers. The push-to-talk (PTT) circuit is also switched so that only one transmitter can be keyed at a time. By using separate amplifiers, output levels can be set individually, the required output impedance can be selected to match the individual transmitters, and only one microphone is required for fixed-station operation.

Construction should require only a few evenings, and all components should be available from local electronics supply stores or mail-order firms. Layout drawings appear in Figs. 3 and 4 for those who desire to fabricate their own pc cards. The finished amplifier should be mounted inside a Minibox or other enclosure that affords complete shielding. Any suitable connectors that are fully shielded can be used for input and output terminations. Alternatively, the output cables can be hard wired to a terminal strip inside the enclosure, as shown in the photo of the three-channel unit. Whichever method is chosen, be sure that all input and output cables are fully shielded to avoid hum and rf pickup. Any good-quality microphone cable can be used; however, avoid "economy" cables since the percentage of shielding around the center conductor may be too low to shield effectively against hum. Sometimes it's better to ground the braid of an audio cable at only one end, to avoid ground loops. Start with the arrangement shown in the diagrams, but be prepared to experiment to find the configuration yielding the lowest noise level.

If a readily accessible gain adjustment is desired, a 100 kΩ potentiometer mounted on the enclosure may be used as a substitute for R5. Shielded leads soldered to the pads normally used to mount the trimmer should be used for the connections.

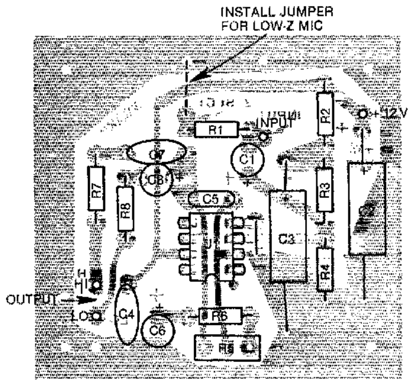
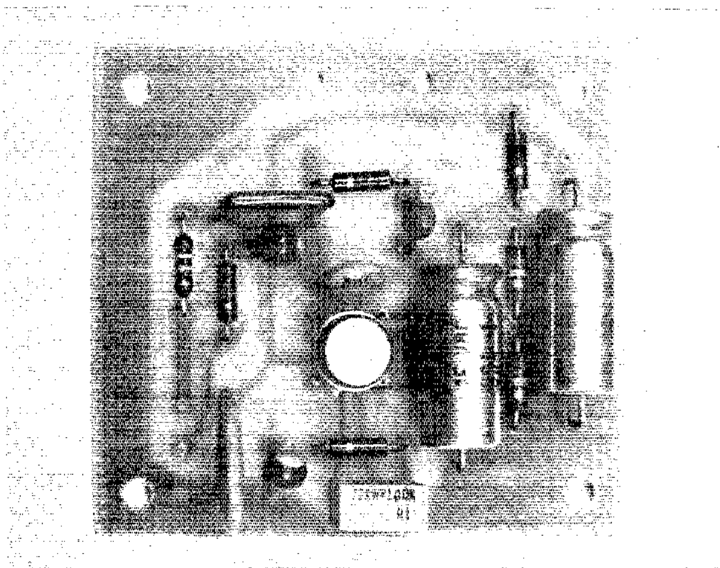


Fig. 3 — Parts-placement guide for the single-channel pc card. Parts are placed on the nonfoil side of the card; the shaded area represents an X-ray view of the copper pattern. (The etching pattern appears in the "Hints and Kinks" section of this issue.) Unmarked lines indicate wire jumpers.



Close-up view of the circuit board. Metal-can or Mini-DIP package op amps may be used without layout changes.

Adjustment

The gain of the microphone amplifier must be adjusted to avoid overmodulation or overdeviation in the transmitter. For a-m or ssb rigs, a monitor scope should be used to check the rf envelope. For fm rigs, a deviation meter is the most convenient way to check for proper audio level. In the absence of such test equipment, a few on-the-air checks can be made for optimum gain adjustment.

Since the frequency response of this amplifier effectively covers the voice range, some operators may desire to attenuate the low-frequency response. For communications purposes, speech is more intelligible if the high-frequency tones are accentuated. C9, shown in Fig. 2, is placed between the microphone and the amplifier. The value of 0.1 μF was chosen

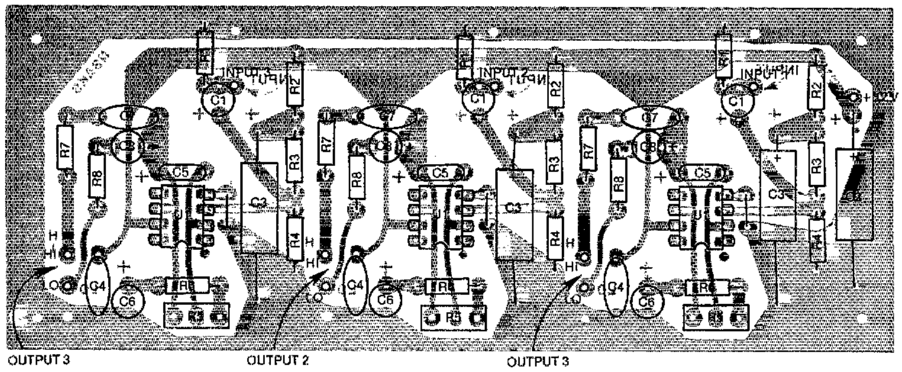
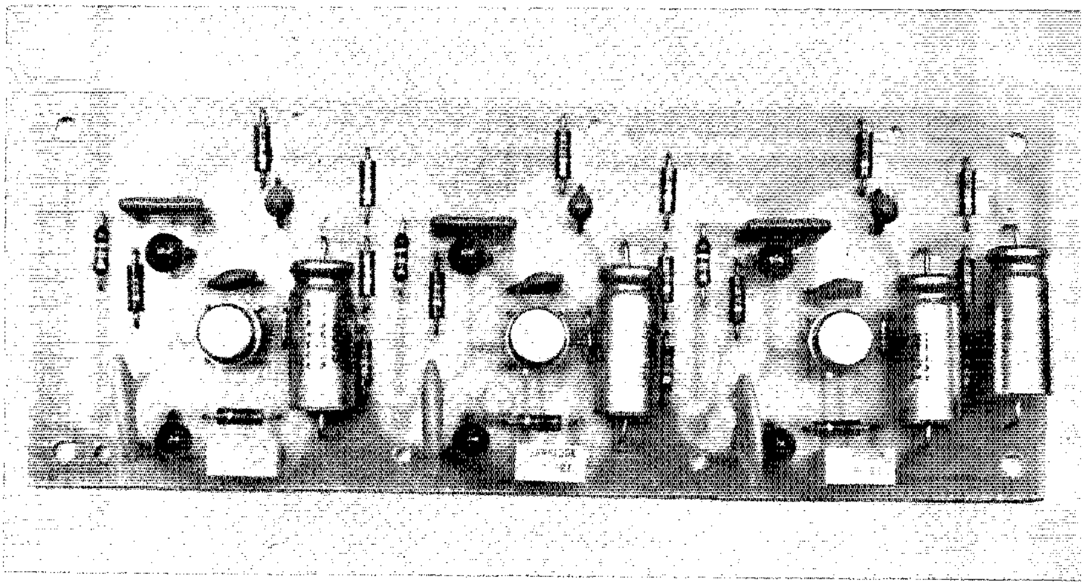


Fig. 4 — Parts placement guide for the three-channel pc card. R1 is omitted if the station microphone is a high-impedance unit.



Three amplifiers built on one pc board. This technique can be extended to any number of amplifiers.

experimentally, observing the amplifier output on an oscilloscope while sweeping a band of frequencies applied to the input through C9. This value of capacitance attenuates the low-frequency response to some extent. In conducting tests, various stations advised the author of favorable tone response using the amplifier and a desk-stand microphone as compared to an unamplified hand microphone. These tests were conducted on 2-meter fm. Differences in individual voices and characteristics of the microphones used may necessitate some experimenting to determine the optimum value of C9, but 0.1 to 0.47 μF should prove satisfactory in most cases.

Conclusion

The author incorporated the three-channel version of this amplifier and a 600-ohm dynamic microphone into his station to provide audio to 2-meter fm, 6-meter a-m, and hf-band ssb rigs. Initial reports indicate favorable performance despite the more pronounced bass response as compared to the tone qualities of the average voice transmission. Since the amplifier greatly increases the microphone sensitivity, the operator can speak at a conversational level for long periods without voice fatigue Because of the increased sensitivity, yo must be careful to keep the ambient nois level low. Besides being a useful station accessory and an easily constructed "first project," this amplifier can give the operator chance to dust off that long-unused des microphone or extend the usefulness of microphone already in service.

Acknowledgement

The author expresses special thanks t George Woodward, W1RN, for his desig suggestions.

• *Basic Amateur Radio*

A Beginner's Look at Op Amps

Part 1: Op Amps are part of many *QST* projects. Here's your chance to get acquainted with these handy devices. The math is easy. We start with a "black box" approach.

By George Woodward,* W1RN

"Op amp" is an abbreviation for "operational amplifier." We tend to think of op amps as integrated circuits (ICs), but the term can be applied to any high-gain amplifier circuit whose transfer characteristic is determined by external components. "Transfer characteristic" means the manner in which the output varies as a function of the input. The external components in an op-amp circuit create a closed loop, or feedback path between output and input. Special-purpose feedback amplifiers emerged shortly after the triode electron tube, but amplifiers designed to perform in a wide variety of feedback loops are a product of the computer age. Analog computers require many op amps to perform mathematical operations such as summation, absolute value generation, differentiation and integration. There's no need to be intimidated by these terms. When you finish this series, you'll be able to throw them around with some authority.

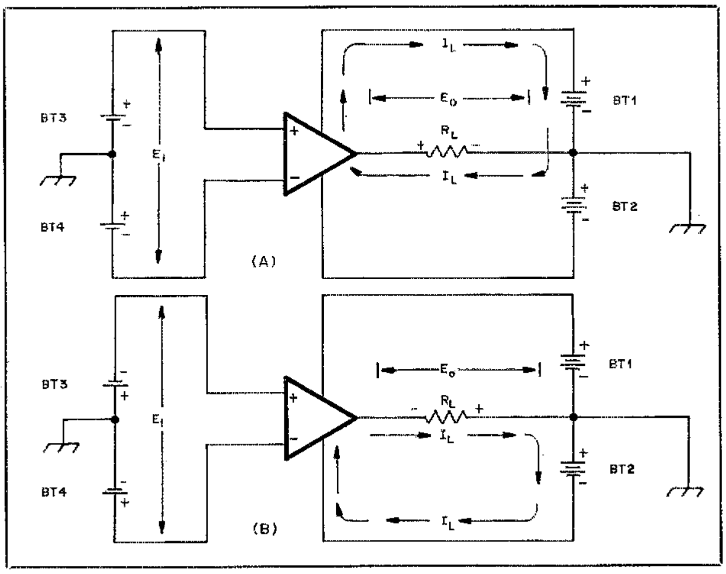


Fig. 1 — Input connections and output current flow in a differential amplifier. The arrows depict the direction of actual electron flow. In A, the input signal causes the amplifier to sink the load current. Reversing the input polarity, as in B, causes the amplifier to source the load current.

The Ideal Op-Amp

A perfect amplifier would have infinite input impedance, infinite gain, and zero output impedance. Infinite input impedance means the amplifier responds to the signal voltage without drawing any current from the source. A device having zero output impedance will supply a constant voltage regardless of the current taken by the load. Another characteristic of our ideal amplifier is absolute linearity, meaning the output is a perfectly proportioned magnification of the input. Obviously we can't have any linearity at all if the amplifier gain is infinite, but we shoot for infinity, hoping for "extremely high" gain. Of course we'd like our amplifier to exhibit infinite bandwidth, zero phase shift and zero noise. We can't realize these characteristics in practice, but the ideal amplifier is a useful model on which to base our study of op-amp theory. For the time being, we'll think of our ideal amplifier as a "black box," without concern for what goes on inside.

*Assistant Technical Editor, *QST*

Differential Inputs

Most electrical devices have two input terminals and two output terminals. Your VOM, for example, has two probes, and its meter movement has two lugs. One probe may be connected directly to the meter, but for electrical analysis they must be considered separately. When using your VOM, you often clip one probe to the chassis of the equipment you're testing and make all measurements with respect to "ground," but you're still making a two-terminal measurement. Many dedicated amplifier circuits are designed with a common input/output terminal, often connected to ground. We'll look at some of these circuits in this series, but the important thing to remember about op amps is that the input (and sometimes the output) terminals are uncommitted; we may connect them as we please.

An amplifier may have two input terminals referenced to a common point such that the input/output transfer functions have opposite signs. This would be called a *differential* amplifier. Sounds awful,

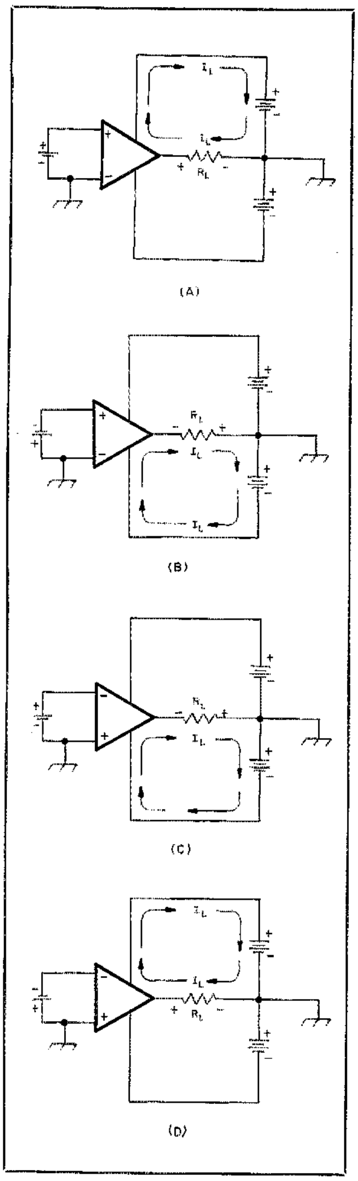


Fig. 2 — Differential amplifier circuits having one input terminal common to the output and power supply returns. When the "+" input terminal is above ground, as in A and B, the amplifier is noninverting, meaning the polarity of the output voltage (with respect to ground or common) is the same as the input. In C and D, the "−" terminal is above ground, and the amplifier inverts the polarity of the input signal.

doesn't it? Just look at Fig. 1 and it should become perfectly clear. Two dc power sources, BT1 and BT2, bias the amplifier and supply the load current. Notice the polarity of the power sources, and that they have a common reference point, which is one of the amplifier's output terminals. The input signal is generated by BT3 and BT4, having equal voltages, which are also referenced to the common output terminal. The terminal marked "−" is called the inverting input, and the one marked "+" is the noninverting input. In Fig. 1 a positive voltage (with respect to "ground") applied to the noninverting input causes the "high" side of the output to go positive and "sink" the load current. Similarly, a negative potential applied to the inverting input causes the output to be positive. Reversing the input batteries, as in Fig. 1B, will make the output go negative and "source" the load current. This time the "−" terminal inverts the positive input signal, and the "+" terminal amplifies the negative input signal with no polarity reversal. If only one of the batteries were reversed, the inputs would oppose rather than aid each other, and the output voltage would be zero. If the input voltages are unequal, the output is proportional to their differences; hence the name *differential* amplifier.

Single-Ended Inputs

For simplicity, we sometimes make one of the amplifier inputs common to the output circuit. I've illustrated this configuration in Fig. 2. The inverting input terminal is common in A and B. The amplifier is noninverting. In C and D an inverting amplifier, made by grounding the noninverting input terminal, is shown. Later we'll see how to get away with a single-ended power supply, too.

Closing the Loop

Remember that our device amplifies the potential difference between the inputs? We can introduce negative feedback around the circuit and use the differential effect to establish almost any desired transfer characteristic. To see how, let's take a simple but practical example. The amplifier in Fig. 3A has its inverting input grounded through R_B. There's no harm in inserting this resistance, because our ideal device doesn't draw any input current. So far we have the same noninverting amplifier we saw earlier (Fig. 2A and 2B). Adding R_A as in Fig. 3B alters the circuit's operation dramatically. For convenience, let's make its value equal to that of R_B. If we apply 1 volt (positive) to the noninverting terminal, the output voltage will rise in the positive direction. When the output potential reaches 2 volts, the potential at the inverting terminal will be 1 volt because R_A and R_B form a two-to-one divider. But now both inputs have the same potential and there's no difference to amplify, so the output stops increasing. If the output overshoots the 2-volt mark, the inverting input will exceed 1 volt. Now we have some input differential, and its polarity forces the amplifier's output voltage in the negative direction. Our circuit is a servo system, and as long as the amplifier doesn't develop too much phase shift, it will be stable.

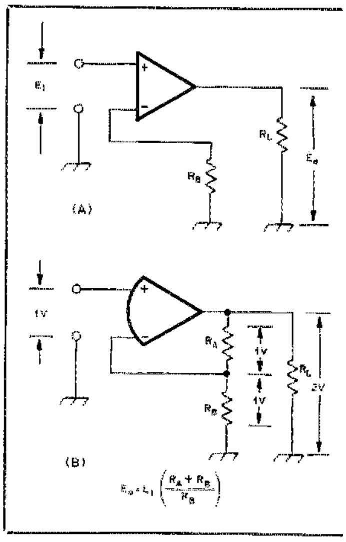


Fig. 3 — Our ideal amplifier has infinite input impedance; therefore we can insert a resistor in either input leg. In A, R_B is between the "−" terminal and ground. The circuit is very similar to those of Figs. 2A and 2B. In B, R_A creates a negative feedback path. Differential amplifiers intended for closed-loop applications are called op amps and are represented schematically by a convex edge on the input side. Given an ideal amplifier, the characteristics of the circuit in B are determined almost entirely by the feedback network.

Let's make R_A twice as large as R_B. If we apply the same 1-volt input signal, the inverting input voltage won't reach 1 volt until the output reaches 3 volts, because R_A and R_B form a three-to-one divider. By now, I'm sure you've deduced that the numerical voltage gain of this type of circuit is simply the ratio

$$\frac{R_A + R_B}{R_B} \quad \text{which reduces to } 1 + \frac{R_A}{R_B}.$$

What has become of the input and output impedances? If we make the load resistor smaller, we'd expect the output voltage to drop. If it does, the input-voltage differential will increase, causing the output voltage to return to its lightly loaded value. Defining dynamic impedance as $\Delta Z = \Delta E/\Delta I$, where Δ (delta) is a small change, we see that $\Delta Z = 0$, because $\Delta E = 0$. Actually, I'm only talking about the *resistive* component of impedance here. My use of "impedance" rather than "resistance" is not an attempt to confuse the reader, but rather a reflection of popular usage.

The input impedance of the device is high to begin with, but applying negative feedback makes it still higher. The tiny current taken by the input of an actual op amp is a function of the differential input

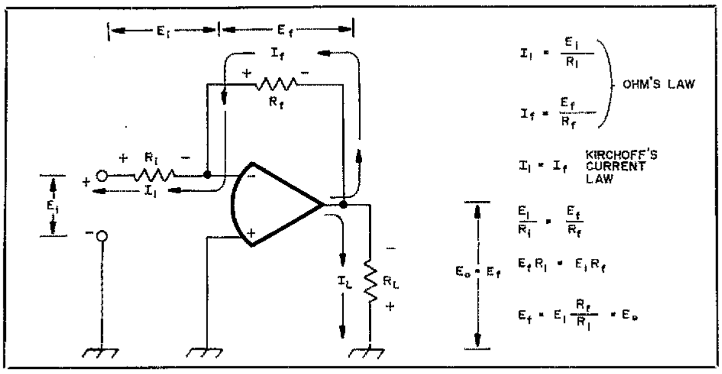


Fig. 4 — An inverting op-amp circuit showing the polarities and directions of the input, feedback and load voltages and currents. The equations are discussed in the text.

voltage. By minimizing the differential input voltage, the feedback minimizes the input current, making the dynamic input impedance approach infinity. We can establish any convenient input impedance by shunting a resistor from the noninverting input to ground. Glen Thome uses this technique in his variable-gain microphone preamplifier, described elsewhere in this issue.

The Voltage Follower

If we eliminate R_B in Fig. 3B, we will have 100% degenerative feedback. To maintain zero input voltage differential, the output must track the input exactly. Our voltage gain is unity. R_A can be a short circuit in most voltage follower applications. What's the point of building an amplifier with no voltage gain? A voltage follower is the ultimate impedance transformer. The feedback causes the input impedance to approach infinity, and the output impedance to approach zero. With this circuit we can sample the signal from a high-impedance source without loading it down, and apply it to a low-impedance load without any voltage step-down. The result is a tremendous power gain.

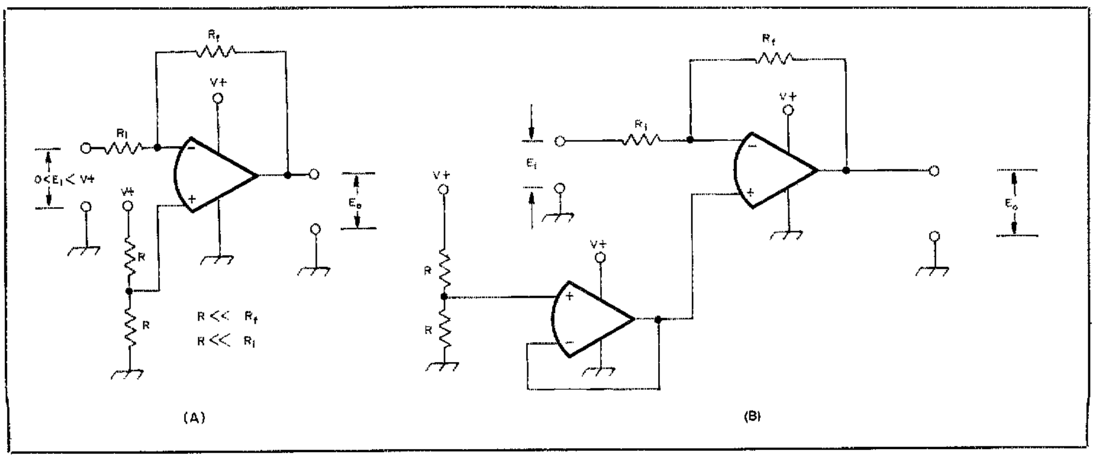
Inverting Amplifiers

How do we control the gain of an *inverting* amplifier? Fig. 4 shows a common circuit. For this configuration, the noninverting terminal is grounded and the signal is applied to the inverting terminal through an input resistor R_i. A feedback resistor, R_f, is connected from the output to the inverting input. The servo action of the feedback loop will tend to maintain a zero voltage differential between the input terminals. Since the noninverting terminal is tied to ground, which is our zero-voltage reference point, the inverting input will have zero potential also.

When the amplifier is connected this way, we call the inverting input a *voltage node, summing junction* or *virtual ground.* Because the voltage at this point is always zero, the junction looks like a ground to the rest of the circuit, hence the name "virtual ground." The circuit's input impedance, then, is simply R_i. We can't tie the junction to true ground because that would short circuit the amplifier's input terminals. Let's make R_f twice as large as R_i and inject a positive 1-volt input signal. Because the inverting input terminal is held at zero potential, our 1-volt input signal is developed across R_i. The current through R_i, denoted as I_i, equals E_i/R_i, which in our example is $1/R_i$. Our ideal amplifier doesn't draw any significant current, but the input current has to go *somewhere*. The only available path is through the feedback resistor. Kirchhoff's current law states that the sum of the current flowing into a junction must equal the sum of the current flowing out of the junction. (You need to know this law for your General class license exam.) The feedback current, then, I_f, equals E_f/R_f. Since we made R_f twice the value of R_i, $I_f = E_f/2R_i$. By Kirchhoff's current law, $I_f = I_i$. Therefore we can equate the expressions for I_f and I_i: $E_i/R_i = E_f/R_f = E_f/2R_i$. The means-extremes property of proportionality tells us that $2R_iE_i = E_fR_i$. Dividing both sides of this equation by R_i leaves $2E_i = E_f$. E_f is measured from the output to the inverting input, which is a virtual ground, so $E_f = E_o$. Our circuit has a voltage gain of two, which you suspected all along, right? The gain of an inverting op-amp circuit is simply R_f/R_i, and this equation is derived in Fig. 4. Just as in the noninverting case, the output impedance is zero.

Sometimes only one power supply is available. If we leave the noninverting input terminal grounded, a positive input signal will cause the output to attempt to swing negative. Without a negative supply, the amplifier isn't capable of negative

Fig. 5 — An op amp may be operated with a single power supply if the common input is returned to an artificial ground having half the supply voltage. In A, this ground is approximated by means of a resistive voltage divider, but a lower impedance can be obtained from the voltage follower configuration shown in B.



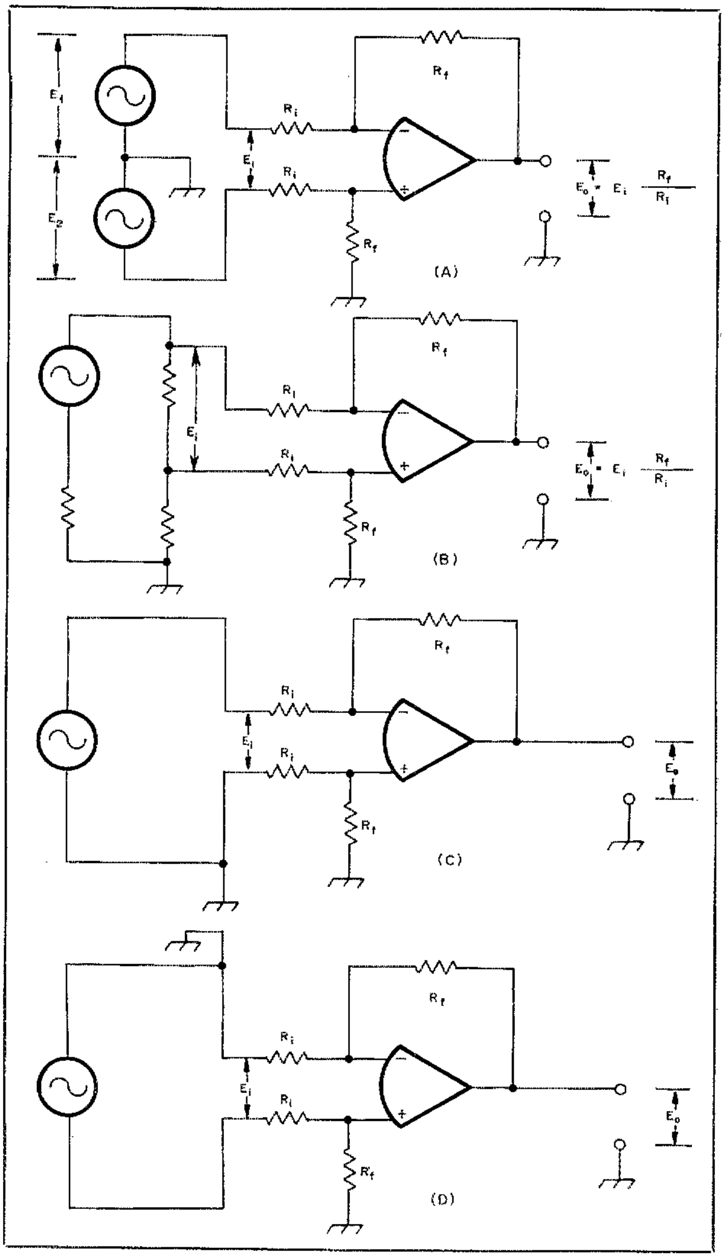


Fig. 6 — Differential op-amp circuits. In A, the input voltage E_i is represented by two components, E_1 and E_2, each referenced to ground. In B, the input voltage is sensed across a resistor with neither end directly grounded. C and D illustrate the two limiting cases used to derive the transfer and impedance equations for the general case presented in A.

output. The trick here is to attach the noninverting terminal to a "pseudo ground" having half the supply voltage. A simple resistive divider as in Fig. 5A will work, but the resistors must be small compared to the input and feedback resistors if the ground is to be "stiff" enough. A better solution is illustrated in Fig. 5B. Here the divider is isolated from the inverting amplifier by means of a voltage follower. With this circuit, the noninverting terminal sees a zero impedance at half the power supply voltage. The exact voltage isn't important so long as it's within the expected input signal range, but biasing the amplifier to half the supply voltage ensures the widest input dynamic range.

Closed-Loop Differential Amplifiers

Suppose we want to sense a voltage source with neither side grounded. The circuit in Fig. 6A will serve the purpose. Of course, the input source must return to ground *some* way, but it can take a roundabout path. The generator and resistor network depicted in Fig. 6B is a typical situation. The equation for the transfer function is $E_o = E_i R_f/R_i$, where the polarity of E_o is that of the noninverting side with respect to the inverting side. Without going through a rigorous proof, we can motivate this result by analyzing the two limiting cases. Fig. 6C shows one side of the input voltage source grounded. Since the input terminals of the device don't draw any current, the values of the resistors connected to the noninverting terminal are inconsequential, and the circuit degenerates to the single-ended inverting amplifier we've already studied. In this case, the voltage gain is R_f/R_i. Grounding the other side of the source, as in Fig. 6D, makes the circuit look something like our original noninverting configuration. The gain from the noninverting input to the output is

$$\frac{R_f + R_i}{R_i}$$

but we have a loss coefficient of

$$\frac{R_f}{R_f + R_i}$$

between the source and the inverting input. Our source-to-load gain is the product of these coefficients:

$$\left(\frac{R_f + R_i}{R_i}\right)\left(\frac{R_f}{R_f + R_i}\right)$$

The $(R_f + R_i)$ terms cancel and the expression reduces to R_f/R_i. Intuitively, we can conclude that placing the ground reference anywhere between these extremes will not alter the gain. In the differential op-amp circuit of Fig. 6A, the equivalent impedance to ground looking into the inverting side is

$$\frac{|E_1|R_i}{\left|E_1 + E_2\left(\frac{R_f}{R_i + R_f}\right)\right|}$$

You must account for the polarities of E_1 and E_2. For the noninverting side, the equivalent impedance to ground is simply $R_i + R_f$. In the degenerative cases illustrated in Fig. 6C and 6D, the input impedances to ground become R_i and $R_i + R_f$, respectively.

And Next Time . . .

That's enough to digest for now. In the next part of this article we'll look inside the black box and talk about some things to consider when designing real circuits.

An Analysis of the Balun

What does a balun do for you? What happens if you don't use one? Does a balun really make a difference?

By Bruce A. Eggers,* WA9NEW

bal·un (bal'un), n. a word formed from the words "*bal*anced" and "*un*-balanced." Identifies any of a series of devices used to couple unbalanced transmission lines to balanced loads.

Okay, so that's what a balun is. But what does it do for you? You've probably heard that a balun is used to feed a balanced antenna. What is a balanced antenna? The determining factor is how the antenna is fed. Perhaps the best way to answer this question is to cite some examples. A half-wave dipole, current fed across a center insulator, is perhaps the most common example. This antenna is designed to perform best when each side is fed separate currents of equal amplitude and opposite phase.

Having established this basic idea on defining a balanced antenna, we can now look at some common variations. The folded dipole is one. The currents flowing in the various elements of a folded dipole may be of different amplitude, and you can have more than the common two radiators, but if the feed principle is the same, it's a balanced antenna. The cubical quad can be viewed as a variation of the folded dipole. From this you can see that loops, rhombics, Yagis, and a whole host of antennas, depending upon how they are fed, can all be balanced antennas. On the other hand, a vertical antenna and a ground-plane antenna are unbalanced — the current in these antennas does not flow in identical fashion away from each of the two conductors of the feed line.

In today's marketplace just about all of the transmitters use the same output circuit, the pi network. This single-ended circuit has become very popular for a variety of reasons, not the least of which is the popularity of coaxial cable. While coax isn't the answer to all of the problems with feed lines (and it certainly has high loss problems at the higher frequencies), it does have some redeeming qualities. One of the more convenient things about coax is that, when used properly, you can route it just about anywhere. No need for standoff or feedthrough insulators.

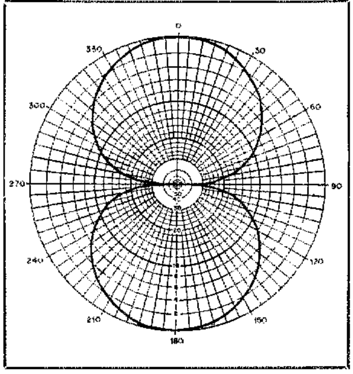


Fig. 1 — Classic response pattern of a half-wavelength dipole in free space. The concentric-circle scale is indicated in decibels down, relative to the response in a broadside direction from the axis of the dipole. The outer scale shows degrees of departure from one broadside direction. The axis of the conductor is common with the line between the 90° and 270° outer-scale markings.

But coaxial cable is an unbalanced feed line. All of the current flows *inside* the line. The inner conductor and the inside of the shield are the two conductors in this line. Therein lies the problem. Feeding a balanced antenna with unbalanced feed line may cause currents to flow on the *outside* of the shield. In fact, given a feed-line length that is significantly long at the operating frequency (e.g., greater than on the order of 0.15 wavelength), one can model the coaxial feed line connecting a single-ended or unbalanced transmitter output to a balanced antenna as a three-conductor feed line!

The "third conductor" and its associated current is the outside of the coaxial shield. The magnitude of this current is a function of the impedance to ground of this conductor. And this impedance can be controlled. If the feed-line length is greater than one quarter of a wavelength long, a "skirt" one quarter of the wavelength long can be placed around the outside of the shield and shorted to the shield one quarter of a wavelength from the load. Such a device, commonly referred to as the "bazooka," is adequately documented in all recent editions of the ARRL *Handbook* and *The ARRL Antenna Book*. It is also well described in any of several other references.[1]

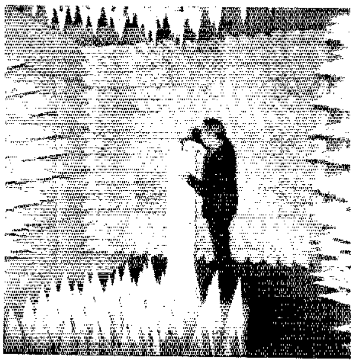
If the feed line is not a quarter wavelength long, or if one wants to accomplish the same effect with lumped components, then there are a variety of other ways to accomplish the same thing. One of the more recent and original ideas presented in the literature on this subject is contained in the article by Reisert, W1JR, in the September 1978 issue of *Ham Radio*.[2] So now let's move on to the question, "What happens if you don't use a balun?"

The Great Experiment

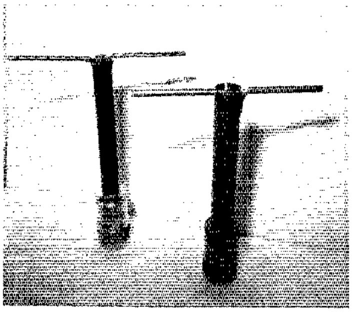
Everybody recognizes the classic "figure-eight" radiation pattern of a half-wave dipole in free space. Fig. 1, taken from *The ARRL Antenna Book*,[3] shows

*14 Judith Rd., Chelmsford, MA 01824

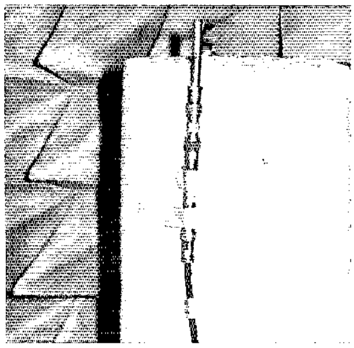
[1]References appear on page 21.



The author positioning one of the test antennas on the rotatable Styrofoam support in the rf anechoic chamber.



Close-up photograph of the two 1.6-GHz half-wave dipole antennas used in the author's tests.



The balun-fed test antenna mounted on the antenna support. (This mounting technique is not recommended for regions subjected to high winds or heavy icing.)

what this looks like. But this figure is an idealized pattern based on current flowing only in the antenna. What does this pattern look like in a real-world situation and what happens to it if we allow current flow on the outside of the feed line? Figs. 2 and 3 answer the question.

The radio-frequency anechoic chamber at North Carolina State University was available to us. An rf anechoic chamber is simply a room in which the walls, floor and ceiling are covered with a material that is designed to break up an electromagnetic wave and absorb its energy. If you put an antenna in such a chamber it can not "see," or be influenced by, any surface or objects that can reflect or reradiate electromagnetic energy. How about that! "Free space" right here on earth! But putting just one antenna in a chamber isn't going to do you any good. You still can't see or measure the radiation pattern. To take care of that problem you have to provide a source of radio-frequency energy. Then if you put an antenna in the chamber, you can observe how it performs as you change its orientation.

For these tests the source of the rf was a half-wave balun-fed dipole, similar to the one on the right in the photograph above, mounted horizontally at one end of the chamber. The balun is electrically equivalent to the quarter-wave bazooka balun discussed above and in reference 1. It was mounted at the same height as the receiving antenna and fed a few milliwatts of power at 1.6 GHz. The test antennas were then mounted, one at a time, horizontally, at the other end of the chamber, on a rotating support. The supports for both antennas were made of Styrofoam with a relative permittivity of about 1.03.[4] (No metal towers to affect this pattern!) The test antennas were then rotated a full 360 degrees. The received signal was carried to the receiver outside of the chamber on a coaxial feed line. The feed line dropped away from the antenna perpendicularly for a distance of about nine wavelengths. (How would you like to

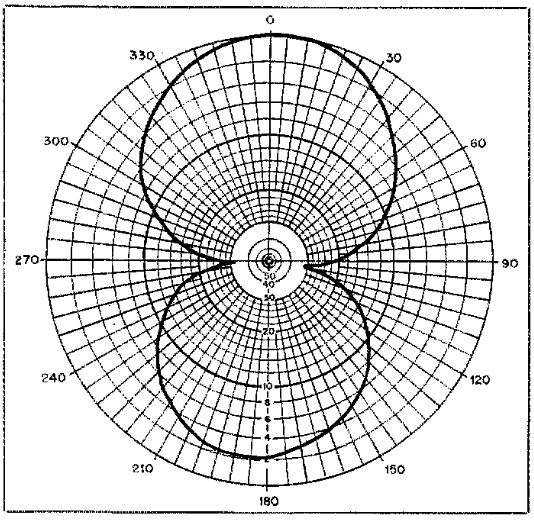


Fig. 2 — Response pattern of the balun-fed half-wavelength dipole in the rf anechoic chamber. The apparent front-to-back ratio exists because the antenna was not located at the exact center of the rotating support. This response and that of Fig. 3 are drawn to the same relative scale.

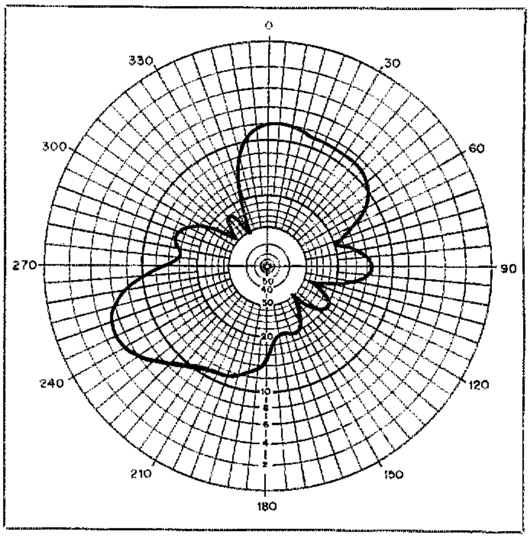
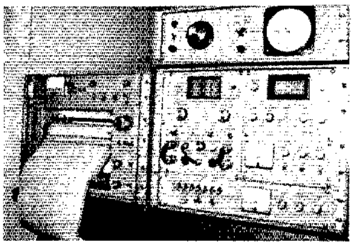


Fig. 3 — Response pattern of the half-wavelength dipole without a balun. The pattern changed significantly during tests if the coaxial feed line was relocated, no doubt caused by changes in the amplitude and phase of currents flowing on the outside of the line.



The Scientific-Atlanta, Inc. test equipment outside of the chamber. The series 1520 rectangular recorder is on the left. The series 4100 position-control unit sits atop the series 1600 receiver.

have your 80-meter dipole that high!)

The receiving, recording and antenna-positioning equipment are all from Scientific-Atlanta, Inc. The series 1600 receiver tunes from 50 MHz to 32.8 GHz in nine bands. The received signal level is fed to a series 1520 rectangular recorder,[5] where the feed rate of the chart is controlled by the series 4100 position-control unit. The recorded signal level is kept as low as possible, consistent with producing a usable output signal with the antennas in the least optimum position, to minimize the effects of any reflected energy that might be received and processed.

Fig. 2 shows the pattern of the balun-fed antenna. The signal level in the nulls off the ends of the antenna is about 32 dB below the "broadside" signal level. Noise precludes identifying nulls significantly deeper than that level in this particular setup.

Fig. 3 shows the pattern of a dipole without the benefit of the balun. The peak amplitude of the signal is about 5 dB below that of the balun-fed antenna and one of the nulls, 30 degrees from broadside, is just as deep as was the null off the end of the balun-fed antenna. There are a couple of points about this trace that need to be considered. First, the exact location of peaks and nulls is highly dependent upon the relative location of the feed line as the antenna is rotated. In repeating the experiment with a different relative position of either, the pattern changes. Fig. 3 can only be considered as representative of how a half-wave dipole performs as a receiving antenna when used without a balun and when used with a long feed line. Second, the overall drop in signal level is not necessarily representative of what you should expect from the antenna in a transmit application. Reciprocity notwithstanding, antenna currents flowing on the outside of the coax are, in general, lost to the receiver. These same currents, in the transmit mode, can radiate energy which effectively fills in the nulls noted here. The pattern of Fig. 2 is fully predictable and can be easily reproduced in a repeated experiment. That of Fig. 3 cannot.

So what does a balun do for you? It gives you a predictable pattern. The biggest benefit which accrues from this feature is applicable to using a balanced element in a directional array. Can you imagine using a radiator with a pattern like that of Fig. 3 in a parasitic array? But many do! In such an application, the presence of the parasitic elements in the near field no doubt tends to smooth out the irregularities of the far-field pattern. But, as the old saying goes, "You can't make a silk purse out of a sow's ear."

Conclusions

The results of this experiment should not necessarily be interpreted to mean that installing a balun on your 80-meter dipole is going to result in any detectable differences. Remember, this dipole was in "free space." Your antenna interacts with all kinds of reflecting and reradiating objects. Every piece of material in the vicinity of the antenna has an effect. And it seems reasonable to assume that the number of nulls and peaks in Fig. 3, and the depth of the nulls, is related to the length of the feed line. The pattern of your 80-meter dipole might not look as bad as Fig. 3, but you can rest assured that it probably doesn't look like Fig. 2 either. The majority of the variations between a real-world antenna pattern and an idealized pattern, at least in regard to simple antennas on the lower frequencies, will result from objects in the near field of the antenna. The additional variations introduced as a result of not using a balun in an application of a coaxial-fed balanced antenna will become most significant at higher frequencies with multielement antennas.

If one had ready access to a facility such as this anechoic chamber on a regular basis, it would be most interesting to run a series of these experiments using a variety of different antenna types. Perhaps someone could do that. I, for one, would like to see the effects of a balun on other antenna types. The author wishes to express his appreciation to Dr. J. Frank Kauffman of the Department of Electrical Engineering at North Carolina State University for his assistance in the conduct of the experiment, and to Pershing Hicks for his photography. QST

References

[1]Jordan and Balmain, *Electromagnetic Waves and Radiating Systems*, 2nd edition, Prentice-Hall, p. 407.

[2]Reisert, "Simple and Efficient Broadband Balun;" *Ham Radio*, September 1978, p. 12. Also see Nagle, "High-Performance Broadband Balun," *Ham Radio*, February, 1980.

[3]*The ARRL Antenna Book*, 13th edition (1974), Fig. 2-13, p. 37.

[4]Kraus and Carver, *Electromagnetics*, 2nd edition, McGraw-Hill, p. 58.

[5][Data provided in rectangular form by the author has been replotted in the more familiar polar form for presentation in Figs. 2 and 3. — Ed.]

Strays

NARROW BAND COMMUNICATIONS PROJECT

☐ Narrow Band Communicators (NBC) recently activated a 100-mW, 2-meter, linear translator in the hills of Oakland, California, about 800 feet above sea level. Signal reports from the San Francisco bay area are excellent. Stations in the San Joaquin-Sacramento valley and the Sierra Nevada mountains have also worked the translator. The system which is operating very well, demonstrates the efficiency of narrow-band communications. — *Vivian Franco, WB6VTG, Daly City, CA*

NORTHWEST ONTARIO SENIOR CITIZENS TUNE IN THE WORLD

☐ An Amateur Radio Station, VE3LMB, has been established in Grandview Lodge, a senior citizens home, in Thunder Bay, Ontario. Funds for the project were provided through a "New Horizons" grant from the Department of Health and Welfare. This project gives retired people the opportunity to share their interests, skills and talents in developing and carrying out projects of their own design and choosing.

Early last year 10 retired hams founded the Northwestern Ontario Senior Citizens Amateurs, and a search began for a site to set up a senior citizens station. They needed a site with adequate space, light and heat, as well as easy access for handicapped persons and flexible operating hours. Club members discovered that the Grandview Lodge had a ground floor room available. Soon thereafter work began on the radio room. The club gained a room and the lodge gained a hamshack. The club has fulfilled all three of its original objectives: (1) to establish and operate an Amateur Radio station for senior citizens, (2) to establish a service department where members can repair their own equipment, and (3) to assist senior citizens throughout Northwest Ontario in making contacts with friends and loved ones.

MORE MILES PER WATT

☐ Frank Crowe, WB6UNH, of Carpinteria, California, reports working nine states on 1 mW or less output. Frank has also worked about 35 states at 1 watt or less, and is working on DXCC with 10 watts or less output. His best miles-per-watt performance is from Carpinteria to WB9LTY in Indianapolis, Indiana, on 0.1 mW output. Worked All Continents at 10 watts was "too easy" — he's working on getting it with 250 mW.

• *Basic Amateur Radio*

20, 40 and 80 Meters with the "Basic Radio Receiver"

Last month we learned the fundamentals of simple receivers. Now let's build a down-converter for reception of signals on 20, 40 and 80 meters!

By Doug DeMaw,* W1FB and Bob Shriner,** WAØUZO

Have you been anxious to listen to something other than WWV on 2.5 MHz since constructing our tunable i-f receiver from March *QST*? By now you must have every clock in the house, and the one on your wrist and in the automobile, set precisely to the second! So let's get on with the remainder of the project. You're probably anxious to hear amateur signals in the 80-, 40- and 20-meter bands.

With this month's converter, visible in Fig. 1, you can listen to any 200-kHz segment of the three amateur bands for which our converter is designed. The only change that needs to be made in the circuit of Fig. 2 for ssb reception is the selection of crystal frequencies for Y1, Y2 and Y3. One set will permit coverage of the cw bands, and the other will allow you to listen to the phone portions of the bands.

How Does a Converter Work?

A converter merely changes one frequency to another frequency as a matter of convenience. In our case, the main tunable receiver covers from 2.5 to 2.7 MHz. Therefore, we must do something to the 3.5-, 7.0- and 14.0-MHz signals so

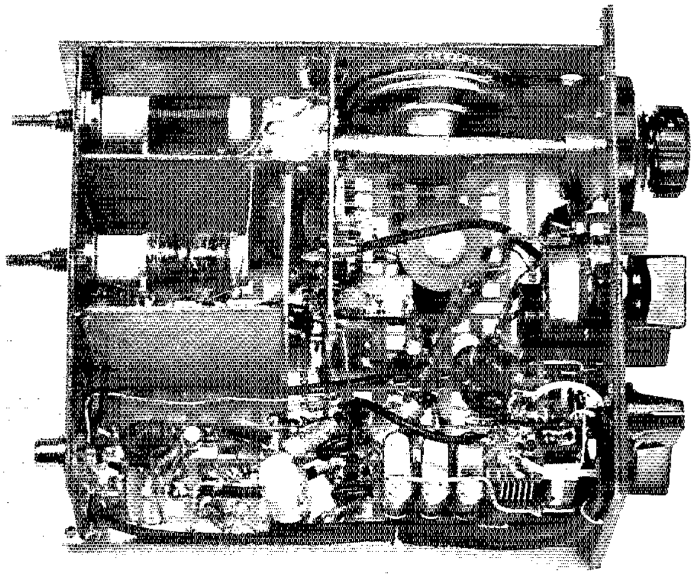


Fig. 1 — View of the composite receiver after the crystal-controlled converter was built along the side of the main circuit board. An additional pc-board shield plate has been added (left center of photograph) to help isolate the converter from the tunable receiver described in March *QST*. The coax cable from T1 of Fig. 1 is routed through a small hole in this partition to L1 of the main receiver. This view is seen without the receiver side wall in place.

*ARRL Senior Technical Editor
**Box 969, Pueblo, CO 81002

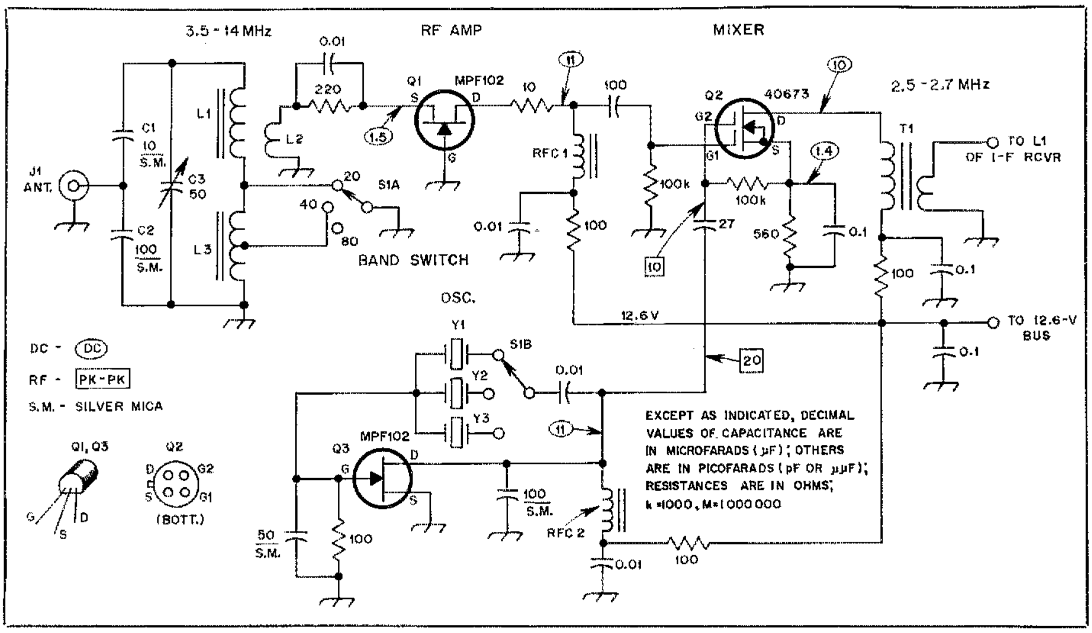


Fig. 2 — Schematic diagram of the three-band down-converter. Fixed-value capacitors are disc ceramic unless otherwise indicated. Resistors are 1/4-or 1/2-watt composition types.

C3 — 50-pF variable.
J1 — Phono jack (J1 from March *QST* project).
L1 — 4-µH toroidal inductor. Use 31 turns of no. 24 enam. wire on an Amidon T50-6 toroid core.
L2 — 6 turns of no. 24 enam. wire over L1 winding on same core.
L3 — 46-µH toroidal inductor. Use 90 turns of no. 30 enam. wire over Amidon T68-2 toroid core. Tap 35 turns from L1 end.
Q1, Q3 — High-frequency n-channel JFET. Motorola MPF102, Siliconix U310 or 2N4416.
Q2 — RCA dual-gate MOSFET. 3N211 also suitable.
RFC1, RFC2 — 1mH rf choke. J. W. Miller Co. 70F103AI or equivalent.
S1 — 4-pole, 3-pos. single wafer switch.
T1 — Broadband toroidal transformer, 112:1 impedance ratio. Primary contains 40 turns of no. 28 enam. wire (1 mH) on an Amidon FT-50-43 toroid core (950 mu). Secondary consists of 4 turns of no. 28 wire over the primary winding.
Y1 — For 20-meter cw — 16.7 MHz. For 20-meter ssb — 16.85 MHz.
Y2 — For 40-meter cw — 9.7 MHz. For 40-meter ssb — 9.8 MHz.
Y3 — For 80-meter cw (3.5-3.7 MHz) — 6.2 MHz. For 80-meter cw (3.6-3.8 MHz) — 6.3 MHz. For 75-meter ssb (3.8-4.0 MHz) — 6.5 MHz. All crystals are in HC-6/U style holders, 30 pF load capacitance. International Crystal Co. type GP or equivalent.

that the receiver can accommodate them. Thus, the task is one of mixing the signals from each of these bands with a suitable local-oscillator frequency so that the resulting intermediate frequency (i-f) is in the 2.5- to 2.7-MHz range. A converter can be used to accomplish this job. In essence it converts 3.5, 7.0 or 14.0 MHz to 2.7 Mhz for use with our direct-conversion receiver from March *QST*. When the little receiver is tuned to the opposite end of its range (2.5 MHz) we will hear amateur signals at 3.7, 7.2 or 14.2 MHz, depending on the position of S1 of Fig. 2. In other words, as we tune the receiver we will hear amateur signals between 14.0 and 14.2 MHz, 7.0 and 7.2 MHz, and 3.5 and 3.7 MHz.

The technique we are employing is called "down-converting." It is possible and practical to "up-convert" also. Some commercial receivers use that scheme. For example, if we had a tunable receiver that covered 14.0 to 14.2 MHz, we could build an up-converter that would enable us to hear the 80-meter band from 3.5 to 3.7 MHz. We would have to select the proper crystal frequency for the converter oscillator. It would be necessary also to employ the appropriate coil and capacitor values for reception of the 80-meter band. From this it can be seen that up-converting is as practical as down-converting.

Our Project this Month

It will be helpful to those who build this month's project if we examine the circuit of Fig. 2 and explain how it works. The first stage of the circuit employs a grounded- or common-gate JFET rf amplifier. The input impedance at the source element of the FET will be low — on the order of 200 ohms, depending on the exact transconductance of the FET used ($Z_{in} = 10^6/g_m$, where Z is in ohms and g_m is the transconductance in micromhos). Therefore, a small coupling link (low impedance), L2, is used between the input tuned circuit and the source of Q1. L1 and L3, in combination with C1, C2 and C3, permit the input circuit to be tuned to 80, 40 and 20 meters. The circuit is designed for use with 50-ohm antennas. That is why a capacitive divider (C1 and C2) is employed. The junction of the two capacitors provides a 50-ohm connection point for the antenna feed line.

Q1 does not provide as much gain in the grounded-base configuration as it would in a grounded-source arrangement. The gain of Q1 in this circuit is on the order of 6 dB. If the output of Q1 had a tuned circuit instead of an rf choke, the gain could be as great as 15 dB, according to theory. Practically, it would be closer to 12 dB. In a grounded-source circuit the gain could approach 20 dB. But we have chosen the grounded-gate hookup in the interest of circuit stability. Generally, if the gate lead is kept short in this type of circuit there will be little chance for unwanted self-oscillation of the rf amplifier. The 6 dB of amplifier gain is ample for our purposes. The collective gain of Q1 and the mixer, Q2, is 15 dB. This is about right for our tunable i-f receiver in the interest of good performance under strong-signal conditions. Too much gain leads to receiver overloading — a condition we want to avoid.

The output of Q1 contains a 10-ohm resistor. It prevents unwanted vhf parasitic oscillations. RFC1 acts as a very broad tuned circuit, thereby allowing us to accommodate signals from 3.5 to 14 MHz without a tuning capacitor in that part of the circuit. The primary sacrifice in using this arrangement is a loss of stage gain, which we discussed earlier.

Q2 is the mixer in our converter. It mixes the incoming amateur signals with energy from the oscillator (Q3) to provide the desired 2.5- to 2.7-MHz i-f. A broad-

Fig. 3 — Closeup view of the band switch, showing the toroids and some other small parts mounted on the rear of the switch (see text).

band transformer (T1) is used at the mixer output. It eliminates the need for still another tuned circuit, which would have to be adjusted each time we moved the tuning dial on our main receiver. Once more, the elimination of the mixer-output tuned circuit reduces the amount of gain the mixer is capable of providing. The proper name for mixer gain is *conversion gain.* Q2 in this circuit provides 9 dB of conversion gain. With a tuned circuit for 2.5 to 2.7 MHz in the drain circuit, the gain would be approximately 15 dB in a

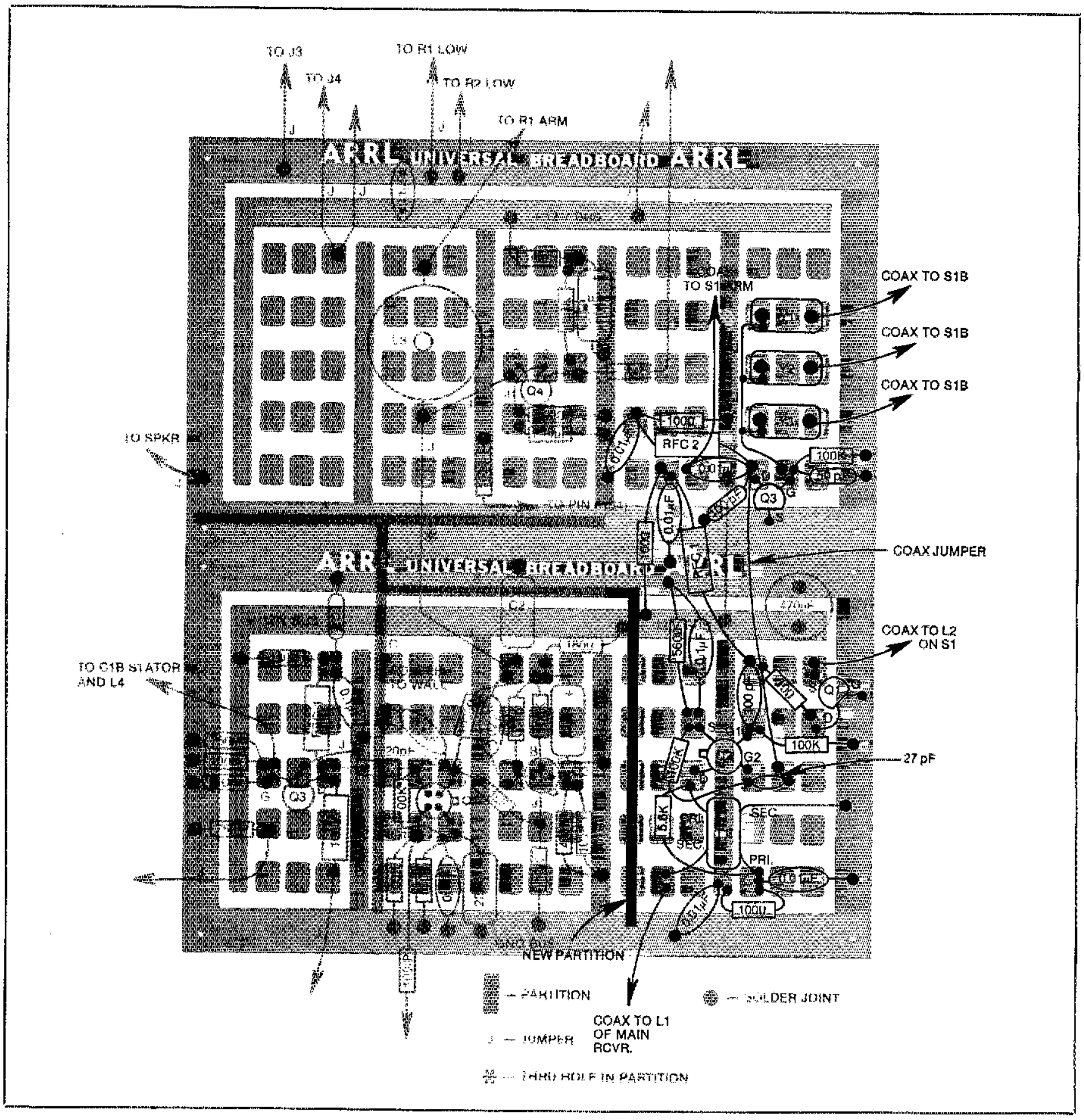


Fig. 4 — Parts-placement guide for the overall receiver. The converter components are shown at the right in heavy lines. The black dots indicate solder joints. The scale black-and-white pattern for this board was presented in Basic Radio, September 1979 *QST.* C3 is mounted on the front panel.

well-designed circuit.

A Pierce type of crystal oscillator is used at Q3. RFC2 is used instead of three individual tuned circuits to simplify our circuit and eliminate the need for an extra switch section at S1. The 50- and 100-pF silver-mica capacitors determine the feedback ratio for the oscillator. The values were chosen to ensure reliable oscillator operation while providing approximately equal amounts of rf output voltage to Q2.

Assembling the Converter

Fig. 1 shows the converter after it was built into the vacant space of our March *QST* receiver.[1] All component leads should be kept as short as possible to prevent self-oscillations and stray signal pickup. Miniature coaxial cable (RG-174/U or equivalent) is used between the contacts of S1 and the circuit-board pads to which it connects. Similarly, the small coax cable is used between J1 of Fig. 2 and S1. A short length of the cable is employed between the output winding of T1 of Fig. 2 and L1 of the main tunable receiver. The shield braid of the coax cable should be grounded at each end of each cable.

A length of bare wire is soldered to the case of each crystal, then soldered to the ground lug of C3 and the front panel. This prevents the metal cans on the crystals from radiating energy into other parts of the receiver.

C1, C2 and the Q1 source resistor and capacitor (220 ohms and 0.01 μF) are soldered directly to the switch terminals of S1 (see closeup photograph in Fig. 3). In a similar manner, L1 and L3 are located at the immediate rear of S1.

We can see more clearly how the parts are mounted on the circuit board by observing the layout in Fig. 4. Make certain that good solder joints are made each time a part is added. Be sure to start mounting the parts near the center of the receiver, then work your way out to the edge of the circuit board. This will simplify your work with the soldering iron. It should also prevent you from burning the components that are already in place! Details of the switch wiring are given in Fig. 5.

After all of the parts are mounted you should check carefully for loose joints and unwanted solder bridges between circuit-board pads. Wiggle each component to make sure its pigtails are soldered firmly in place on the board.

Checkout and Use

Attach an antenna for the band of interest (J1). Set the band switch to the appropriate band. Turn on the power supply and peak C3 for maximum signal, as heard in the speaker or phones. If all is as it should be, no further work will be necessary. If the circuit fails to function, check the various voltages that we have noted on the schematic diagram in Fig. 2. Departures of 10% are entirely acceptable, owing to differences in the characteristics of the transistors you may have wired into the circuit. If there are major differences in the operating voltages, check to see if the transistors are wired correctly into the circuit. If they are, but the circuit still will not perform, recheck your wiring job and look for errors.

There should be a definite peak in signal level for each of the bands when you adjust C3. The crystal frequencies we have specified are for reception of the cw bands. If you are interested only in ssb reception, consult the parts list of Fig. 2 for alternative crystal frequencies.

After the circuit is made operational you may install the remaining pc-board side panel on the receiver. A top cover can be fashioned easily from perforated aluminum stock of the type sold at hardware stores. A cover can also be made from double-sided pc board.

Some Final Comments

We hope you have learned something about simple receivers while reading the March and April issues of *QST*. If you want to get deeper into the receiver design, read the ARRL's *Solid State Design for the Radio Amateur* ($7 from ARRL or your local dealer).

This is by no means the end of our Basic Radio series, so please stand by for more interesting projects and the accompanying theory. Later on we'll be describing a simple keyer with built-in paddle, a universal tester and a frequency counter. Be sure to have a good supply of solder and plenty of replacement tips for your soldering pencil!

[1]Circuit boards, negatives and parts kits for this and other *QST* projects are available from Circuit Board Specialists, Box 969, Pueblo, CO 81002.

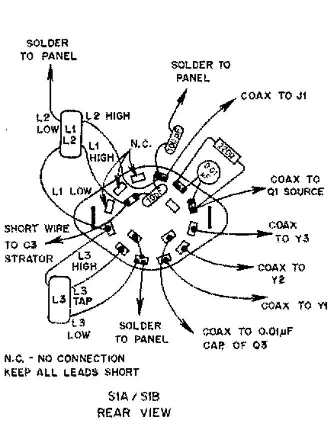


Fig. 5 — Pictorial detail of how the band switch is wired. The blank switch-section lugs are used as tie points only.

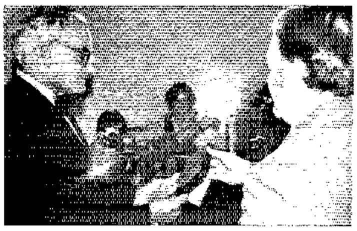
Strays

NN3SI OPERATING SCHEDULE

□ Special-event station NN3SI, operating from the Nation of Nations exhibition of the Smithsonian Institution, Washington, DC, adheres to the following schedule:

Day	Time (UTC)	Frequency (MHz)
General Monitoring		
Monday-Friday	1300-1345	7.090
	1700-1800	7.265
Sunday	1800-2130	28.1-28.2 or 21.1-21.2
Daily Scheduled Operation		
Monday	1900-2000	28.640
	2030-2130	14.220
Tuesday	1900-2000	28.640
Wednesday	1900-2000	28.640
Thursday	1500-1700	18.030-28.040
	1800-1900	21.030-21.040
	1900-2100	14.030-14.040
Friday	1900-1945	21.255-21.265
	2015-2100	21.155-21.165
	2130-2200	3.925
Saturday	1900-2000	14.300
Sunday	1500-1700	7.125
	1900-2000	28.640

NN3SI is operated in conjunction with the Smithsonian ARC and the Independent Volunteer Placement Service of the Smithsonian Associates. QSL address is NN3SI, Smithsonian Institution, Washington, DC 20560.



Senator Barry Goldwater, K7UGA (R-AZ), recently accepted an honorary membership in the Binghamton (NY) Amateur Radio Association (BARA) from BARA treasurer John J. Connors, WB2GHH. Senator Goldwater was honored for his constant efforts to advance the radio art and for representing the amateur in legislative matters.

Granville Klink, Jr., W3AFV (right), received the ARRL 50-year membership award from ARRL President Harry J. Dannals, W2HD, at the Old Timers QCWA annual banquet in Gaithersburg, Maryland, during 1979.

A T-Network Semi-automatic Antenna Tuner

Good harmonic suppression and the capability of matching a wide range of antenna-system impedances are offered by this T network. Semi-automatic tuning is an added bonus!

By Bill K. Imamura,* JA6GW

There it is, ready for the initial test! For a moment you stand admiring your just-installed antenna, anticipating the new wallop your signal will have. Even though the work had been hampered by weather and the mischievous workings of Murphy's law, you've added the final touch only moments before darkness approached. Now to the rig!

As the first surge of power goes down the transmission line to the antenna, you anxiously watch the meters to see "how she loads up." Then there is a hesitation, retuning of the final, followed by a telltale frown. Ah so, the "Law" has one more game to play. The SWR turns out to be much more than the 1.5:1 or 2:1 you'd expected. What then? Adjustments on the antenna could produce an improvement, but suppose the improvement is not enough? In that case, the alternative is to construct a matching network.

If, in reality, you are faced with the need to acquire an antenna tuner (more properly an antenna impedance-matching network), one decision to be made is whether to buy or build. If you elect the construction approach, the next choice will be that of the circuit.

Various configurations of so-called "tuners" have been described in Amateur Radio publications. L and pi networks, used extensively in the past, have been replaced as popular choices by the T-network Transmatch circuit introduced to *QST* readers nearly two decades ago by Lew McCoy, W1ICP.[1] The T network found in the Transmatch is basically a form of a high-pass filter that contains two capacitors in series with the transmission line.[2] These are sometimes referred to as capacitance arms. But, another configuration of the T match is the basic low-pass network. This arrangement is used widely in broadcasting in America. The advantages of the low-pass network (with inductive arms) are good harmonic suppression and the capability of matching on three separate bands without bandswitching. I use this system, as described

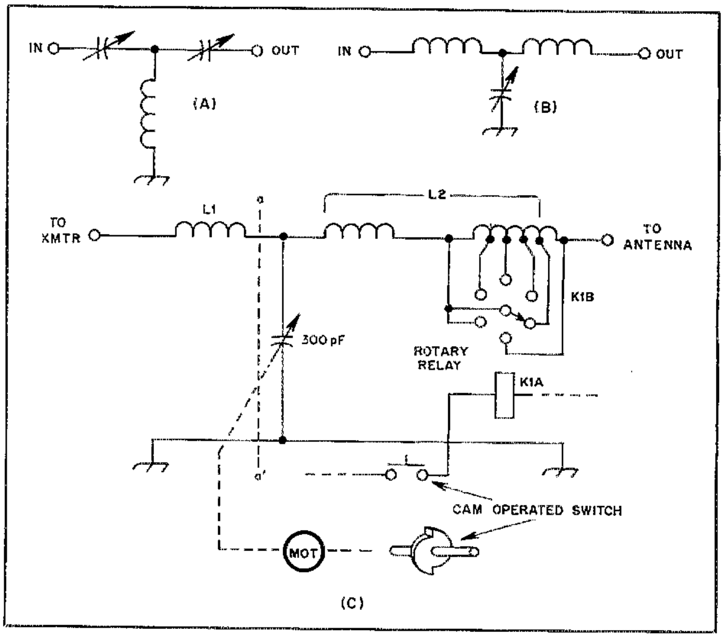


Fig. 1 — T-network configurations. An arrangement with capacitive arms is shown at A, while B shows a T network with inductive arms. The system with inductive arms, at C, offers a wide range of antenna impedance matching besides being an efficient means of harmonic attenuation. Step switching of the taps on L2 is provided by a rotary relay. The variable capacitor is motor tuned.

*2-3 Hikari-ga-oka, Fukuoka City, Japan 816
[1]Notes appear on page 30.

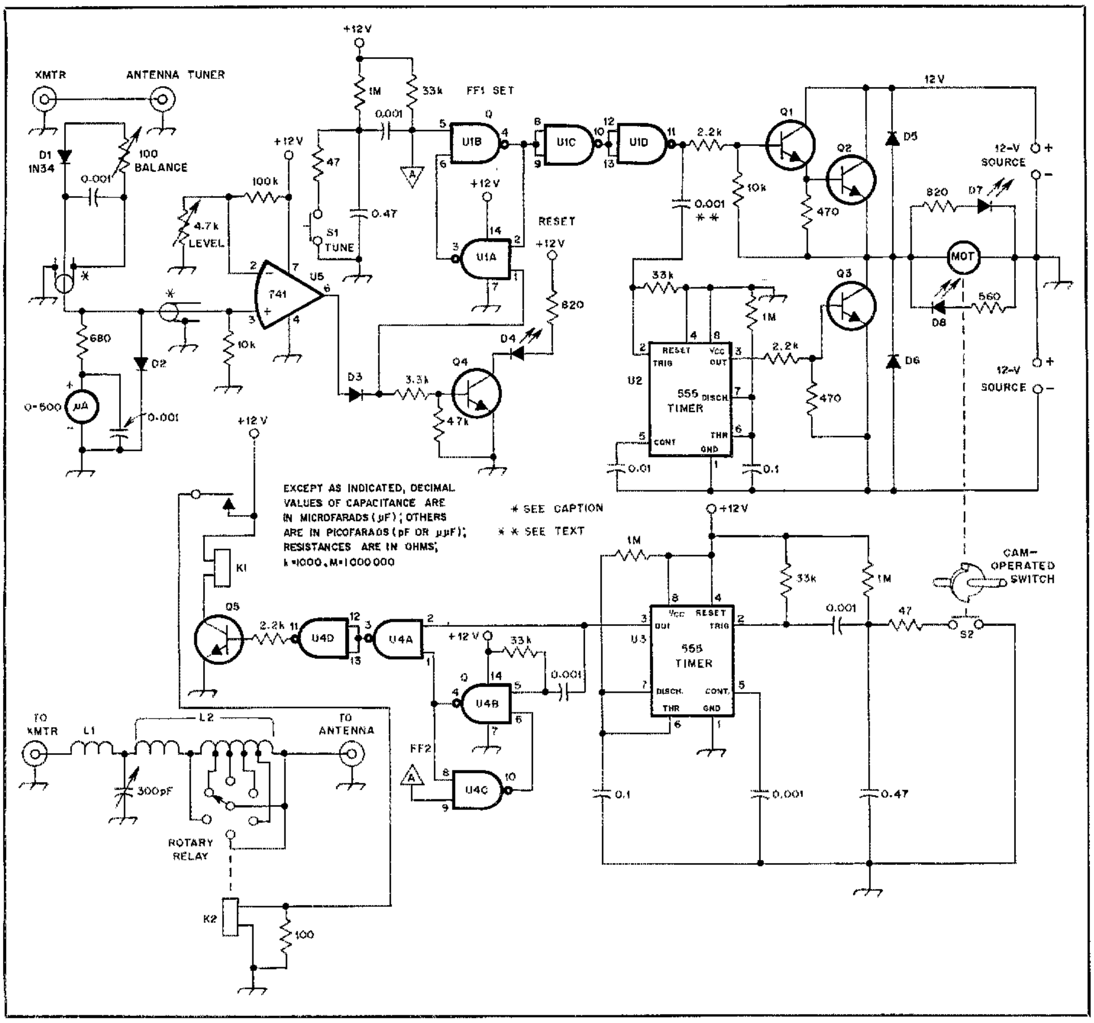


Fig. 2 — The solid-state semiautomatic antenna tuner designed by Imamura. A cam mounted on the shaft of the variable capacitor actuates the micro switch (S2) at every 180° of rotation. The motor, (MOT), a small, 12-V clutch type, is connected to the variable capacitor through a gear train. A dual-polarity power supply furnishes the required 12 volts.

D1 — 1N34 germanium diode.
D2, D3 — Silicon diodes, Toshiba LS1588, Workman 1062 or equiv.
D4, D7, D8 — LED, Radio Shack 276-033 or equiv.
D5, D6 — 1N4002 diodes, 600 V, 1 A.
K1 — 12-V miniature relay, Radio Shack no. 275-003 or equiv.
K2 — Rotary relay, Poly Paks no. 92CU6052.
Q1, Q4 — Npn silicon transistor, Toshiba 2SC372, Workman 372 or equiv.
Q2, Q3, Q5 — Npn silicon transistor, National (Panasonic) 2SC1226, Workman 751 or equiv.
U1, U4 — Quad 2-input NAND gates, MC14011.
U2, U3 — 555 timer.
U5 — 741 operational amplifier.

below, in conjunction with my tribander antenna on 14, 21 and 28 MHz. The T match is most satisfactory for this situation.

The T Network

Fig. 1 illustrates the two general types of T networks, namely the type with capacitive arms and that with the inductive arms. The circuit I use is also shown in this drawing. It provides good matching between the 50-ohm output of a transmitter and the feed point of any antenna if the SWR is no greater than 3:1. In the design of this tuner, I chose an operating Q of 2.0 for 14 MHz and a Q of 4.0 for 28 MHz. An optimum matching-circuit design is one in which the Q is low.

As you look at the circuit diagram in Fig. 2, you will note that only four taps are on the output coil, L2. The reason for this is that the rotary relay I have provides five positions. The fifth position serves to short out the coil.

For a T-network design such as the one I've shown, the worst-case SWR might be as high as 1.06:1 after final tuning adjustments are made. I believe that an SWR of 1.06 is quite practical for Amateur Radio purposes.

I wish to state that an SWR of 1.06, as referred to above, can be quite different from the 1.06 displayed on some SWR meters. Let me explain. Many SWR monitors sold these days consist of a capacitive/inductive (C-M) sensor

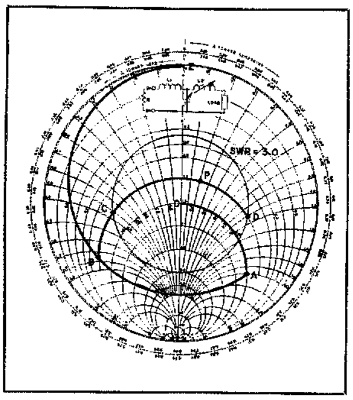


Fig. 3 — The T network is designed with the aid of this Smith Chart. This tuner will match those impedance values that lie within the 3.0-SWR circle. See text for details.

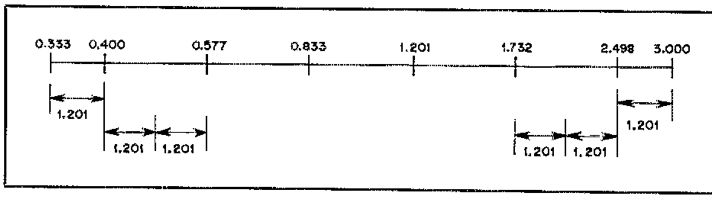


Fig. 4 — See explanation in text.

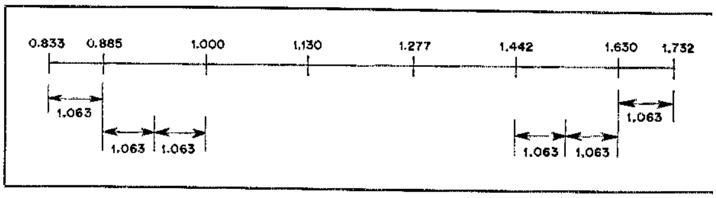


Fig. 5 — See explanation in text.

whereby the pickup coil is coupled to the transmission line through capacitance, mutual inductance and a diode rectifier. Because a diode does not conduct until the voltage across it reaches a certain value, known as threshold voltage, I am doubtful if inexpensive SWR meters will show any reliable deflection at low SWR levels such as 1.06.

Network Design

Delving into a theoretical discussion of network theory is not the intention of this article. I offer, instead, only a brief explanation of the procedure for determining the values of the T-network components.

Calculating the parameters of a T network is simplified by the use of a Smith Chart[3] like the one in Fig. 3. Observe that a constant SWR circle representing an SWR of 3.0 is shown. We are to understand, then, that the network to be designed is to match any impedance within this circle. Every impedance for the design is normalized. That means we divide the impedance by 50 ohms, which is the characteristic impedance of the transmission line.

The impedance of the input port is R = 1.0 and is plotted at prime center, 0. With an operating Q of 2.0 at 14 MHz, the reactance X_{L1} is 2.0. Connecting X_{L1} in series with R permits us to move the impedance to the right along the resistance circle of R = 1.0 until the reactance coordinate reads X = 2.0. Then the impedance at a-a′ in Fig. 1 is represented by point A.

Draw a circle centered on the resistance axis and let it pass through points A and Z. With the capacitive reactance of the variable capacitor in parallel, the impedance locus moves along the circle, for example, to B. AB is the value of capacitive reactance of the circuit.

Now let's suppose the load impedance is shown at P with R = 0.7 and X = 0.2. The length of the arc BP represents the reactance required for X_{L2}. Therefore, along the resistance circle of R = 0.7, the length of BC or BD yields, respectively, the minimum or maximum reactance required for X_{L2} to match a load impedance, which appears on the resistance circle of R = 0.7.

Varying R in the resistance circle from 3.0 to 0.33 in small increments enables you to calculate the required reactance values. The results are shown in Table 1. Values of the resistance component of load impedances within the SWR 3.0 circle range from R = 0.333 to R = 3.000. Note in Fig. 4 that the range of 0.333 to 3.000 is divided in a geometric ratio having six steps. What we are saying here is that we can cover from R = 0.333 to R = 3.000 with a worst-case SWR of 1.201:

$$\left(\frac{3.000}{0.333}\right)^{1/12} = 1.201$$

Table 1 shows that the maximum reactance for L2 occurs at R = 1.732, and the minimum at R = 0.833.

Table 2

Coil and Capacitance Data

Band	Operating Q	L1	C	L2
14	2.0	1.14μH	128→261pF	0.47→2.11μH
21	3.0	1.14	69→127pF	0.61→2.03
28	4.0	1.14	41→74pF	0.61→2.01

Now let's divide the range (1.732 to 0.833) into six steps as shown in Fig. 5. We see that any impedance can be matched with a worst-case SWR of 1.063:

$$\left(\frac{1.732}{0.833}\right)^{1/12} = 1.063$$

Reactance X_{L2} should be 0.822 at a minimum and 3.711 at a maximum. Values for 14 MHz, therefore, are 0.47 μH and 2.11 μH. The values of the inductance and capacitance calculated for each band are tabulated in Table 2.

Circuit Description

A negative-going pulse, generated when

Table 1

Results of Smith-Chart Calculations

On Resistance Circle OF	Reactance Coordinate of B	Resistance Circle Intersects with SWR Circle At		Reactance Required for X_{L2}	
R = 30	−2.449	0		2.449	
2.498	−2.500	−1.042	+1.042	1.458	3.542
1.732	−2.379	−1.332	+1.332	1.047	3.711
1.201	−2.136	−1.249	+1.249	0.887	3.385
0.833	−1.863	−1.041	+1.041	0.822	2.904
0.577	−1.598	−0.768	+0.768	0.830	2.066
0.400	−1.356	−0.416	+0.416	0.940	1.772
0.333	−1.247	0		1.247	

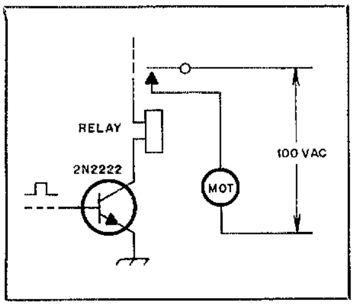


Fig. 6 — A method of actuating a tuning motor such as the one described in the text.

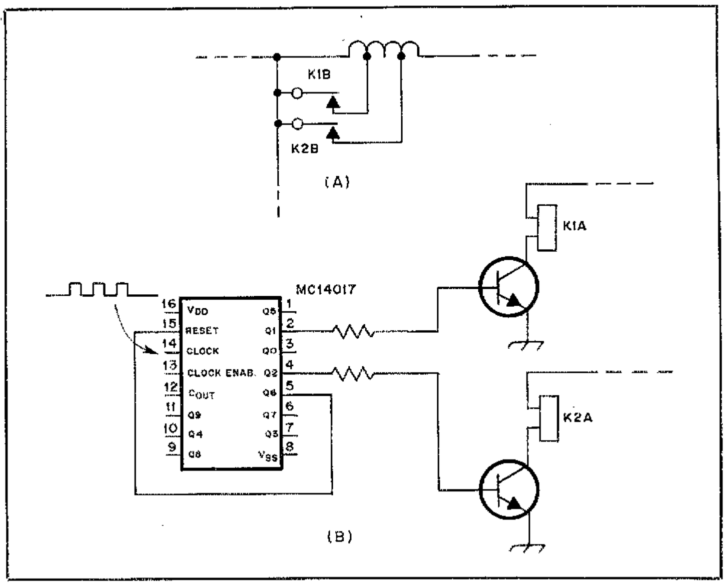


Fig. 8 — An alternative to the rotary relay may be constructed with multiple relays controlled by a decade counter, as suggested by this diagram.

the TUNE button is pressed, sets FF1 (gates U1A and U1B), causing the output Q of the gates to go high. This action turns on the Darlington pair, consisting of Q1 and Q2, causing the motor to turn. A reduction gear train connects the motor to the tuning capacitor. Two inverters in cascade between FF1 and Q1 prevent noise pulses, generated when the motor starts or stops, from falsely triggering the flip-flop.

A Micro Switch is actuated at every 180-degree rotation of a cam mounted on the shaft of the variable capacitor. Closing of the switch permits the rotary relay to be energized, resulting in a change of the coil tap position.

The reflected wave is detected at the C-M sensor, then applied to the comparator. The 741 operational amplifier operates without negative feedback. A slightly positive bias is applied to the inverting input by means of the voltage divider.

Depending on whether the voltage of the reflected wave at the noninverting input is greater than or less than the bias voltage at the inverting input, the output voltage of the comparator swings up to + Vcc or down to − Vcc. As the variable capacitor reaches resonance, the reflected voltage becomes zero, causing the output of the 741 to drop to − Vcc. FF1 consequently is reset. With the output Q driven back to low, the motor comes to a stop. Voltage at the reset input of FF1 is prevented from going below zero by D3.

With the resetting of FF1, the transition of the output voltage from high to low is differentiated by the small capacitance of 0.001 μF and the 33-kΩ leak resistance.[4] A negative pulse is produced that triggers the monostable multivibrator type 555 which, in turn, develops an output pulse of a certain length of time. The values of 0.1 μF and 1 MΩ, shown connected to the 555 in Fig. 2, are chosen for a time constant of 0.1 second. As Q3 conducts, the motor is momentarily driven backwards, causing it to work as an effective brake.

On-the-air testing of the matching unit in conjunction with my TA-33 triband antenna disclosed that one of the taps had enough margin to cover the variation of load impedance on both the 14- and 21-MHz band. The SWR is fairly low even at the band edges. Coil-tap switching is found unnecessary on those bands, provided an antenna of good design is in use.

I devised a scheme to skip the first pulse from the Micro Switch to ensure at least 180° of rotation of the tuning capacitor before the coil tap is switched. It shortens tuning time.

By pressing the TUNE button, a negative-going pulse is generated as mentioned earlier. This pulse is applied to the reset input of FF2 (U4B and U4C). The output of Q goes low, turning off gate U4A through which no pulse can then pass.

The first pulse from the Micro Switch cannot go through gate U4A but the pulse does set FF2. The output Q then goes high and the gate opens. Because the second pulse and subsequent ones pass the gate, the rotary relay is energized.

About the Motor and Rotary Relay

My tuner was constructed on a junk-box basis. The motor is no exception, for I found it at a junk shop in Tokyo. Although the manufacturer and specifications are unknown, the motor appears to be well made and probably was fairly expensive when new.

I would like to recommend the use of a motor with a built-in magnetic clutch. Recently, Yokogawa Sertec Co. placed such a motor on the market. It is satisfactory in every respect except the price (10,000 yen or about 40 dollars). For information concerning the availability of this motor, you could write to the Yokogawa Sertec Co. Ltd., 1-380 Nekabu, Ome-shi, Tokyo-to, Japan 198. A suggested control circuit for the Yokogawa Sertec motor is shown in Fig. 6. This is for 100-V ac operation. I must mention that there is no brake circuit. For those *QST* readers interested in this arrangement, a Radio Shack no. 275-003 relay should handle the relay requirements.

Small dc motors manufactured for toy

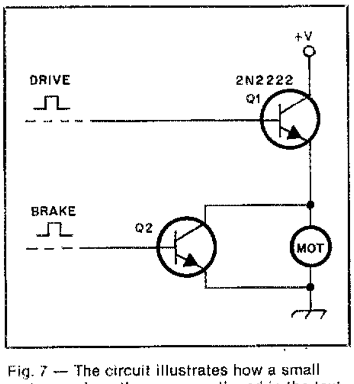
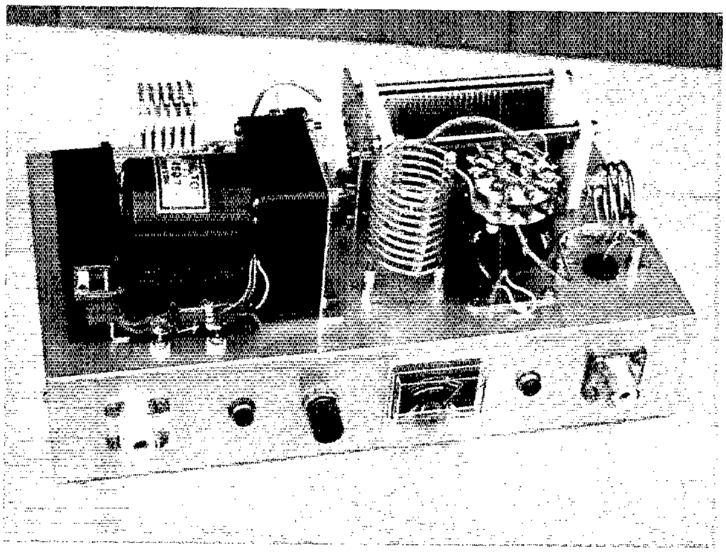


Fig. 7 — The circuit illustrates how a small motor, such as the ones mentioned in the text, may be instantaneously stopped by shunting the armature with a transistor.



Imamura's semiautomatic antenna tuner.

cars are more economical. A popular motor in Japan in known as the Mabuchi, named after the manufacturer. I found one, along with plastic reduction gears, at a local toy shop. The price is quite reasonable. A desirable feature of this motor is that it has a permanent-magnet field, whereby effective brake action may be obtained by simply short-circuiting the armature. To control this type of motor, I suggest the use of the circuit in Fig. 7.

When Q2 of this circuit is *on*, the armature is electronically shorted. Since the motor performs as a dynamo with infinite load, it stops immediately. Q2 should be a transistor or IC capable of handling 2 amperes.

Suitable motors of the toy type are produced by the Sankyo Seiki Mfg. Co. Ltd., 1-17-2 Shinbashi, Minato-Ku, Tokyo, Japan 105. Type GA-201B-01 is capable of turning at 2300 rpm. The price range in Japan is 700 yen or about three dollars.

Suitable rotary relays are currently available from Poly Paks of Lynnfield, Massachusetts (see ads in *QST*). The catalog number is 92CU6052. At the time of this writing, Poly Paks priced them at $11 for a set of three.

Amateurs who have difficulty in obtaining a rotary relay may consider the scheme shown in Fig. 8. In this arrangement, a decade counter, such as the MC14017, serves to drive six relays through buffers. This method should be satisfactory.

Final Comments

The tuner has been used successfully for more than a year at JA6GW. Yet, I consider it still in the experimental stage, for there is room for future development. I am pleased that the reading of the reflected-wave indicator is practically zero when the tuner comes to a stop.

I'd like to point out that stopping the motor instantaneously is of prime importance. A revolving mechanism which has no momentum cannot be found. For that reason, a motor with a built-in magnetic clutch is strongly recommended for this tuner.

Another matter concerns how much operating Q should be selected. Indeed, the higher the Q, the better the harmonic suppression, but where a higher Q is desired, a more precise stop mechanism is required. A Q of 2 on 20 meters is a compromise between the electrical performance and the availability of the drive mechanism.

One word of caution concerns bypassing. Every Vcc terminal of active devices and + Vcc lines must be bypassed adequately in order to eliminate switching spikes. More likely than not, rf intrusion through the power supply can cause trouble. The necessity of good bypassing cannot be overemphasized.

Notes

[1]McCoy, "The Ultimate Transmatch," July 1970 *QST*.

[2][Editor's Note: Even though the circuit configuration of the Ultimate Transmatch is that of a high-pass network, it will provide attenuation of harmonic energy when properly adjusted for a match.]

[3]See *The ARRL Antenna Book*, 13th edition, ARRL, 1977, pp 76-81.

[4]Refer to Fig. 2. See connections to U2 marked with asterisks (**).

Strays

QST congratulates . . .

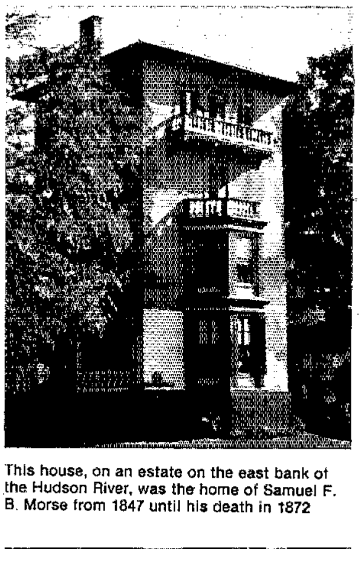
☐ Don Harris, WB4DLB, of Columbia, South Carolina, who recently received the first annual Bill Wall, WA4WND memorial "Ham of the Year" award from the Columbia ARC. Don was presented the award for the many hours he has spent helping fellow hams in the construction of antenna towers.

APPLE COMPUTER INFORMATION

☐ The Apple computer net meets Sunday nights at 0100 UTC on or near 14.239 MHz. If you have a suggestion or problem concerning programming this may be the place to air it. SWLs may mail questions to Jim Hassler, WB7TRQ, 129 Park Ave., Orchard Valley, Cheyenne, WY 82001.

LISTEN FOR THE MORSE HOME

☐ The Poughkeepsie (NY) ARC has undertaken a project to celebrate the public opening of the Young-Morse National Historic Site, in Locust Grove, NY, on Sunday, May 18. To help celebrate this event and to remind all amateurs of our debt to Samuel F. B. Morse, the club will operate from Locust Grove from 1300 UTC on May 18 until 0100 UTC on May 19. Both phone and cw will be used on 10 through 80 meters. A commemorative QSL card will be available for all contacts (s.a.s.e., please). For an additional fee of $1, contacting hams will also receive a commemorative certificate. Amateurs and the general public are invited to visit the club station on May 18 during normal site visiting hours (10-5) when a special reduced admission fee of $1 will be in effect.



This house, on an estate on the east bank of the Hudson River, was the home of Samuel F. B. Morse from 1847 until his death in 1872

A Portable 2-Meter Repeater for Emergency Communications

Thinking of assembling a repeater? Perhaps some of the ideas presented here may well suit your needs. The complete unit is geared for maximum emergency preparedness.

By Everett L. Beall,* K6YHK

Portability of equipment, low cost and general freedom from noise have made 2-meter fm a popular means of communication. This popularity and the operational characteristics of the band make it a "natural" for amateurs who engage in public service or who provide emergency communications during periods of real or simulated disaster. If hand-held transceivers are used to communicate over an appreciable area, another item is necessary — a suitably located repeater.

The group of amateurs who supported fire-fighting efforts during the 1977 Marble Cone fire in California discovered the desirability of a precisely located repeater. Fortunately, a 28/88 "machine" happened to be ready to go and was waiting for a hilltop home. It was installed quickly to provide communications coverage of the fire area, and it really paid off!

The significance of the occurrence was not forgotten when a group of Santa Barbara County amateurs met to assess our emergency-preparedness status. We learned a most important lesson — the excellent repeater facilities normally enjoyed could be lost easily as a consequence of the very disaster for which its use would be required. Local repeaters that afforded the best coverage were dependent on commercial power, were not designed for portability and, in fact, were located in rather high-risk fire areas. A need existed for a portable repeater; an emergency communications tool to be used as a backup for, or supplement to, a local fixed repeater. It would be a minimal facility maintained in a ready condition, but not kept on the air. The machine should have the following features: (1) be truly portable, no more than 1 or 2 cubic feet in size (which ruled out a large-cavity duplexer system); (2) operate from a 12-V dc source, unattended, for several days (this dictated a power output in the vicinity of 5 watts); and (3) break down into approximately three packages — repeater, power source and antenna system. Each package would be of a weight and size that would allow the entire system to be hand carried or backpacked almost anywhere by a few people. It should operate on a repeater pair for which local amateurs had crystals. Yes, *crystals!* Not many amateurs own hand-helds or small portable rigs that are synthesized. Finally, the package must function as a repeater only, or as a net-control base station with built-in repeater capability to "tie the hand-helds together."

These goals mandated that power consumption be kept to a minimum, especially when the repeater was to be operated unattended. Therefore, steps were taken to reduce power drain to a low, practical limit; turn off the local audio amplifier when the repeater was unattended; and include an automatic cw i-d timer system and a minimal remote-control system. (The FCC requires that one be able to turn the machine off.) When the repeater is to be used as a net-control or base station, provisions should be made to allow it to operate as a base-station transceiver while retaining simultaneous repeat capability. It should also be able to turn off the automatic i-d system and use whatever 12-V dc source is available — battery or ac-operated supply. Included in the package should be battery clamps, alligator clips, banana plugs and other items that afford flexibility.

Question: If a cavity duplexer system were not used, how would receiver desensing be avoided? Some "digging" led to a *QST* article by Ed Tilton, W1HDQ.[1] Intrigued, we built one of the "trap filters" and were amazed at the degree of isolation this small unit was capable of providing. Perhaps two filter systems would permit the use of one antenna for duplex operation. Although we were skeptical of satisfactory operation using one antenna,

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[1]Notes appear on page 36.

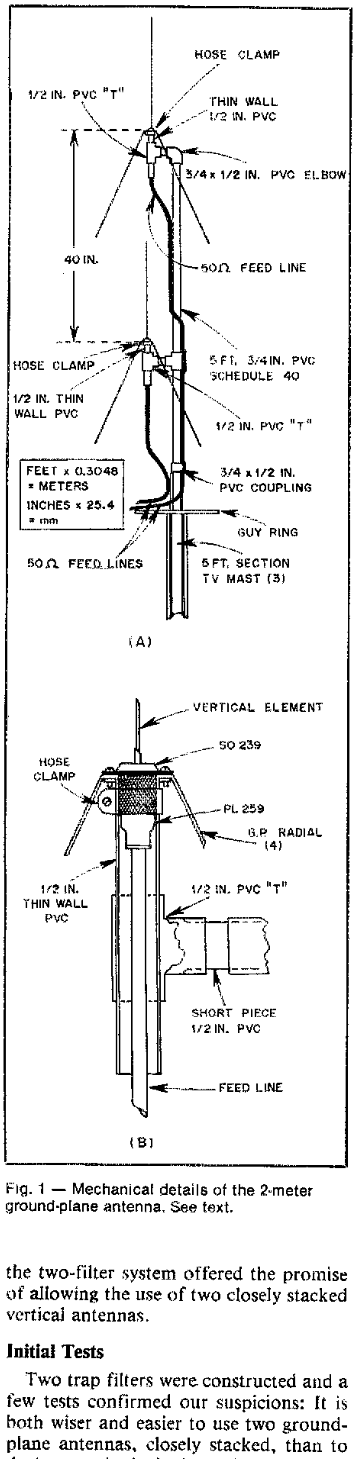
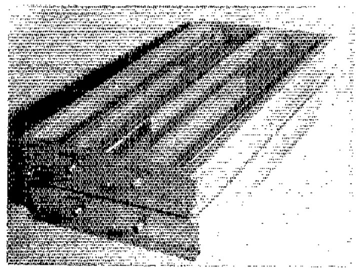


Fig. 1 — Mechanical details of the 2-meter ground-plane antenna. See text.



The input/output end of the filter assemblies. The two units shown here are bolted together using 6-32 hardware making a rigid and compact duplexer package. The tuning-capacitor adjustment screws and loading plates are at the opposite end of the assemblies and not visible in this photograph. Note the use of aluminum channel stock for unit construction.

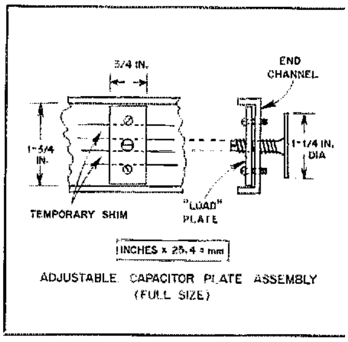


Fig. 2 — This drawing shows the assembly of the adjustable capacitor plate. The "loading" plate is provided to eliminate sloppiness in the capacitor plate adjusting the screw.

the two-filter system offered the promise of allowing the use of two closely stacked vertical antennas.

Initial Tests

Two trap filters were constructed and a few tests confirmed our suspicions: It is both wiser and easier to use two ground-plane antennas, closely stacked, than to devise a method of using a single antenna. Next, two quarter-wavelength ground-plane antennas were constructed and mounted so the vertical separation could be altered for test purposes. We stopped just short of "nesting" the vertical element of the lower (receive) antenna into the ground-plane radials of the upper (transmit) antenna, and still had no trace of receiver desensing! This degree of spacing might not be sufficient if higher transmitted power levels are used. The antenna system adopted for K6YHK/rpt consists of two quarter-wavelength, ground-plane antennas stacked vertically 40 inches (102 mm) between feed points and mounted on a support of schedule-40 PVC pipe, as shown in Fig. 1.

This antenna system is almost as compact as one J or 5/8-wavelength antenna. The receiver bandpass filter is tuned to the center of the received frequency, while the trap filters are tuned to notch out the transmit frequency. The transmit bandpass filter is tuned to the transmit frequency, and the trap filters are tuned to the receive frequency. Adjustment may be accomplished as outlined in the Tilton article.

The Filters

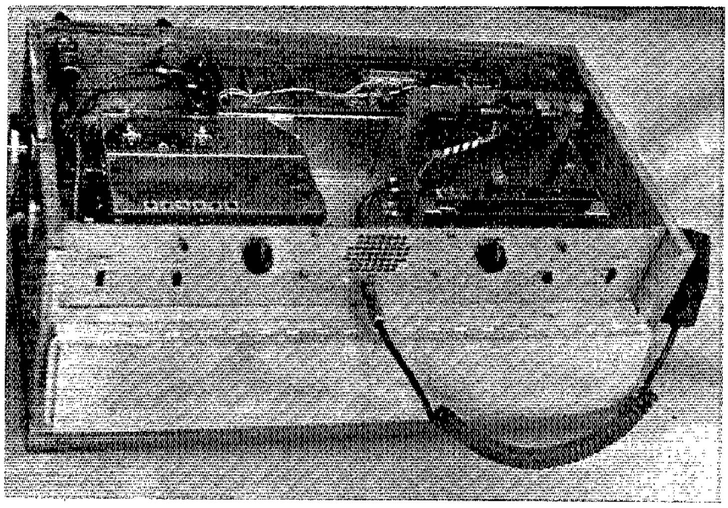
The trap filters are the heart of the system. Therefore, they will be examined in detail.

Tilton stressed the need for a mechanically rigid assembly. For this project, 2- × 1/2- × 1/8-inch web-extruded aluminum-channel stock was used for the frame.[2] Typical construction may be seen in the accompanying photograph. The work involved may be easily handled using ordinary hand tools. Holes through the 1/2-inch lip may be drilled and tapped, a procedure that is necessary in the aperture-forming partitions and other places. In some areas, 4-40 machine screws and nuts may be used for most of the assembly (buy the hardware in boxes of 100s to save some money). The filter length is 18 inches on the inside with tuned lines 17-1/2 inches long. This length of line requires less capacitance to tune the filter to the desired frequency. This allows the use of wider capacitor-plate spacing, which mean less chance of flash-over in the transmit filter. Wide spacing also tends to minimize detuning caused by temperature changes. The voltage present at the tuned end of these high-Q lines can be very high at resonance, even when used with a low-power transmitter. The plates on the end of the tuned lines were increased to 1-1/4 inches square in size and the discs on the capacitance-adjustment screws were made 1-1/4 inches in diameter. Tests indicated the transmit line filter had an insertion loss in excess of 3 dB when the notch of the series traps was tuned to the receive frequency, 600 kHz away. Reducing the aperture between the bandpass section and the series traps decreased the insertion loss caused by over-coupling, but with some sacrifice in notch depth. As adjusted, the aperture at 5-1/2 inches produced an insertion loss of under 2 dB with a notch depth of more than 60 dB. No changes were made in Tilton's aperture dimensions for the receive filter. Two frames and four aperture partitions may be made from a single 16-foot length of aluminum channel. The aperture-forming partitions between the bandpass lines are fashioned from two pieces of 2- × 3/16-inch aluminum bar stock. The cross section of each filter element is 2 × 2 inches. Thus, the overall inside width of each enclosure is 8 inches plus the thickness of the three partitions. A 2- × 8-11/16- × 1/16-inch thick brass plate inside the input end of the filter has 5/8-inch holes (made with a chassis punch), into which the tuned lines were press-fit and soldered. The lines were made from 1/2-inch copper water pipe. The top and bottom plates are made of aluminum stock 0.040- to 0.050-inch thick.

Some Hints

There must be absolutely no looseness in the capacitor-adjustment-screw

The drill press is being used as a clamp to aid in the assembly of the filter lines. To prevent the drill press table from acting as a heat sink during soldering, scrap aluminum, asbestos sheet and a block of wood are used between the table and the brass end plate of the filter line assembly.



The interior of the repeater with the covers removed. The audio/control board is raised to the top of the card guides within the auxiliary equipment enclosure which also houses the i-d board at the front and the COR board near the center. Two LM309K regulators are mounted outside this enclosure. The box to the left contains the 2-meter exciter in the front compartment and the power amplifier on the back wall. The PA heat sink is mounted outside this back wall.

assemblies. A change of even 0.001 inch in the position of the tuning-capacitor disc associated with a trap line will change the notch depth many dB. Locknuts are not an answer to the problem. A method of "loading" the 10-32 adjustment screws is needed since conventional threading results in far too much play.

One solution is shown in the detailed drawing of Fig. 2. Make two plates from brass or hard aluminum cut to the dimensions shown. Center one of these plates over the spot where the capacitor-adjustment screw comes through the end channel. Drill two holes through the loading plate and end channel using a no. 43 drill. Drill out the holes in the loading plate to clear 4-40 screws (no. 33 drill) and tap the holes in the end plate for 4-40 machine screws. Temporarily shim the loading plate from the end channel with metal strips approximately 0.010-inch thick. Tighten the 4-40 screws. Drill a small pilot hole through the loading plate and the end channel at the center of the 2- × 2-inch cross section of the filter. (This hole should line up with the center of the square plate on the end of the tuned line.) Enlarge the pilot hole by means of a no. 21 drill. Use a 10-32 tap to tap a hole all the way through both the loading plate and the end channel. The loading-plate shims are removed after final assembly. The 4-40 screws are then used to provide the desired amount of loading for the capacitor-adjustment screw.

A drill press is helpful in making the tunable capacitor disc assemblies. Discs are cut from heavy sheet brass or copper (0.020-inch thick) with a diameter slightly larger than 1-1/4 inches. Cut a screwdriver slot in the threaded end of a 1-inch long, 10-32 flat head, brass machine screw. Secure the screw in the drill press and place the flat head of the screw against the center of one of the discs and lock the drill-press feed. Solder the disc and screw using a propane torch or high-wattage soldering iron. When the work has cooled, unlock the feed and, with the drill press running, place a file against the edge of the rotating disc to round it out. A fine-grade sandpaper may be used to finish the disc.

Two useful jigs may be fashioned from a scrap of aluminum and a piece of lumber measuring 2 × 4 × 12 inches. Cut an aluminum plate the size and shape of the brass end plate. Lay out the location of the 5/8-inch holes, clamp the two plates to the piece of wood, and drill four small pilot holes through both metal plates and into the edge of the wood. The holes in the metal plates may be enlarged with a 5/8-inch chassis punch. A 5/8-inch high-speed wood bit in the drill press (with the depth stop set for approximately an inch) will make all four holes in the wooden piece of equal depth. Now the brass plate with four 17-1/2 inch copper lines is press fit into the four holes. The jig on the opposite end of the lines is mounted in the drill press which is used as a clamp. Check for alignment of the four copper lines and then solder them to the brass end plate. The 5/8-inch holes in the aluminum jig are reamed to permit sliding the jig on the lines. The jig maintains correct spacing of the lines while drilling through them and the bottom plate of the enclosure, where the 3/4-inch ceramic standoff insulators will be installed. The drill press may be used as a clamp while soldering the square end plates to the copper lines. (Note: Remember to remove the aluminum jig before soldering!)

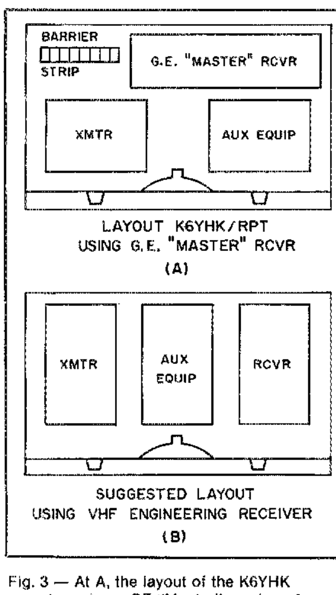


Fig. 3 — At A, the layout of the K6YHK repeater using a GE "Master" receiver. A suggested layout for use with the VHF Engineering equipment is shown at B.

Packaging

The minimum size of the repeater

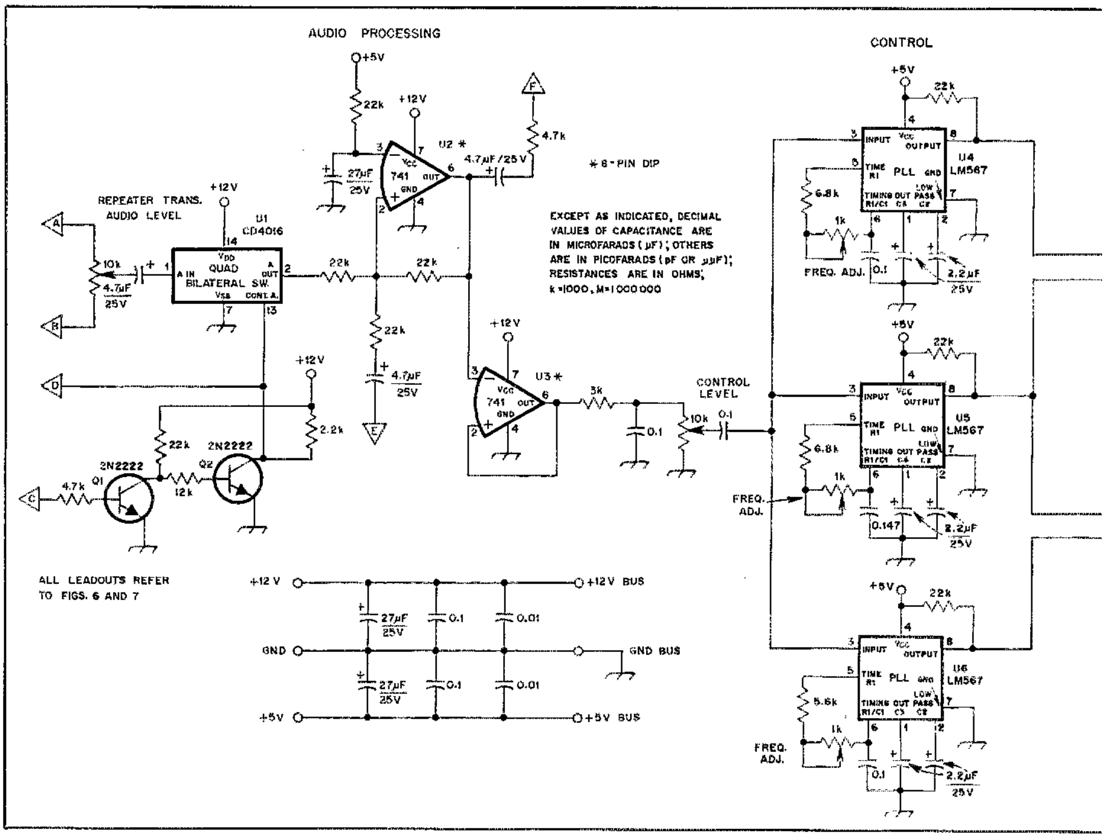


Fig. 4 — The audio processing and control section of the repeater. All fixed-value resistors are 1/4 W.

enclosure was dictated primarily by the size and shape of the filters. Each filter assembly is approximately 2-1/2 × 19 × 9-1/2 inches (HWD). The repeater proper is 4 inches high. The enclosure, made of 1/2-inch plywood covered with sheet aluminum, is 10 × 22 × 12 inches (HWD) — just over 1.5 cubic feet of repeater! Fig. 3 is a sketch of the layout of the repeater electronic packages. A shelf was cut from 3/8-inch plywood and covered with a sheet of aluminum on the top side. This makes a good ground plate on which to mount the modules. The 3-1/2 inch front panel was placed 1 inch back from the front edge of the shelf to allow for clearance between the control knobs and switches and the closed front door of the package. This is shown in the accompanying photograph.

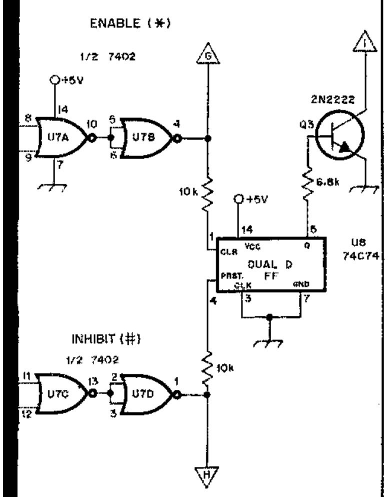
An article by George Allen, W1HCI, and Bob Brown, W2EDN, will be valuable to anyone constructing a repeater.[3] Allen and Brown stressed the necessity of adequate rf shielding and bypassing, and suggested that cast-aluminum enclosures be used for both the transmitter and receiver modules. LMB no. 753 chassis boxes provide adequate rf shielding. Do not forget to use feed-through capacitors for all dc and audio lines into and out of the chassis boxes.

Other Considerations

The machine was intended to be used as a command post net-control station while it was simultaneously operated as a repeater. This meant that a fixed level of audio must be used for the transmitter while providing a local audio-gain control for the base station. A method of accomplishing this by means of L or T pads is shown in Allen and Brown's article.

The system used here (see Fig. 4) was designed to allow the use of a tone decoder for the remote-control system and with the hope of conserving power. The audio for the transmitter and the control decoders is taken from the high end of the audio-gain control potentiometer. This way, the audio-gain control affects only the local audio level and permits turning off the audio-power amplifier when the unit is operated as an unattended repeater. With this arrangement, however, the repeater audio was obtained from a point ahead of the squelch system in the receiver, so an additional squelch system had to be incorporated. This was done by using the receiver COR (carrier-operated relay) voltage to switch the repeater audio on and off. One section of a CD4016 does this nicely, but since the COR voltage must be raised to + 12 V, a two-transistor dc amplifier was added to the COR line. A 741 op amp following the switch also derives its input from the identifier (i-d) board and furnishes repeater audio to the transmitter. The 741 loaded the audio amplifier in the transmitter exciter and made it impossible to use the local microphone. A $4.7-k\Omega$ isolation resistor was installed at the line input of the transmitter to correct this problem. The output of the first 741 feeds a second 741, whose output goes to the control-system-level potentiometer. Here, it was necessary to incorporate de-emphasis at the output of the second op amp to balance the level of the tones going to the NE-567 tone decoders.

The control system is straightforward. When using the asterisk (*) for on and the pound sign (#) for inhibit, the



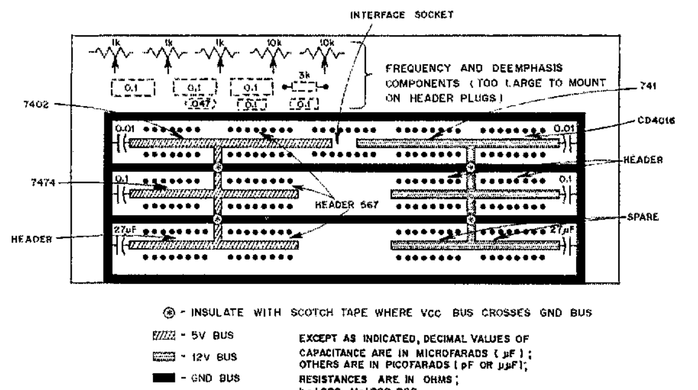


Fig. 5 — A drawing of the audio-processing and control-board layout of the K6YHK repeater. This is a wire-wrap layout and is offered as a suggestion. A mechanically neat decoder assembly may be made by mounting an 8-pin header plug and an NE567 IC in a single 16-pin DIP socket. The header plug is used to mount most of the parts that are external to the IC. Note the bypassing of the Vcc buses.

configuration is as shown. If a different code is desired, select one tone common to both tone pad pushbutton switches. The output of the tone decoder is low when locked. With a low at the output of the two decoders, the output of the associated 7402 gate goes high and it is necessary to invert the signal again with another 7402 gate. To shut down the transmitter, a high from the 74C74 is used to bias the transmit-inhibit transistor on. While this control system works perfectly, the total savings in battery drain while operating the system as an unattended repeater turned out to be quite small.

The audio/control circuitry is built on 0.1-inch spacing Vector board having the same dimensions as the VHF Engineering cw i-d board. The layout is shown in Fig. 5. It is necessary to use wire-wrap sockets

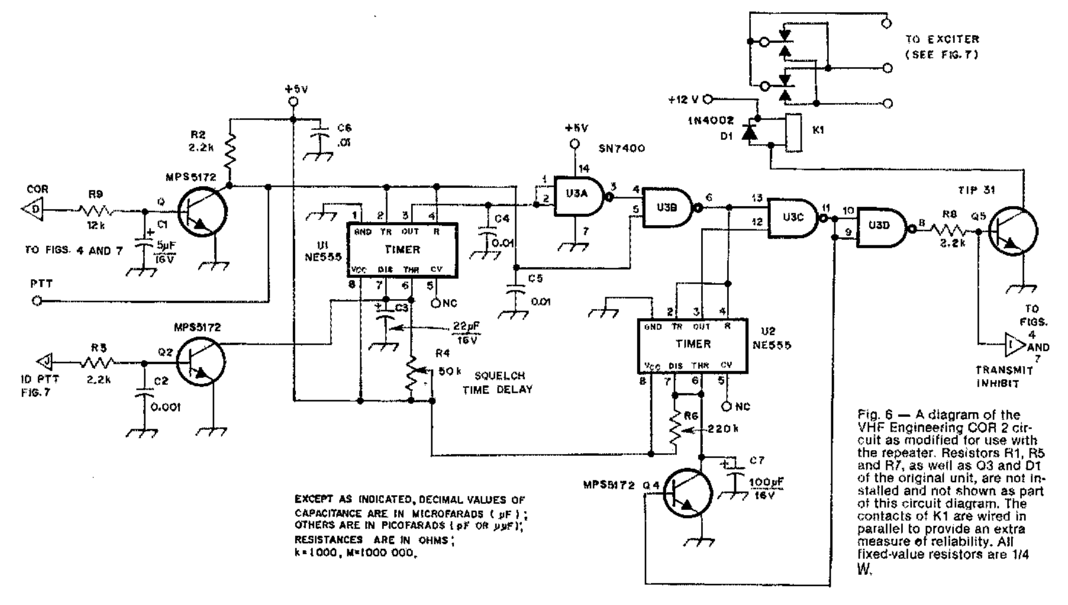


Fig. 6 — A diagram of the VHF Engineering COR 2 circuit as modified for use with the repeater. Resistors R1, R5 and R7, as well as Q3 and D1 of the original unit, are not installed and not shown as part of this circuit diagram. The contacts of K1 are wired in parallel to provide an extra measure of reliability. All fixed-value resistors are 1/4 W.

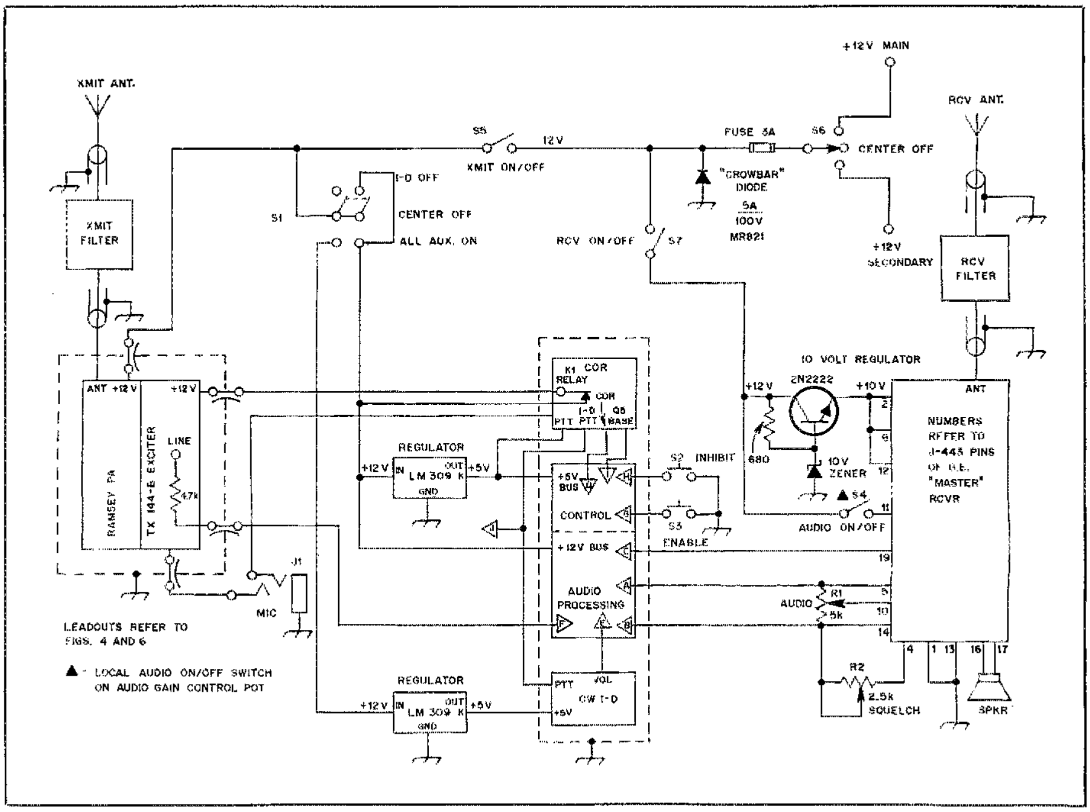


Fig. 7 — The interface wiring of the K6YHK repeater. The main requirement of the polarity-protection diode is that it be capable of carrying sufficient current to allow the fuse to open and prevent damage to the repeater circuits.

and related techniques to obtain the required component density. A DIP socket and plug are used for interfacing. The terminations at the DIP socket are shown in the audio-control diagrams. Adhesive-backed copper tape was used for the 5-V, 12-V and ground buses. Layout is noncritical. The use of positive and negative buses eliminates a large part of the "rat's nest" of wire-wrap construction and greatly facilitates trouble shooting. Also, it is wise to align all wire-wrap IC sockets on a board with pin 1 facing in the same direction.

The 2-meter amplifier, a 30-watt solid-state unit, loafs at 5-watts output with approximately a watt of drive from the VHF Engineering TX144B. The COR contacts are in the 12-V line to this exciter. The amplifier has the 12-V line permanently connected to it.

The VHF Engineering COR was modified as shown in Fig. 6. Do not install R1, R5, R7, Q3 and D1 of the original circuit. Connect "COR IN" to Q1 through a 12-kΩ resistor. The base of Q4 is connected to U3 pins 9, 10 and 11. This arrangement allows the 3-minute timer to be reset only when the repeater carrier drops. The transmitter-inhibit line is connected to the PTT input point at the base of Q5. The COR relay is mounted on the bottom of the control box rather than on the pc board.

The VHF Engineering cw i-d unit is used without modification. Program the desired call, make time, level and speed adjustments and connect it to the audio/control board at the point indicated on the diagram. The supply voltage may be routed through a switch to provide a means for disabling the i-d.

A close look at the photograph of the repeater interior will clarify how the i-d, COR and audio/control boards were installed in the auxiliary-equipment enclosure. Fig. 7 shows the interconnections of the separate units. Surplus card guides were used and all interconnections were cabled with sufficient slack to allow any card to be lifted clear of the enclosure (while still being connected) for adjustment or troubleshooting.

Summary

This repeater was not a club project, although all members of the committee are also members of the Satellite Amateur Radio Club, Inc. (W6AB), Vandenberg Air Force Base, California. A great deal of credit goes to Bob Couger, W6KPS, Ron Dickerson, WD6EYB and Ray Isenson, N6UE. Bob acted as chief engineer of the project, Ron was my good right hand in construction, and Ray lent his talents to photography and technical writing. The team donated all components used — scrounging or building what we could and buying only what we had to. We sincerely believe it was worth the effort. QST

Notes

[1]Tilton, "A Trap-Filter Duplexer for 2-Meter Repeaters," *QST*, March 1970, p. 61.
[2]Inches × 25.4 = mm. Feet × 0.3048 = meters.
[3]Allen and Brown, "Build Your Own Repeater for Only $365," *73 Magazine*, February 1975, p. 76.

FDX — A Challenge Accepted

This is a singular account of atypical amateur genius, covering several years of R & D. The conclusions reached by the author will make you proud to also be a "ham."

By Justin Thyme,* WAOK

During the past two decades, the plethora of papers on receiver sensitivity has probably been exceeded only by the definitely definitive treatments of SWR and its importance. Here at SAAR* the writer's interest in receivers was rekindled by a reference to Gooch's Paradox[1] and the obvious truth that radio signals never die, they just get weaker. Most investigators have apparently concluded that the signals get too weak to be heard in the noise. But what about those long-delay echoes that have been reported and studied? After all, the decay curve should be exponential, similar to a capacitor discharging through a high resistance, and we know that never reaches a value of zero. (See Fig. 1.)

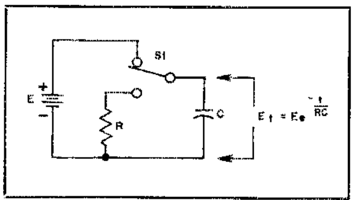


Fig. 1 — Classical capacitor-discharge experiment. When S_1 is closed, capacitor C discharges through resistor R in accordance with formula shown. (See *Radio Amateur's Handbook*, 1980 edition, page 2-16.) Use care in duplicating the experiment, since the capacitor is never completely discharged unless R = 0.

Boldly borrowing from radio astronomy and satellite techniques, a hyper-sensitive receiver was constructed that yielded a *negative* noise figure. (The secret is an obvious one, once known to but forgotten by many an old timer. Use regeneration, or "negative resistance" as it is sometimes called. Just see what happens when you use *negative* resistance in the formula for noise factor.[2]) There was only one slight disadvantage — it didn't work. *That* required getting *below* the cosmic noise level!

This realization slowed down the work for almost a week. However, recalling that the great recent strides in receiver design involved only *frequency* selectivity, *amplitude* selectivity was considered. It was the answer! Once an amplitude-selective system was devised, it became a simple matter to go *below* the noise and copy the weak signals with the hyper-sensitive receiver.

Many entertaining hours were spent copying signals that had originated days, weeks, months and finally years ago (March 1975) as the receiver was refined and honed to a high degree. One evening while "reading the mail" (as they say) a thought occurred. Why not build a transmitter that would permit a QSO with this 1975 group, or others in the past?

The idea was very intriguing. But a little cogitation showed it to be impossible. Logs that still exist today would have to be changed, but how? Two of the operators heard are now Silent Keys — might not my operating inadvertently reveal my privileged knowledge and upset them? No, it was impossible. And, anyhow, how could a radio signal be sent back in time?

The Alternative

But how about sending a signal *forward* in time? It is well known from wave-guide techniques that phase velocity (PV) exceeds the speed of light. PV^n is even swifter.[3] Using atomic overdrive, the velocity depends simply on the overdrive ratio (n = 1 ÷ overdrive ratio).

There was only one way to determine if this principle could be applied to a radio system; it is the ham way. Try it! A breadboard version of an atomic-overdrive phase-velocity local oscillator was built and substituted for the local oscillator injection of an existing transceiver that used the hyper-sensitive principles in the receive mode. (Phase-velocity oscillators are computerized end results of the primitive pm transmitters currently used on 144 MHz. The overdrive is the author's modest contribution.)

While waiting impatiently for some of the hardware fabrication to be completed, thought was given to where to send the signals (forward) in time. The author has worked a majority of the terrestrial

*c/o Society for Advanced Amateur Research, Knollridge, KS 60606

[1] "The rf never gives up," Dr. J. B. Gooch, 1948.

[2] $NF = 10 \log_{10} 20 IR$

[3] From Thomas Swift, an early pioneer. n is a very positive integer.

countries and he has bounced signals off the moon. Where will the signals of future hams be found? Obviously either around the Earth or out in space. It was decided to try first for future signals still Earth-bound. The 14-MHz band seemed the logical choice, since it is obvious that in the future no one will be able to afford the real estate required for a good 40- or 80-meter antenna. And, too, present surveys show an increasing decline in activity in the "good old 20-meter band," so the QRM shouldn't be too bad.

The relatively minor problems with the converted transceiver were purely physical and technical and are of little concern to most radio amateurs. However, one aspect might be of interest. First tests at the remote field station were completely negative and a bit discouraging. Everything seemed to be working properly but absolutely no signals were heard. Was there a war? Had we lost the 20-meter band? Finally, after many hours of fruitless search, the unit was turned off. Just as it was turned off, a signal blasted through. Eureka! With the PV^n in overdrive it was running forward in time too fast for any possible signal copy! An additional control was added, to permit the operator to run out the oscillator to a future date and then lock it in to a normal light-velocity rate. This simple addition readily brought in signals from stations that weren't in the 1979 *Callbook*. (Can you believe WMØDCHG, or RU12OM?) "Reading the mail" on a number of QSOs, much discussion seemed to revolve around the relative merits of "panoramics" vs. "scanners."

A Test

It was decided to use a north-south orbit for the first CQ, since calculations indicated the magnetic field of the Earth would add an extra 37.4 dB of power, hopefully helping to compensate for energy loss through the time journey of our signal. After tuning up in a clear spot on the uncrowded band, it must be admitted that it was not without some trepidation that we ventured a short CQ. Suppose our work was for naught? Suppose we were on a one-way street again?

As the rig dropped back into the receive mode, it immediately became apparent that something was wrong. Smoke curled up from the unit just before it burst into flames!

While recuperating in the hospital, the author analyzed the incident and decided that he wasn't quite ready for FDX (future DX). Obviously his simple old-fashioned CQ on what seemed to be a clear spot was enough to precipitate a pile-up that his FDX receiver section could not handle. However, on the drawing board there is already a more-sturdy design. If that doesn't work it might be wiser, for the sake of science, to omit from his next signover, "Portable in Tibet."

Strays

OPERATION SANTA CLAUS IN DES MOINES

☐ The 30th annual "Operation Santa Claus" sponsored by the Des Moines Radio Amateur Association collected $7000 for needy families in the Des Moines, Iowa, area. Fifty-seven hams participated in the event. Proceeds aided 3300 people from 769 families. — *Bob McCaffrey, KØCY, Des Moines, IA*

FOOTBALL OR OSCAR?

☐ What do OSCAR command station operators talk about when they get together? When Bill Clepper, W3HV, journeyed to California for the Super Bowl he got together with Bud Schultz, W6CG, and George Dillon, W6ELT, and discussed OSCAR, of course. They did find time to attend the Super Bowl game, but most of their time was spent discussing OSCAR. One of the items discussed was the six-turn helix antenna that Bud and George built for 435 MHz.

These three AMSAT-ARRL volunteers are part of the worldwide team of command station operators. Dedicated to the preservation of our existing satellites, these operators have the equipment and expertise to keep the OSCAR satellites operating normally. Demanding as these jobs are, these amateurs still find time to operate through the satellites and give lectures about Amateur Radio and the Amateur Satellite Service. Want to join in? New satellites are on the horizon! Write today to AMSAT Hq., P. O. Box 27, Washington, DC 20444, or ARRL Hq., 225 Main St., Newington, CT 06111, for AMSAT membership forms. Help support the future of Amateur Radio. — *Bernie Glassmeyer, W9KDR*

FANCY 6-METER WAS CERTIFICATE AVAILABLE

☐ If you are a recent recipient of the 50-MHz WAS (prior to award number 360), we now have "fancy-lettered" 6-meter certificates available. To receive one of the newer certificates, send all the information that is typed on your original certificate to the Communications Department at ARRL hq.

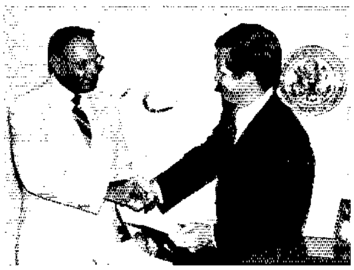
EXPERIENCE — THE BEST TEACHER

☐ Steve Flyte, K7SF, of Portland, Oregon, was recently able to put some of his 15 years of experience with Amateur Radio antennas to good use. Steve, who is an electronic news gathering (ENG) engineer with TV station KATU, ran into difficulties when setting up a microwave circuit to transmit video tapes. The circularly polarized feed section for the 4-foot dish antenna that is mounted on the roof of the mobile news van was missing. Without this component, the news van was out of business. A check of a local TV station and an electronics company did not turn up a replacement or substitute part.

Faced with certain failure, Steve found a short piece of RG-11/U coaxial cable in the back of the news van. He called back to the TV station and asked someone to check the proper focal length for the dish antenna feed section. It turned out to be about 22 inches. Remembering his years of Amateur Radio experience with dipoles and Yagis, Steve fanned the shield and center conductor on the end of the RG-11/U coax into a small dipole, each side being 3/4-inch long. He ran the coax through a small hole in the center of the 4-foot dish, pulled it out to 22 inches from the center and taped the little dipole in place. After some minor adjustments and tuning, a clear, fine-quality signal was being transmitted back to the TV station. A mixture of Marconi, Rube Goldberg and Steve's experience put the news van back in business.

BATTLESHIP OPERATION

☐ The Azalea Coast ARC, WD4ORA, will operate from the battleship *U.S.S. North Carolina* Memorial in Wilmington, North Carolina, from 1430 to 2200 UTC on April 12 and 13. Operating frequencies will be 25 kHz up from the lower edge of the General phone bands. QSL with s.a.s.e. to ACARC, P. O. Box 4044, Wilmington, NC 28403.



Charles Watters, W4RHE, left, receives a letter of appreciation signed by President Carter from Florida Congressman Bill Nelson. The letter thanked Charles for his "valuable work in maintaining communications between the United States and Iran during the recent upheaval last winter."

Over-the-Horizon or Ionospheric Radar

Here's the story of our powerful new neighbors in the hf spectrum. The new U.S. Air Force radar will follow a "good neighbor" policy.

By O. G. Villard, Jr.*, W6QYT

Front view of receiving antenna near Columbia Falls, Maine. V-shaped monopoles are driven with respect to a large ground screen (in the foreground); telephone poles support a vertical grid of wires forming a reflecting screen.

At one time or another, almost every user of hf has heard the insistent "knock-knock-knock" of the Soviet over-the-horizon radar. Now, it seems, the U.S. Air Force has begun a year of experimentation with an over-the-horizon radar of their own, located near Bangor, Maine. This article describes both the radar and the efforts that are being made to avoid interference to hams and other services. Some interference, however, may be unavoidable owing to sidelobes in antenna patterns and modulation waveforms. This article tells roughly what to expect, and whom to contact if you have a problem.

An event clearly impacting users of the hf spectrum, including hams, is the comparatively recent appearance of powerful over-the-horizon radars (OTHRs). Under development since the early 1960s, these devices are now approaching the operational testing phase, which means that signals much stronger than those of the past are being used. Furthermore, they tend to be on the air 24 hours per day. Because a perfect antenna and perfect receiver selectivity don't exist — particularly at hf — there may, alas, be instances of interference caused to other services by the radars, and vice-versa. Since the radars serve a useful purpose, and represent a considerable investment, they

*Senior Scientific Advisor, SRI International, Menlo Park, CA 94025, and trustee, W6YX, Radioscience Laboratory, Stanford University, Stanford, CA 94305

aren't likely to disappear overnight. It seems that the only reasonable attitude for hf operators like the writer is to learn what they are, how they work, and how best to live with them. It's a bit like the Loran A pulses on 160 meters — sharing is awkward, but it can be done.

OTHRs Described

Over-the-horizon radars use the ionosphere as a mirror to "see" around the curvature of the earth. They have a variety of uses, both civilian and military. At present, the Soviet Union is operating what sounds like a most potent one (the ubiquitous "woodpecker").[1,2] The United States Air Force has just placed into service an experimental facility in Maine which, if successful, will be expanded into two major facilities, one on the East Coast and one on the West Coast. The Australians have also been testing a prototype. In addition, lower-powered developmental sets such as the NRL (Naval Research Laboratory) "MADRE"[3] and the ONR (Office of Naval Research) Wide Aperture Research Facility[4] have been in sporadic operation for years.

Although there are obvious disadvantages, OTHR has certain fundamental attractions. First, it can cover an enormous area in comparison with line-of-sight radars, and do so from *one station*. Second, it has been estimated to be less than one-tenth as expensive as putting radar(s) in orbit. Third, OTHR can track aircraft targets right down to ground level, and for all practical purposes cannot be underflown. OTHRs can be used for tracking the eye of a hurricane traveling over water (see Fig. 1), for providing warning of regions of high winds and waves and the location of weather "fronts," for tracking aircraft and ships, and warning of the launch of ballistic missiles.

How OTHRs Work

The foregoing capabilities are impressive, and the story of how it is done is fascinating. The essential tricks are these:

1) The normal ionosphere proves to be much more stable than had previously been thought. The physical reason for this is that the incredibly tenuous ionized gas which does the reflecting actually has a molasses-like viscosity. There are daily tidal changes, of course. But over intervals of half an hour or so, the F layer at a given location is actually quite well-behaved. This is true in the sense that, in the absence of disturbance, the F layer can bounce a given signal in a nearly constant direction with nearly constant amplitude — just what is required for good radar operation. The regular E layer is even better behaved.

2) The way to take advantage of this useful characteristic is to separate the modes, or "hops," and to use the smallest possible number. This a radar can do by using its range resolution and by choosing the right radio frequency. Unfortunately, the traditional hf communicator cannot in general gain the same advantage, because he deals with essentially continuous signals and must operate on a few fixed, assigned frequencies where multipath propagation is present for a very large fraction of the time. This is why the radar possibility escaped attention for so many years; everyone knew that signals from distant shortwave stations fade comparatively rapidly, and that their direction of arrival constantly fluctuates. But until pulsed oblique sounders came along in the 1950s or thereabouts, there was no opportunity to separate modes and thus to observe how remarkably stable the individual ionospheric layers are.

[1]Notes appear on page 43.

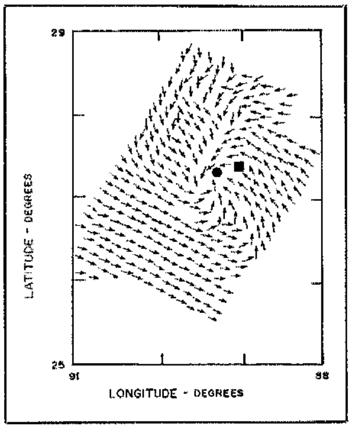


Fig. 1 — A hurricane in the Gulf of Mexico tracked in real time by an hf radar located in California. Wind directions, indicated by arrows, are determined by processing radar scatter from water waves. The round dot indicates the position of the hurricane eye as derived from the arrows; the square represents the best information available from the National Hurricane Center. (Hurricane Eloise, September 22, 1975, 2030Z. Plot courtesy of Dr. J. W. Maresca.)

3) Like any radars that must look down at the earth's surface, OTHRs receive enormous amounts of backscatter, both from land and sea. They have to be designed so as not to be overloaded by this clutter. Since targets of interest are normally in motion, they can be picked out by the Doppler shift of their echoes, even though the shift may amount to only a fraction of a hertz. Digital data processing makes possible both great dynamic range and remarkably fine frequency discrimination.

4) OTHRs make use of wide-aperture antennas to generate antenna beamwidths comparable with microwave practice, even though the wavelength is some 200 times as long! Since detection distances are so great, however, the distant area from which backscattered energy is received at any given instant (the resolution cell) may be 15 by 15 miles (24 by 24 km) in size, or larger.

5) One might think that to an hf radar, salt water would effectively be a smooth surface — at least in comparison with land characterized by trees, mountains and the like. But, as sailors know, the open sea is traversed by waves of all sizes, moving in a variety of directions. There will always be some that are moving directly toward the radar, and some that will be moving away. The radial direction is a preferred one insofar as the radar is concerned because energy scattered from such waves comes straight *back*, instead of going off elsewhere.

In the size spectrum of waves moving in these radial directions, there will always be a component whose length exactly matches that of the radio wave. Radio scattering from these length-matched ocean waves is very strong (perhaps 20 dB) in comparison with the ocean background, because scatter from them adds up coherently at the radar, and the radar pulse is long enough to include many such length-matched waves. (This is known as Bragg scattering; it is analogous to the method of operation of the diffraction grating in optics.) It turns out that clutter received by an OTHR looking at the ocean is comparable in strength to land clutter because of the Bragg effect, and its frequency spectrum contains just two lines, each Doppler shifted by the motion of the waves in the two radial directions! To an hf radar, the ocean is a moving target, and a fixed object, such as an island, stands out because of its lack of motion.

Ocean waves in the size range picked out by OTHRs have another valuable property: Their amplitude follows the local wind velocity very closely. (Sailors know very well how quickly a sudden wind increase is followed by appearance of a nasty chop.) Thus, these ocean waves can be used as tattle-tales to indicate to the distant radar operator both wind direction and speed. By fine-grain analysis of resonant ocean-wave scatter, it is possible to infer the size and to some extent the directional spectrum of all the ocean waves in the illuminated region.

Historical Perspective

Radars operating at hf date back to World War II. In those days, vacuum tubes developed for shortwave broadcasting were the only sources of high rf power. It is therefore not surprising that the earliest British radars worked in the high end of the hf band where they were bothered by what we now know to be over-the-horizon ground clutter. This actually led to wartime attempts to detect convoys approaching Britain by use of skywave propagation, but the problem wasn't understood well enough at the time and tests were dropped.

The U.S. and USSR apparently started to develop ionospheric radar at about the same time.[5,6] *QST* readers with long memories may remember an article on backscatter sounding which appeared in March 1952.[5] The cover photo of that issue was, in fact, a plan-position display of ground clutter as registered by a ham set converted into a crude rotating-antenna "radar." Such displays proved useful for study of the ionosphere, and a world wide chain of similar sounders was established during the International Geophysical Year.

To pick out aircraft target echoes having Doppler shifts of only a few hertz in the midst of such clutter required sophisticated technology. A "magnetic drum integrator" was developed in the 1960s by the Naval Research Laboratory and used in their pioneering MADRE radar — the first in the free world to show that the normal motion of ionospheric layers is small enough to support aircraft detection.[3] Not long thereafter, the Office of Naval Research-supported "WARF" facility in California showed that the same stability extends also to direction-of-arrival, thus making truly precision hf radar possible.[4]

Relatively little is known in the U.S. about the USSR's OTHR development effort over the years. It is possible that the Soviets were impressed from the very outset by military applications. Their present easily audible signals dubbed the "woodpecker," probably come from radar installations which for some types of targets (such as nuclear explosions) may well have a worldwide range.

CONUS OTHB

The U.S. counterpart of the woodpecker is still experimental. The first word of the name is an abbreviation for "*Continental U.S.*"; the "B" of OTHB stands for "backscatter," to distinguish it from another, earlier form of OTHR called "forward scatter." The mission of CONUS OTHB is to give early warning of bomber attack via the northeast oceanic approaches to the U.S. and Canada. It will do this by establishing a surveillance zone, or barrier, which is the solid-white region shown in Fig. 2. Since all aircraft flying over the water must routinely file flight plans in advance, those seen by the radar within the above zone are then compared with their reported plan; if a target or targets cannot be associated with such a plan, appropriate action is taken. The radar can go from a general search mode to a spotlight mode for a closer look if desired. Fig. 3 shows in more detail how the tracking would be done.

Although the Soviet radar transmits on-off pulses (a conventional approach that permits the transmitting and receiving functions to share one antenna), the U.S. radar employs separate transmitting and receiving sites so that the transmitter can radiate a continuous signal which is fm-modulated or "chirped" for range resolution.

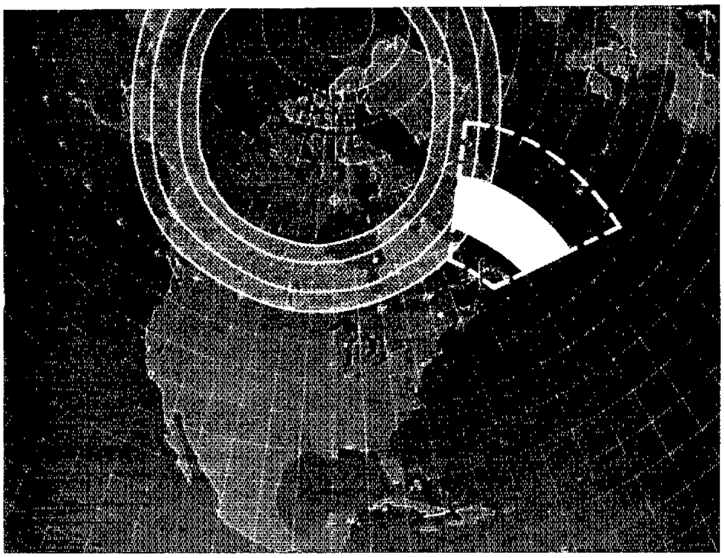


Fig. 2 — Solid-white region shows the coverage area of the USAF's CONUS OTHB experimental radar system, located in Maine.

The radar is located in Maine to place the barrier far enough away from the U.S. border for adequate warning time. Maine also provides a good test both of the extent to which "unknowns" can be discriminated from the very heavy North Atlantic air traffic, and the extent to which the radar can cope with occasional auroral disturbance in the northerly portion of its operating region. To this latter end, the receiving antennas have been provided with exceptionally good sidelobe discrimination.

OTHB Specifics

The relatively long wavelength used requires antenna dimensions of impressive proportions. For example, the broadside receiving array shown in the title photo, located at Columbia Falls, Maine, is about 4000 feet in length. Since mechanical rotation would hardly be practical, scanning is accomplished by digital beamforming and slewing. The beam is made unidirectional by means of a reflecting screen located about a quarter-wave behind the radiating elements.

Essentially the same design is used at the transmitting location, except that the transmitting beam is made wider so as to floodlight the area within which multiple receiving beams conduct a fine-scale search. The average transmitter power is roughly 1 megawatt.

It will be noted that the individual receiving-array elements are broad-band vertical elements over a ground screen. (The transmitter array is similar, except that it uses dipoles.) Thus the transmitted and received beams are fan-shaped, with only modest vertical directivity. This was a concession to economics. The radar must, of course, be able to operate at short ranges as well as long, and must cope with varying ionospheric layer heights. It would be nice to have vertical directivity and steerability, but the cost of the necessary towers and electronics was felt to be prohibitive.

Economic considerations have dictated the present operating frequency range — 6.7 to 22 MHz. It would be nice to be able to go both lower and higher, and perhaps this will be possible in the future.

Fig. 4 shows the frequency bands in which the radar is authorized to operate. Note that the amateur, as well as the maritime- and aeronautical-mobile bands (and several others) are specifically protected. Operation of the radar is permitted on a "noninterference" basis, which means that if there is a significant threat to any other service, something has to be done. The bands in which the radar *may* operate include such services as point-to-point teleprinter (whatever is left of it these days), shortwave broadcasting, and the like.

OTHB Operating Philosophy

Since the primary mission of the radar is to maintain a watch within the solid-white regions of Fig. 2, it must choose frequencies which (1) propagate into the region, and (2) are as free of interference as possible. The radar is, of course, computer-controlled and extraordinarily

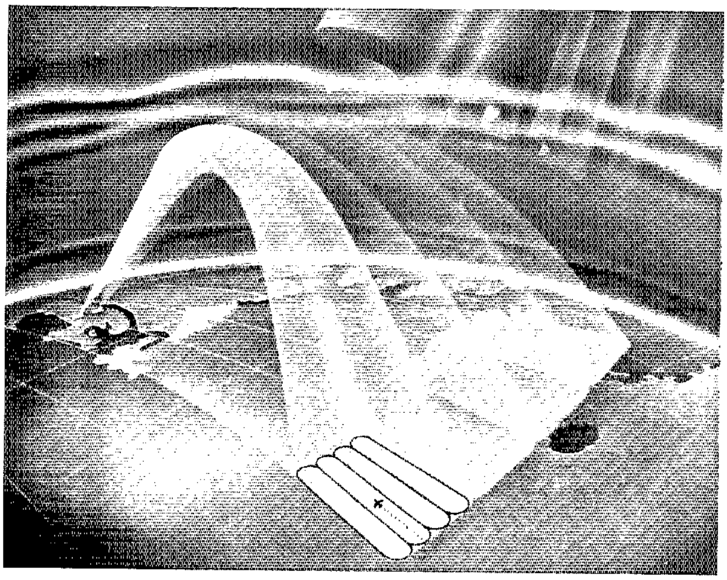


Fig. 3 — Closeup view of the way in which approaching aircraft would be tracked. Large squares are the regions illuminated by the transmitting beam; narrow strips are defined by receiving-antenna directivity.

flexible. It is provided with a low-power auxiliary sounder which repeatedly checks all the available frequencies to determine what propagation paths are present, what their loss is, whether they are adequately stable, and whether multipath is present. A separate facility automatically checks all the available channels for interference, measuring not only the level at any given instant, but also the time history of that channel's usage.

All these input pieces of information plus many, many more (such as worldwide geophysical data) are taken into account by the radar's main computer, to which, of course, is fed mission-related information. For example, how likely to be dangerous (on the basis of other information) is a given unknown reflection?

So long as it is performing its mission satisfactorily, the radar's operating guideline is to cause as little interference as possible. Thus, when propagation is good, it can reduce power. (Much of the time, the full transmitter power of an OTHR is not needed. It is, of course, required when propagation loss, e.g. absorption, and QRN levels are high.)

The actual method of operation is approximately as follows. First, the useful band of frequencies is determined from soundings and other data. Then the open allocated channels within that band are identified and ranked in order of desirability. Low path loss, low multipath and low noise are the chief criteria. The radar then comes up on the most desirable frequency and continues there until conditions change or interference develops, at which point is instantaneously changes to the frequency which at that moment is at the top of the continuously updated "most desirable allowable frequency" list.

Often the radar will shift from an otherwise excellent frequency in order to resolve range or Doppler (velocity) ambiguities. A practical problem is coping with multipath. The ionosphere — even if there is only one layer doing the reflecting and thus one "hop" — can support essentially four paths by which signals can travel between one point and another. These are the lower ray, the upper ray, and the two magnetoionic versions of each of these, the so-called O-mode and the X-mode. Fortunately, the latter two show up mainly as polarization rotation; but even so, an ionospheric radar under even simple conditions can normally receive two echoes for every target. It might be thought that such proliferation would cause intolerable confusion, but actually there are many remedies. Changing the frequency slightly is one.

Co- or adjacent-channel interference is perceived by the radar as another form of "noise." OTHRs are designed to work through some level of interference, no matter what its origin. For example, there are circuits which convert interfering carriers (from Teletype or shortwave broadcasting stations, for example) into what the radar receiver perceives as relatively harmless broadband noise. This can be done because the radar has full control of its transmitted signal and receiv characteristics.

How to Recognize Radar Interference

There is little problem in recognizi the Soviet OTHR signals, so long as th continue the present format consisting millisecond-length pulses at a rate of per second. When these first came on tl air, they seemed to come up on almost a frequency, often for long periods of tim to the great annoyance of almost all use of the hf spectrum. The situation is no much better; the radar seems to respe the bands occupied by low-power statio and even the amateur bands, althou there are occasional transgressions. A m jor change is that they no longer stay f very long on any given frequency; th constant shifting around makes it possib for fixed-frequency users to get essenti traffic through, albeit with occasion delays.

The American radar signals, by way c contrast, will sound on an a-m receiv more like power-line hum, but at any or of several modulation frequencies from 2 Hz to 60 Hz. They should be much le irritating than on-off pulsing. Becaus they will be coming from a sourc physically closer to some U.S. amateur however, they may be troublesome whe propagation is exceptionally good. Th essential problem is illustrated in Fig. 5 As everyone knows, it is impractical t build a receiver with a passband havin perfectly square sides. Similarly, it i unfeasible to transmit a waveform havin a spectrum with perfectly square sides. A a result, when a radar such as CONU OTHB operates adjacent to a ham ban and its signals become strong enough there may be enough side-frequenc spillover to be bothersome.

The radar, of course, radiates an in tense beam in the forward direction. N American amateurs will be located in th CONUS OTHB illuminated area (unles of course they are operating maritime o aeronautical mobile). Since the transmit ter beam (like the receiver) is formed by broadside array of elements, an almos equally strong beam would appear in th reverse direction were it not for the actio of a reflecting curtain, which cuts th backward radiation by some 20 dB, th exact amount depending on the fre quency. Thus, amateurs off the back o the transmitting array in the appropriat direction will be the most likely to en counter interference when propagation i strong.

What To Do If Interference is Encountered

First, be sure that the troublesom signal really comes from Maine. This car be checked by switching between anten nas, or by rotating a beam. *Second,* check the center frequency of the signal by tuning outside of the band using a

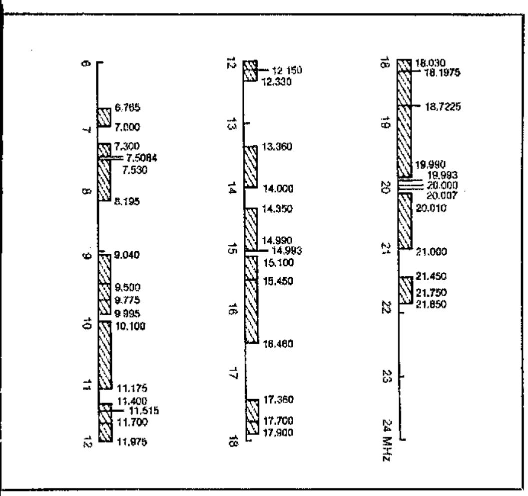


Fig. 4 — The crosshatched frequency intervals are the ones expected to be used on a noninterference basis by the CONUS OTHB.

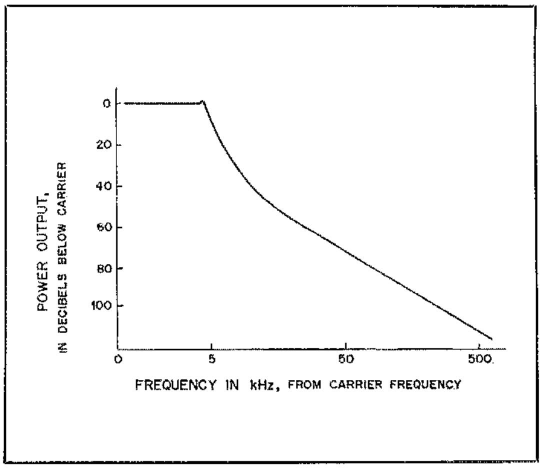


Fig. 5 — Plot of the frequency spectrum of the experimental OTHB radar, in normal operation. Note the very rapid dropoff at the edge of the band.

separate receiver if necessary. If the center frequency falls inside the band, report it to the FCC at once. But if the center frequency (that is, the frequency at which the signal is strongest) is clearly outside the band, then proceed as follows. *Third,* check the rate at which the interference falls off as you tune into the band from the band edge. If it falls off rapidly, that may well be the normal situation. In such a case there isn't much that can be done. The radar should not stay on any one frequency very much of the time. If you are bothered by it for more than four or five minutes, by all means do complain, as that shouldn't happen either. *Fourth,* if the interference seems to fall off quite slowly as you tune into the band, the problem you are experiencing may well be caused by cross-modulation of the front end of the receiver. Checking with a neighboring ham having a different type of receiver would be useful in such a case. Many solid-state receivers are easily overloaded by strong out-of-band signals. A simple attenuator, if not already provided, can work wonders. A better but somewhat more complicated method is to provide additional rf selectivity — a high-Q tuned circuit which helps restrict reception to the ham band in use. There are commercial preamplifiers on the market which can perform this function. *Fifth,* if the interference is really broad-band, check to make sure there are no rectifying contacts anywhere in or close to your station that are causing cross-modulation or harmonic generation. Corroded fence wire, tired TV antenna guy wires, etc., are often culprits. Such secondary signal sources can be searched for by use of a portable receiver; their signal strength should increase very rapidly as the source is approached. Shaking possible offending wires will often cause a telltale change in signal intensity. Checking with a neighboring ham often helps diagnose these problems.

Finally, if the interference persists in spite of all the above, maintain an accurate log of times and frequencies and contact your local FCC field office. The Air Force has made the necessary arrangements to have reports of actual interference by the OTHB handled promptly and expeditiously. A special board of QRM experts has been set up as overall interference coordinator for the CONUS OTHB. This board will appreciate your report and will do everything possible to assist you. Its address is: OTH Radar Office, U.S. Air Force Electronic Systems Division, Code OCUE, Hanscom AFB, MA 01731.

Amateur Help Requested

CONUS OTHB is the most powerful radar of this type ever to have been operated in the U.S. Interestingly, a number of U.S. experimental radars (WARF, MADRE, White House) all having a power output about an order of magnitude lower than CONUS OTHB, have been operated for a number of years with practically no reports of interference. However, these radars have not been obliged to operate 24 hours a day in all kinds of ionospheric conditions. In spite of careful electromagnetic compatibility studies made in advance, there is always a chance that something unexpected may occur. As a result, the U.S. Air Force will welcome amateur reports of its signals and their apparent level, whether there is interference or not. Reports of signal strength (and time), with antenna characteristics included, will be of value in checking propagation and in relating this to radar performance.

Acknowledgement

The author wishes to thank the Electronic Systems Division of the U.S. Air Force for assistance in the preparation of this article and for permission to publish it.

Notes

1 Jane's *Weapon Systems* 1979-80 edition, suggests that there are "up to four" stations, and that the powers are in the "20 to 40 megawatt" range. (Jane's Yearbooks, London. McDonald and Jane's Publishers, Ltd., Toulton House, 8 Shepherdess, London N1 7LW.)

2 Cohen, "Dateline . . . Washington, D.C.," *CQ,* August 1979, p. 60.

3 Headrick and Skolnik, "Over-the-Horizon Radar in the HF Band," *Proceedings of the IEEE,* Vol. 62, No. 6, June 1974.

4 Washburn and Sweeney, "An On-Line Adaptive Beamforming Capability for HF Backscatter Radar," *IEEE Transactions on Antennas and Propagation,* Vol. 24, No. 5, September 1976, pp. 721-732.

5 "Instantaneous Prediction of Radio Transmission Paths," *QST,* March 1952, pp. 11-20.

6 Kabanov and Osetrov, "Backscatter Ionospheric Sounding," *Moscow,* The Soviet Radio Press, 1965.

An Oriental Wedding

Here's a shot of the happy couple. Years of wedded bliss are in store for the well-matched pair!

Here's an inexpensive way to "marry" a remote VFO to your FT-101ZD. Not only are the bride and groom happy with the arrangement, but so is the best man — you!

By Paul K. Pagel,* N1FB

One of the currently popular amateur transceivers on the market is the Yaesu FT-101ZD.[1] Billed as the "little brother" of the FT-901DM, the '101 offers many of the features of its larger relative while some of the frills have been eliminated. This results in a substantial savings to the would-be purchaser. The itch to bring a new rig into the shack had been needing a scratch for some time. When the neat gray box was seen face-to-face, I knew trading time was at hand. Now, how about a remote VFO? Well, that took a little more thought.

The companion VFO for the FT-101ZD is the FV-901. This unit was designed to mate also with the FT-901DM and the price tag shows it — over $400! But were the scanning and memory features of the FV-901 really needed? Not really, just the basic VFO. A search disclosed that a number of remote VFOs are available that cover the same basic frequency range of 5.0-5.5 MHz, some with a bit of overlap at the band edges. Any of these units (such as the Heath series) can be adapted to work with the '101ZD. Through the goo graces of W1FB, I acquired a Kenwoo VFO-520 he had in his shack. Now all tha had to be done was to get the combinatio running!

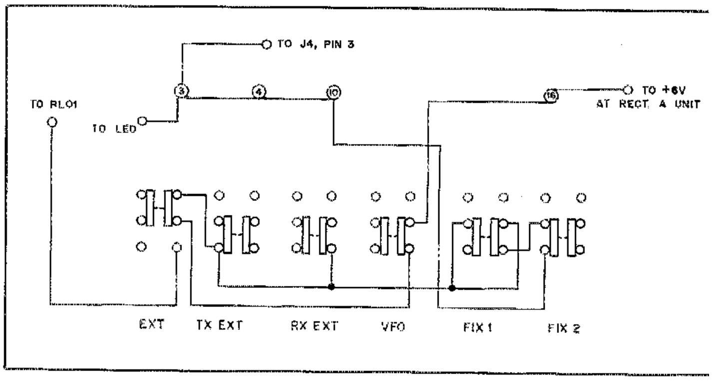


Fig. 1 — A simplified wiring diagram showing how the operating voltage is applied to the remote VFO jack in the FT-101ZD. Note that the EXT switch has been selected and the VFO switch is "out."

*Assistant Technical Editor, *QST*
[1]Footnotes appear on page 45.

Table 1

Pin Connections and Voltages Present at the Pins

FT-101ZD Pin no.	*Voltage present*	*VFO-520 Pin no.*
1	Remote VFO signal	1
2	Cable shield	2 and 3
3	+6 V	9
4	12.6 V ac (HEATER on)	4
5	+ 12 V dc (on xmit)	5

Minor wiring changes are required at the sockets of the two units; refer to the text for clarification.

Table 2

Switch Positions During Operation

FT-101ZD	*VFO-520*
VFO	Inoperative
RX	REC or REC/XMIT
TX	XMIT
EXT	REC/XMIT

Table 3

Frequency Coverage of the Two VFOs

Band Segment	*FT-101ZD*	*VFO-520*
160	1.4607 - 2.0284	1.4775 - 2.1351
80	3.4609 - 4.0286	3.4777 - 4.1353
40	6.9612 - 7.5290	6.9780 - 7.6357
20	13.9612 - 14.5290	13.9781 - 14.6357
15	20.96. - 21.5288	20.9779 - 21.6356
10A	27.9607 - 28.5285	27.9776 - 28.6352
10B	28.4615 - 29.0292	28.4784 - 29.1359
10C	28.9614 - 29.5292	28.9783 - 29.6359
10D	29.4609 - 30.0287	29.4778 - 30.1354

The result is similar to a mixed marriage of a couple of countrymen. The interconnecting cable reflects a bit of individuality at each end. Nevertheless, as in all good marriages, a little "give and take" is necessary. So, too, compromise is made here to the delight of everyone concerned. Funny enough, the 9-pin plug (found in the junk box) that was used to mate with the Kenwood VFO was from an ICOM unit. Matchmakers and modifiers are a heartless group!

The Circuitry

A glance at the diagrams is worth a thousand words. At first it may seem that the switching scheme of the '101ZD is a bit confusing, but if one remembers that the switches are mechanically interlocked, it should become easier to trace the paths. The switches shown in the FT-101ZD diagram are arranged such that all are in the "out" position with the exception of the internal VFO button which is "in." The diagram of Fig. 1 shows the '101ZD switches set with the EXT button depressed and the VFO button "out." This allows +6 V to appear at J4, pin 3, to power the remote VFO. This voltage is also applied to the proper LED on the '101 display panel. The TX EXT and RX EXT buttons also route the required operating voltage to the remote VFO socket. With these switching choices, RL01 of the transceiver enters into the picture as well.

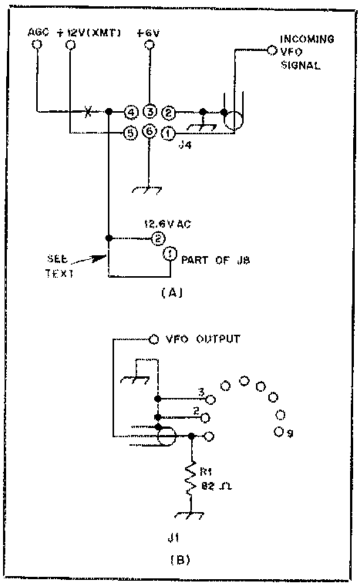


Fig. 2 — The wiring changes to J4 of the FT-101ZD may be seen at A. B shows the wiring addition to J1 of the VFO-520. Pins 1 and 2 of J8 are jumpered by means of the external plug supplied with the FT-101ZD. R1 is a one-half watt resistor. A 9-pin miniature plug (Amphenol 86-897 or equivalent) is used to mate with J1 while a 6-pin DIN plug (GC Electronics 18-106 or equivalent) is mated with J4.

The agc function available at pin 4 of J4 in the '101ZD is not needed. The existing wire at this pin may be removed, covered with insulated sleeving and tied back. A new wire is connected between pin 4 of J4 to either pin 1 or 2 of the accessory socket, J8. (These pins are jumpered by means of the external plug on the '101ZD.) This added wire will be used solely to supply ac voltage to the dial lamps on the remote VFO. Wired in this manner, the remote VFO dial lamps will not be lit unless the HEATER switch on the 'ZD is switched on. If it is desired to have the lamps lit any time the transceiver is turned on, regardless of the HEATER switch position, the wire from pin 4 of J4 should be run to location H on the rectifier A unit.

Pin 3 of J1 in the VFO-520 must be grounded to complete the circuit for the lamps and the internal relay. Interconnections for the two units are shown in Table 1 and the required socket wiring changes are shown in Fig. 2.

It was found that the output level of the '520 VFO was a bit higher than that of the '101ZD. This became evident during transmission and was spotted when checking a cw carrier on an output monitoring 'scope while switching back and forth between the internal VFO of the 'ZD and the remote '520. Installation of an 82-ohm, 1/2-W swamping resistor across the output of the '520 VFO (at J1) brought the level to that of the 'ZD VFO. If the output level of the remote VFO isn't decreased, the drive level on the '101ZD will have to be adjusted when switching between VFOs for transmitting.

With these changes accomplished, make up the connecting cable using the appropriate connectors. A cable length of no more than 3 feet (900 mm) is recommended. Caution should be observed if the type of DIN plug specified is used. The pins are mounted in plastic and even a 25-watt soldering pencil held too long a time on the pin will melt the plastic allowing the pin to move. This will result in misalignment of the pin.

Operation

The function switch of the VFO-520 may be left in any position when not in use. Unless the remote VFO is specifically chosen by the delegation switches on the FT-101ZD, the remote VFO will not operate. Naturally, it must be in any operative position for it to be functional when chosen. In other words, if you have the remote VFO in the off position and select any of the external VFO positions on the 'ZD, you'll have no VFO input signal. The display will read a strange 9-MHz frequency to let you know that you goofed! By referring to Table 2, you can correlate the transceiver/VFO switch positions needed for proper operation. Such operation is indicated by the LEDs on both the transceiver display panel and the VFO dial face. When the RIT button is pressed, the appropriate LED should light and the RIT function be enabled.

As shown in Table 3, the frequency coverage of the VFO-520 is a bit greater than that of the '101ZD on the upper frequency ends of each band segment. The FT-101ZD, on the other hand, has more spillover on the lower ends of each band. By alternating between the two VFOs, you can average about 123 kHz more coverage on each band segment. This extended coverage should prove of interest to MARS operators.

It is hoped that this presentation will provide an incentive for others to follow suit.[2] The use of 5.0-5.5 MHz as a VFO frequency is rather common. Similar applications could be made to other manufactured or home-built gear. Often, a bit of time spent in thought and with a soldering iron in hand can wind up saving a fellow a lot of money. Now — with all that money I've saved — where's that ad for the general-coverage receiver?

Notes

[1]DeMaw, FT-101ZD, "Product Review," *QST*, December 1979.

[2]At the time this "marriage" occurred, the only companion VFO for the FT-101ZD was the FV-901. Recently, Yaesu has announced the availability of the FV-101Z at somewhat lower cost.

Technical Correspondence

Conducted By
John C. Pelham,* W1JA

EXTENDING TRANSMATCH RANGE

☐ When trying to tune my balanced 300-ohm feeders with a Dentron 160-10AT Transmatch on the low end of 80 meters, I found that the output capacitor "wanted" to be at more than the maximum capacitance available. My first thought was to add a fixed padding capacitor of about 500 pF with a high-voltage switch to put it in parallel with the output capacitor when needed. However, I came upon a simpler solution which requires no modifications at all.

In tuners like the Dentron, Heath, Ultimate Transmatch and others, the output capacitor is connected to the single-wire antenna terminal. This is then connected with an external connecting link to one of the balanced feed terminals. By substituting a small air-wound coil of about 2.4 μH for the link (as shown in Fig. 1), the effective value of output capacitance can be increased. The reasoning behind this is as follows: The coil is in series with the output capacitor, which has a maximum value of approximately 500 pF in the Dentron tuner. The resonant frequency of this series L-C combination is just above 75 meters, at 4.6 MHz. A series circuit just below resonance behaves like a capacitor of very low impedance. This is another way of saying that it behaves like a large value of capacitance, larger than the actual capacitor alone.

At 3.5 MHz the effective reactance of this series L-C combination is

$$X_{net} = X_L - X_C$$

$$= 2\pi(3.5 \times 10^6)(2.4 \times 10^{-6}) - \frac{1}{2\pi(3.5 \times 10^6)(500 \times 10^{-12})}$$

$$= 52.8 - 90.9 = -38.1 \text{ ohms.}$$

This net capacitive reactance is equivalent to a capacitor of value

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(3.5 \times 10^6)(38.1)} = 1190 \text{ pF.}$$

In my case the coil was a length of B & W no. 3014 Miniductor stock 1.75 inches (44.5 mm) long, 1 inch (25.4 mm) in diameter, 8 turns per inch. It is left connected on both 80 and 40 meters, but should be disconnected and the link replaced for operation on the higher frequency bands where the coil reactance becomes quite high. It is well to remember, however, that very high voltage can exist at these terminals. Make sure that the transmitter is turned off. Don't make the mistake of leaving the rig on VOX when changing connections on the antenna tuner; the more you yell, the more you'll get zapped! If the output capacitance of the tuner is other than 500 pF, choose L to resonate at a frequency between 4.5 MHz and 5.0 MHz. The exact value is not critical. — *Jacob Z. Schanker, W2STM, 105 Colony La., Rochester, NY 14623.*

*Asst. Technical Editor, *QST*

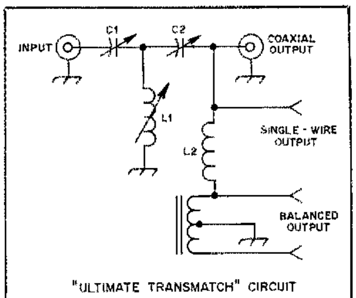


Fig. 1 — A small coil, L2, is added to the basic Transmatch circuit when needed to increase the effective value of output capacitance.

A TUNE-UP BRIDGE NOTE

☐ I built the bridge described in "Tune Up Swiftly, Silenty and Safely," in December 1979 *QST*. I found the circuit to be an excellent QRM-reducer. It allowed me to tune up with 250 mW instead of the much higher power level usually used.

During initial tests of the bridge I noted a problem, however. I conducted a response test of the toroidal transformer used in the bridge with a spectrum analyzer and a signal generator. The results indicated a response rolloff on 40 and, especially, 80 meters. The accepted procedure when designing broadband transformers is to use a reactance value of five times the circuit impedance for good low-frequency response. This would require a secondary reactance of 250 ohms (5 × 50 ohms). I calculated the inductance of the secondary as shown in the article to be 0.57 μH, or 12.5 ohms of reactance at 3.5 MHz. This is far below the ideal value of 250 ohms.

My solution was simple: Increase the reactance of the transformer secondary to at least 250 ohms at 80 meters. This was done by using a toroid of higher permeability. A Ferroxcube type 3E2 0.38-inch (9.65-mm) core was on hand, so I used it to test the idea. I didn't measure the inductance of the coil but would have to say it was quite high. Tests indicated that the useful low-frequency response of the transformer had been extended to 500 kHz, and the upper-frequency limit was 100 MHz. If the type of core I used isn't available, FT23-43 or FT23-61 cores should work as well for power levels of 100 watts or less. Use larger cores for higher power levels. — *Kenneth E. Stringham, Jr., AE1X, 13 Linden St., Attleboro, MA 02703*

[Editor's Note: Also see "A Useful Meter Amplifier" in the "Hints and Kinks" section of this issue.]

AN ANTENNA-PRUNING SHORTCUT

☐ I believe most hams use the formula $\ell = 468/f$ to determine the correct half-wavelength of wire for a dipole. Many times when this length of wire is installed in its final location, checks may indicate a resonant frequency quite different from what was intended. The question then is how much wire to add or subtract to bring resonance to the desired frequency. Rather than haphazardly adding or subtracting wire, requiring many raisings and lowerings of the antenna before a final length is determined, I have found the following method quite satisfactory and less left to chance.

As an example, say a half-wavelength dipole resonant at 7.05 MHz is desired. 468 divided by 7.05 gives 66.4 feet. However, when the antenna is in its final location, a check with an SWR bridge reveals a resonant frequency of 7.15 MHz. Multiplying the original 66.4 feet times the actual resonant frequency of 7.15 MHz yields 475, a new constant to use in the formula in this particular installation; $\ell = 475/7.05 = 67.4$ feet. If the original short dipole is now lengthened to 67.4 feet, the resonant frequency will be very close to the desired 7.05 MHz. — *Joseph H. NeCamp, W4JBQ, 1728 Highland Pike, Fort Wright, KY 41011*

ABSOLUTELY CLICKLESS KEYING?

☐ In the past several months, subjective cw listening tests on the new breed of hf transceivers have been disappointing. Most of them have slight to severe clicks, especially when they are used with a power amplifier. You are to be congratulated for publishing oscilloscope waveform photos for the Yaesu FT-101ZD (December 1979 *QST*) and the Ten-Tec Omni D (January 1980 *QST*). Unfortunately, none were shown for the FT-901DM, IC-701 or TR-7, reviewed earlier.

Restricting my comments to the TR-7, FT-101ZD and Omni D units (just haven't run into many fellows using the '901 or '701 units, or perhaps they have clickless keying and are not noticed), my observations are that almost without exception their key clicks are noticeably more prevalent as compared to the older units such as the Drake T4-X or the Collins 32S-3 transmitters. From the keying waveforms of the FT-101ZD and Omni D, it is no wonder one hears clicks from these units. All it takes is a little hardening of the keying through an amplifier or a minor misadjustment and one has almost a square wave on the "break."

In reference to comments on page 48, January 1980 *QST*, under Fig. 3, I believe you are just a wee bit off base. Ideally, 5 ms from start of carrier to full carrier on the "make" and from full to zero carrier on the "break" will result in clickless keying. But this time span should not be measured from the time one presses or releases the key! As a more authoritative source, let me refer you to any one of the ARRL Handbooks under the chapter "Code Transmissions." The figure 5 ms is again mentioned as the time for rise and decay times referenced to the carrier, not to the keying circuits.

Thus I feel you should revise your statement, as this will mislead many amateurs into thinking their new and fancy rig has "absolutely clickless keying" when this is not true at all. One or two ms rise and decay times are just not enough. — *H. Dale Strieter, W4QM, 928 Trinidad, Cocoa Beach, FL 32931.*

[Editor's Note: OM Streiter's letter is one of several received commenting on the appearance of the cw keying waveforms in the "Product Review" column; the response has been quite favorable. Perhaps others have misinterpreted the caption referred to in Dale's letter. To further clarify the statement, the 5-ms make and break (rise and fall) time constants referred to are meant to apply to the time it takes the actual waveform to rise from 10 percent to 90 percent or fall from 90 percent to 10 percent of its maximum amplitude. It does not apply to the time between the make or break of the key and the generation or degeneration of the wave.

It is unfortunate that many amateurs do not know what their on-air signal sounds like since they have no means of monitoring it or haven't taken steps to check it. Readers may be interested in reading "Why Key Clicks?" by W1DF, in the October 1966 issue of *QST*. — *Paul K. Pagel, N1FB, Product Review Editor, QST.*

TUNED FEEDERS ARE BETTER

☐ I often wonder why most antennas described in books and articles use coaxial feeders when tuned feeders of parallel-conductor line work so much better. They permit the use of an antenna system on several bands, with the added benefit of gain (compared to a dipole) on the higher frequency bands.

An example is the article, "Better Results with Indoor Antennas," in October 1979 *QST*. I liked the way author Brown discussed comparing antennas and the variables involved. The "resonant breaker" is an interesting and useful device. However, I suggest that Mr. Brown use a multiband antenna with tuned feeders in his attic instead of the coaxially fed trap antenna described in his article. If an antenna 20 feet (6.1 m) in length on each side of the feed point (the approximate length of his trap antenna) were installed, on 15 meters it would be a collinear array of approximately two half waves in phase with a gain of 1.8 dB over a dipole. On 10 meters the antenna would be an "extended double Zepp" collinear array with a 3-dB gain advantage over a dipole. On 40 meters the antenna would work as well as the trap dipole. The antenna would also work very well on 20 meters and be usable on 80 meters, two bands not covered by the trap dipole.

Since low SWR has become somewhat of a fetish among amateurs, many of them are using coax-to-coax antenna tuners to reduce the SWR. They don't seem to mind the extra knob-twisting required. If they used balanced tuned feeders they could enjoy the advantages of a truly efficient mutiband antenna system. A coax-to-coax tuner can be easily adapted for use with balanced feeders by adding a 4:1 balun such as described in the ARRL Handbook or Antenna Book. — *Bill Stocking, WØVM, 1030 Weidman Rd., Manchester, MO 63011*

ACCURATE TRANSISTOR VOLTMETER CORRECTIONS

☐ I made two errors in my article, "An Inexpensive High-Z Accurate Transistor Voltmeter," which appeared in December 1979 *QST*. The value of R13 in Figs. 2 and 3 should be 2.4 kΩ *only*, not 2.4 kΩ in series with 100Ω.

Also, unless R21 and R22 of the calibration circuit are selected carefully, it is possible to get a very high error in the calibration voltage. I suggest that the circuit shown here in Fig. 2 be used instead. Adjust the 500-ohm potentiometer for an output of exactly 100 mV, and calibrate the voltmeter on the 100-mV range. — *R. E. Barber, G3NEF/ZC4RE, 7 Northern Ave., Henlow, Bedford, England*

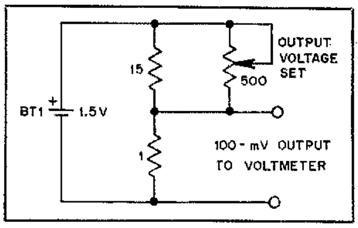


Fig. 2 — A modified calibration circuit for the G3NEF voltmeter. All resistances are in ohms.

CLOTHES-DRYER QRN

☐ For quite some time I'd been having electrical noise interference on the 10- and 15-meter bands. The noise would be on for about six seconds and off for about 20 seconds. It repeated this pattern for many hours. It was present some days for most of the day, lasting well into the night. On other days it was totally absent. I enlisted the help of the local power company to track it down. They used a receiver with a directional antenna.

It turned out to be an old gas clothes dryer with a gas pilot, located about 300 feet from my station. A defective solenoid was the cause; when the dryer would call for heat, the voltage would arc across the open solenoid coil! The main burner would still operate. A large family with lots of clothes to dry was the reason that the noise was present for such extended periods. — *George C. Alich, WØLNT, 924 Bayard Ave., St. Paul, MN 55102*

Feedback

☐ There are three errors in Fig. 1, page 45, of "A Static Morse Keyboard," January 1980 *QST*. Directly under Q1, a wire should be added from the anode of the left-most diode to the base of Q1. A 100-kΩ resistor should be added from the number 12 "B" coordinate line to ground, on the anode side of the diode. In keeping with *QST* style, a connection dot should be added where the cathode of the fifth diode up from the bottom of the schematic meets the vertical line to the right.

☐ In the March 1980 *QST* article, "Microcomputers and Radio Interference," the dimensions given for the third-stage-effort enclosure should have been 3 × 7 × 12 inches.

☐ An error exists in Fig. 3A of "A Simple and Sensitive Impedance Bridge," March 1980 *QST*, page 30. C1 should be placed across the output of the bridge at points X and Y.

☐ In "A Cheapy-Charger for NiCad Batteries," February 1980 *QST*, the charging-current table mentioned in the text of the article was inadvertently omitted. It is given here.

Table 1

Suggested Trial Charging Currents for Cells with Unknown Characteristics.

Cell Size	*Charging Current*
D	60 mA
C	50 mA
AA	25 mA

☐ The new ARRL *Advanced/Extra Q and A Book* has two errors in the Advanced section on electrical principles. In Q. 107, delete the work "peak" or its abbreviation wherever it occurs in the question or the answer. The power dissipated by the resistor is 1 watt. In Q. 113, +30 dBm is 1 watt, not 100 watts as printed. The PEP of a multiple-tone (equal-amplitude) signal equals the rms power of any single tone times the *square* of the number of tones. The "Technical Correspondence" section of May 1980 *QST* will contain a letter detailing these calculations.

☐ The "Stray" item on page 20 of March *QST* mentioned that WA3ZRY had the misfortune of having his home — and QSL card collection — gutted by fire. WA3ZRY is Arthur E. Smith, of 112 Two Line Rd., Telford, PA 18969. The name and address given in the March issue were incorrect. If you have worked WA3ZRY, please send duplicate QSLs to Art at the above address.

☐ An omission occurred in "The WARC Warriors" (March *QST*, page 60). Mr. R. H. Robinson, W4ZR, is a contributor of $100 to the ARRL Foundation WARC Fund.

☐ In paragraph 3 of "FM/RPT" (February *QST*, page 83) 300 characters per *second* (cps) should have been 300 characters per *minute* (cpm) and 550 cps should have been 550 cpm.

☐ The publisher and editor of *RTTY Journal* ("Correspondence," February *QST*, page 77, "Special Techniques" Returns) is Dee Crumpton, P. O. Box RY, Cardiff-By-The-Sea, CA 92007.

☐ John L. McCarthy, W9OTE, was inadvertently listed in the March "Silent Keys" column.

☐ In "A Universal Digital Frequency Readout," January 1980 *QST*, a few errors occurred in Fig. 2 on page 13. U3 is a CD4060, U14-U17 incl. are 74LS190 and U10-U13 incl. are 9374 ICs. All diodes are 1N914 or 1N4148.

Product Review

Conducted By Paul K. Pagel*, N1FB

The HAL DS3100 ASR Video Display Terminal

The HAL DS3100 ASR is a tri-mode terminal capable of sending and receiving Morse, Baudot RTTY (with an optional demodulator) and ASCII. It's the latest addition to HAL's lineup and is their "big gun." Unlike a big gun, however, this terminal is q-u-i-e-t. Hardly a sound comes from the neat-looking brown and tan unit as it quickly goes through its paces; just the soft rattle of the keyboard and the sound of the built-in monitor (active during Morse and for certain line indications), which may be hushed to a low-level mewing. During RTTY operation, there are no whirring motors, slamming carriages, clunking line feeds or the whack of type faces on ribbon and paper. Instead, a restful and easy-to-read green phosphor display silently greets the eye, telling you not only what you're receiving but what you're transmitting, as well as a multitude of terminal status reports including the date and time.

The DS3100 arrived for a review complete with the ST-6000[1] RTTY demodulator and a set of cables prepared for connection to my transceiver. (The customized cabling is an extra-cost option.) A loose-leaf binder contains the instruction manual, and a handy pocket reference highlights the important phases of system operation. Thus, one need not consult the instruction manual for its detailed information when one simply desires to know a key function, for instance. The system interfaces with the outside world by means of RS232C levels as well as the standard high-voltage RTTY current loops. Transistor switches are also provided to key either negative or positive circuits simultaneously.

The 12-inch diagonal measure screen of the monitor (which mounts atop the keyboard assembly) displays a total of 24 lines of 72 characters each in a split-screen format. Generally, the upper 12 lines show received characters and the lower 12 are assigned to text that is to be transmitted. The received text is presented with a brighter intensity than the keyboard-generated text. The display may be altered to devote the entire 24 lines to received text or view operator-selected portions of either the receive or transmit buffers. All data passes through the buffers. Received data is stored in a 150-line buffer, and transmit text in a 50-line buffer. The screen is merely a "window" used to view either storage area. Each displayed line of text is numbered at the left-hand margin of the screen. The right-hand side of the screen keeps the operator informed of the terminal status by means of 13 status indicators. Two transmit buffer cursors show the transmit-output location and the keyboard-entry location. A third cursor indicates where the next received character will be placed.

At the keyboard, you may choose: Morse at speeds from 1 wpm to 175 wpm; Baudot RTTY at 45 to 100 baud; ASCII at 110 to 9600 baud, all both send and receive. With the KOS

The HAL DS3100 ASR Video Display Terminal. This completely buffered terminal offers a multitude of features for completely automated transmission and reception of Morse, Baudot and ASCII RTTY.

(Keyboard Operated Switch) and the KY (KeY switch) features, receive/transmit and auxiliary-function switching is done automatically; no need for external PTT or foot switches.

If you're not a good typist, the '3100 will make you appear to be a "pro." You need never make an error again — that is, at least so that anyone would notice! Hit the wrong key? Simply go back and correct the error before it is transmitted. You can prepare a complete transmission while receiving then simply sit back and watch it "roll off your fingertips." If typing in real-time, SYNCHRONOUS IDLE will make it appear as though you're thinking of something profound to say while all the while you're looking for the right key! SYNC IDLE works not only in ASCII and Baudot modes, but Morse as well appearing as BT (- · · · -).

QBF (Quick Brown Fox/1 - Ø) and RY test messages are available at the touch of a key. Selectable USOS (UnShift On Space), automatic generation of CR (Carriage Return) and LF (Line Feed) and the non-overprint features help eliminate garbled messages. WORD WRAP-AROUND is a non-overprint feature which transfers all characters following the last space to the following line to prevent splitting of a word.

There is a total of 10 different 32-character messages which may be programmed and used as desired by the operator. Two of these messages may be saved even during power-off periods since they are part of the systems EAROM (Electrically Alterable Read Only Memory). Another EAROM function is a WRU (Who aRe yoU) message which may contain up to 10 characters. SEL CAL (SELective CALling) and IDENT (IDENTification) are available too. The IDENT feature will allow Morse only transmission of one of the EAROM messages regardless of the existing terminal mode. The IDENT status indicator in-

[1]"Product Review," *QST*, May 1977.

*Assistant Technical Editor, ARRL

forms the operator that a 10-minute transmission period has elapsed but it does not insert the Morse identification by itself.

The '3100 operator may transmit chosen portions of received text. The information is selectively switched from the receive buffer to the transmit buffer to prepare it for transmission. Editing, too, is easy. Not only may one correct "typos" as they happen, but the operator may return to any line, word or letter (prior to its transmission), and alter it to suit his taste. Half-duplex (normal) or full-duplex operation is possible with the system. Full-duplex operation allows *simultaneous* active receive and transmit functions to be operative. CONTinuous, LINE and WORD transmit modes refer to the manner in which transmitted text is handled. In the CONTinuous mode, characters are transmitted as they are released from the buffer without stopping until the end of the text is reached. LINE mode transmits one line at a time; information within a line not being transmitted until after a new line has been typed. WORD mode outputs one word at a time. A word will not be transmitted until the system recognizes the first character of a new word following a space between words.

There is an internal real-time, 24-hour clock within the '3100. This clock may be programmed with the time, zone and date, and the information may be transmitted at the touch of a button. The clock has to be reprogrammed each time the power is removed from the system.

Operating the '3100 proved to be the most fun I've experienced in a while. ASCII operation was not attempted since it hadn't been approved at the time of review, but Morse and Baudot RTTY proved delightful. I first tried the unit on cw. Having used a keyboard cw generator before, I felt somewhat secure. No matter which mode of operation is chosen, the secret to being an errorless emitter of information and rf is to set the speed of the HAL to somewhat less than your typing speed and prepare some transmit text during the receive period. (Now my secret's out!) The only transmitting "hang-up" I had was my inability to use the space bar effectively. I had never "sent spaces" on a key before! The cure for that turned out to be spending a couple of weeks at the keyboard running RTTY. When I went back to cw, the space-bar malady had disappeared.

Receiving cw with the '3100 was interesting. I never could quite break myself of the habit of copying along by ear; I also wouldn't recommend it be done. While the '3100 does a pretty good job of copying cw, it cannot equal the human brain when it comes to copying a really tough "swing" or copying under conditions of heavy QRM and/or QSB. Occasionally, the unit would get "stuck" (usually because of a station tuning up close to the frequency) but a depression of the CLR (CLeaR) key would get it going again. It's also surprising to watch the screen and see the print-out displayed one letter behind the received information. The system does lag to ensure that the transmitting operator is maintaining the same sending speed, and it will attempt to compensate for timing errors. If the received signal speed changes, the system copying speed changes automatically. It isn't necessary to set a received-speed control for cw; the unit clocks the incoming signal and figures this out all by itself.

Although I'd had some limited exposure to transmitting RTTY many years ago, I'd done nothing but copy RTTY in the recent past. I did quite a bit of practicing with the '3100 (while using a dummy load) to get the "feel" of the operation. My first QSO was a success, and from then on I was "hooked." Cw, my favorite mode of operation, fell by the wayside, and the '3100 (coupled with the ST-6000) kept me occupied for the next few weekends on RTTY. My "better half" was all in favor of such noiseless operation as was I. However, I did miss having an occasional "hard copy" for certain situations, such as RTTY picture reception. A mechanical printer can easily be accommodated by the '3100 for use in such circumstances.

Video-terminal RTTY and cw are quite commonplace today: ASCII is sure to follow soon. With the HAL DS3100 ASR, you'll have it all at your fingertips — silently. The HAL DS3100 ASR is available from HAL Communications Corp., Box 365, Urbana, IL 61801. Price class: $2000. — *Paul K. Pagel, N1FB*

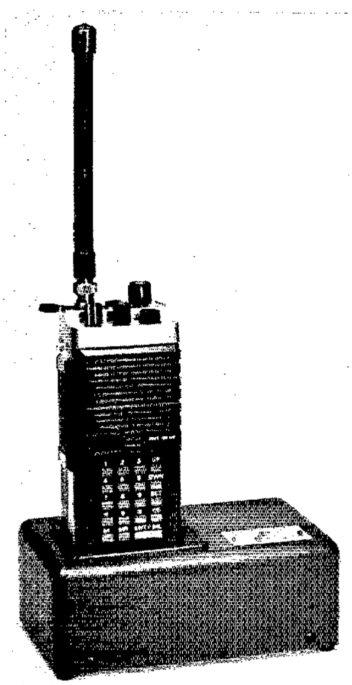
THE YAESU FT-207R HAND-HELD 2-METER FM TRANSCEIVER

Not long ago, having a synthesized 2-meter rig put you among the "elite" on this popular band. It was also convenient if the transceiver had a built-in Touch-Tone encoder so that one wouldn't have a length of wire and a surplus encoder dangling around the car or shack. A few months ago, the Tempo S-1 arrived (see *QST*, June 1979, page 37). Thanks to the wonders of miniaturization, this hand-held package contained its own built-in frequency synthesizer. The gang wondered where we'd go from there. Well, here's the first microprocessor-controlled hand-held — the Yaesu FT-207R!

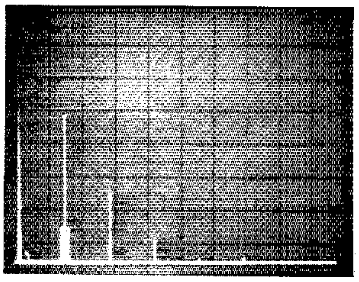
This rig has caused a real stir among radio amateurs, and for good reason. Its versatility is remarkable. The keyboard, shown in the accompanying photograph, is the "command center" for all the transceiver functions. While the intent is not to review the '207R's operating instructions, an example of how you put 'er on frequency is in order.

When the transceiver is first turned on, the LED display (yes, a digital display!) shows 7.00, representing 147.00 MHz. This readout will be displayed following any interruption of power to the memory, such as installation of a fresh set of batteries. For operation on 146.28/146.88 MHz, the keyboard entry is "688," then "ENT/DIL." This programs in the frequency. The −600-kHz repeater offset is available as one of the settings on the appropriate control knob on the top of the transceiver case. Simplex operation and ±600-kHz splits are built into the '207R for convenience. But there's more — splits of *any* amount, 10 kHz minimum, are programmable as long as they do not pass outside the 144- to 148-MHz limits of the transceiver. In a case of mistakenly (or deliberately — I tried!) programming a split resulting in possible out-of-band operation, an "E" on the display flashes to indicate that you goofed!

There are four memory channels in the FT-207R, and any of the splits may be used in conjunction with them. One of the more interesting features is the scanner. The band may be scanned in 10-kHz increments from 144 to 148 MHz (or vice-versa) by depressing the UP or DOWN button. The scan will continue for as long as either button is held down and may be set to stop at a clear or busy channel — a boon to locating repeaters in an unfamiliar area. The scan feature may be employed as well with the four memory channels. Touch-Tone operation is built in, too, as a keyboard function. A CTCSS subaudible tone feature will be available



The Yaesu FT-207R 2-meter synthesized hand-held transceiver is shown nestled inside its matching NC-2 charger.



ARRL lab spectral photograph of the output of the Yaesu FT-207R transceiver. In this photo, the rig was operating at 144.00 MHz with 2.5 watts output. Vertical divisions are 10 dB each; horizontal divisions, 100 MHz. The fundamental frequency has been attenuated approximately 30 dB by means of a two-cavity notch filter in order to prevent overload distortion in the spectrum analyzer. The most significant spurious signal, 10 MHz above and below the fundamental, is down approximately 65 dB; the second harmonic is down approximately 55 dB. This photograph represents the worst-case test; other tests within the band showed better attenuation of spurious products. The FT-207R, therefore, complies with current FCC specifications regarding spectral purity.

Yaesu FT-207R 2-Meter FM Hand-Held Transceiver

Claimed Specifications

Transmitter:

Power output: 2.5 W (min.)/200 mW high/low
Deviation: 5 kHz
Spurious radiation: −60 dB or better at 2.5 W output (see spectral photo for ARRL lab measurements)
Frequency coverage: 144.000-147.995 MHz
Transmitter offsets: 600 kHz or simplex built-in, others programmable, 10 kHz minimum.

Receiver:

Circuit type: Double-conversion superheterodyne
Sensitivity: 0.32 μV for 20 dB quieting
Selectivity: 7.5 kHz at −60dB
I-f: First, 10.7 MHz; second, 455 kHz
Audio output: 200 mW at 10% THD

General

Batteries: 450 mA NiCad pack
Current Consumption: Rx, 150 mA (35 mA squelched, display off) Tx, 800 mA (Hi); 250 mA (Low) Memory backup, approx. 4 mA
Voltage requirement: 10.8 V dc, nominal
Dimensions: 68 × 181 × 54 mm (HWD)
Weight: 680 g including batteries
Price class: FT-207R with wall charger, rubber duck antenna, earphone, belt clip and shoulder strap — $399.
Options: NiCad battery pack — $23; YM-24 speaker/microphone — $32; NC-2 desk quick-charger/ac supply — $86; TA-2 telescoping 1/4-wave antenna — $8.50.

soon as an aid to operation with repeaters in congested areas.

There are other conveniences, too: a LOCK switch for disabling the keyboard so that frequencies can't be accidentally changed; a 5 UP position for repeaters needing that extra 5 kHz (this digit doesn't appear on the display), and a DISP switch which is used to turn off the display to conserve battery power. This latter function may appear to be inconvenient, but it's not. Even with the display off, each time a frequency is changed the display momentarily comes on to show just what is happening. The 4-bit microprocessor chip inside the rig makes it all happen! the operator has a choice of 2.5 W or 200 mW of output power, switch selectable from the bottom of the transceiver case. For a hand-held, this certainly is a multitude of functions.

It takes some reading to cover the thorough instruction manual supplied with the '207R, but on-the-air contacts become easy to make once the operator has been "programmed." There is, for memory support, a constant drain on the NiCads in the transceiver. Consequently, if the rig is fully charged and unused for several days, the unit will have to be recharged. The memory draws 4 mA, so the 450 mA NiCads (fully charged) will run the transceiver for about four days with the unit at rest. By means of the offset switch, the memory backup may be disabled, thereby increasing the battery charge life.

One minor inconvenience I've noted during operation outdoors is that the LED display couldn't be read unless it was shaded with my hand. In the car, for ease of operation, I have been using a UG-255/V BNC-to-UHF adaptor to mate the '207R connector to my existing antenna lead in. The 2.5-watt power level is adequate for working repeaters in this area. Yaesu's optional speaker/microphone would be a welcome addition for extended mobile use. During all repeater contacts, I received excellent audio-quality reports.

When the FT-207R arrived here at Headquarters, it was supplied with the optional NC-2 desk charger/ac supply and two optional NiCad battery packs. The charger has a tapering charge rate, from an initial 450 mA to a pulsed 45 mA. Although the charge rate doesn't drop off completely, the LED indicator will show a slow pulsing as the batteries approach a fully charged condition, indicating that the '207R's ready to go. Yaesu does not recommend that the charger be left on indefinitely, as possible damage to the NiCads may occur from overcharging.

There's a lot in this small package, indeed, but it's well presented and housed in a rugged case. A belt clip and shoulder strap are provided. My overall operating impressions are very favorable. Once the operating instructions are mastered — not difficult at all — the FT 207R really shines in 2-meter versatility. — *Sandy Gerli, AC1Y*

MURCH UT-2000-B TRANSMATCH

"Slick and built to handle the power" were my thoughts as I peered into the exposed innards of the Murch UT-2000-B matching network. The fundamental circuit is pretty similar to that of most of today's commercial Transmatches, but the circuit of such a unit is not the only consideration. The matching resolution is just one function to contemplate. Another is whether or not the components can handle the full legal amateur power without arcing, overheating or melting. This Murch unit fills all of these requirements.

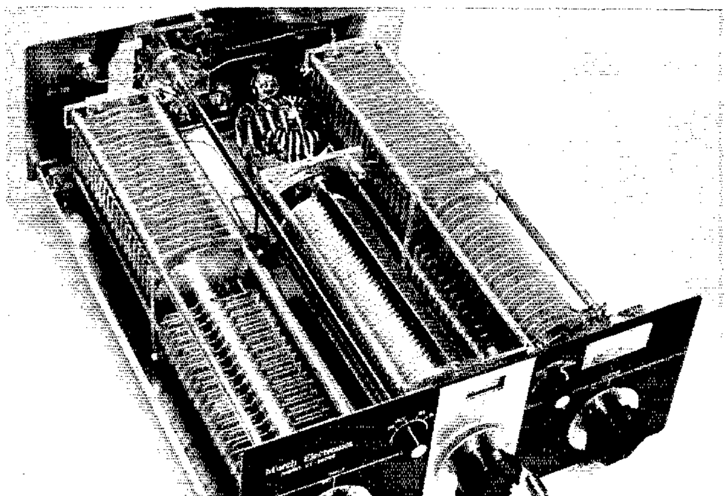
The circuit is essentially the popular T-network that evolved from the James Millen Co. 50-Ohmer matching network which was developed some years ago. Late in the 1960s, a homemade version — The Ultimate Transmatch — was described in *QST* by W1ICP. That innovation of the 50-Ohmer inspired numerous manufacturers to use the design for their marketed wares. Murch was the first to produce a commercial version of the so-called Ultimate Transmatch. The UT-2000-B is the newest model being sold by Murch, and one might well class it as their "super matcher."

Circuit Highlights

Fig. 1 shows the basic circuit of this type of Transmatch. The version at A is found in many commercial products. However, the technique at B (single-section input capacitor) provides equal results at reduced mass and cost. This was demonstrated a few years ago in the ARRL laboratory by Walt Maxwell, W2DU.

It can be seen that under certain load conditions the network functions as a high-pass circuit, and, hence, there is no harmonic attenuation. Under different load conditions, the circuit can perform as a bandpass network (desirable). Furthermore, a match can be obtained at a variety of settings for some load conditions. Minimum insertion loss will occur when the series output capacitor is at the maximum-capacitance setting that will provide an SWR of 1.

Matching resolution, mentioned earlier, is best achieved by using a roller inductor type of coil. The UT-2000-B contains one. Some commercial Transmatches utilize tapped inductors, which do not always permit a perfect match to a given load. The roller inductor, on the other hand, provides continuously variable inductance, right to a fraction of a coil turn. This becomes especially important at the upper part of the hf spectrum. I had occasion during my VP2MFW operation on Montserrat to use a "brand X" high-power Transmatch which did not have a roller inductor. Consequently, the match on 20, 15 and 10 meters was never 1:1. Admittedly, an acceptable match could be ob-



The Murch UT-2000-B Transmatch. The function switch (see text) is a welcomed operator convenience which eliminates cable switching.

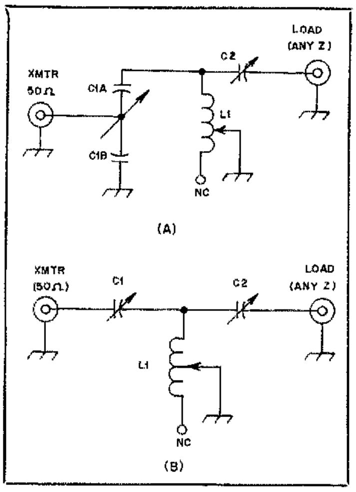


Fig. 1 — The circuit at A is found in most commercial Transmatches. It contains a dual-section variable capacitor at C1, which is not necessary for proper performance. The circuit at B is less expensive and will work as well as that at A (see text).

tained (1.5:1 to 2:1), but most of us like to shoot for a 1:1 condition when possible.

A reflected-power meter is built into the UT-2000-B. A 200-μA dc movement is used to permit good sensitivity even at low power levels. A sensitivity control enables the operator to set the meter response in accordance with the power output of the transmitter. I made comparative tests with a Bird wattmeter and learned that the Murch meter tracks very well with that of the Bird.

The function switch provides for bypassing the Transmatch, placing it in the transmission line or routing the transmitter output into a dummy load. A fourth position grounds the antenna for safety purposes during storms.

This instrument can be used with unbalanced or balanced feed lines. In the balanced condition, a toroidal transformer (broadband) converts the otherwise single-ended output to a balanced arrangement. This is useful when antennas are fed by means of twin-lead or open-wire lines. Similarly, the unit will work well with end-fed wire antennas. The maximum power rating for the Transmatch is 2-kW PEP.

Laboratory and on-the-air tests with 1 kW of dc input power to the amplifier showed no significant power loss through the unit. There was no arcing of the switches or variable capacitors, and none of the network components became unduly warm.

Craftsmanship

Perhaps the most notable aspect of this product is the craftsmanship which is evident throughout. Charlie Murch manufactures nearly all of the components he uses. The roller inductor, including its ceramic form, is made by Murch. The variable capacitors and switches are also made at the factory. The natives of this region like to refer to this kind of endeavor as "good old New England craftsmanship." This ex-Midwesterner certainly must agree with the description!

The only exception to the foregoing was noted after several weeks of daily use. The roller inductor became increasingly difficult to rotate. Eventually, the turns-counter dial no longer provided meaningful readings; the calibration became inaccurate as a result of the mechanical problems attendant to the rotary inductor.

Inspection indicated that the movable contact (small brass wheel) on the rotary-inductor coil had been binding on the brass rod that passed through its center. In fact, the binding had been so severe that the rod had developed shallow grooves that were formed by the restricted wheel during adjustment of the inductor. Excess torque had also caused the brass contact arm at the minimum-inductance end of the roller to bend and become loose, thereby allowing the small brass wheel to skip coil turns. This caused the turns-count calibration to get out of kilter. The loose parts were removed, bent back into the proper shape, then reinstalled. A thin coating of silicone grease was applied to the brass rod on which the wheel travels. This cured the binding problem and made the Transmatch much more enjoyable to use thereafter. Owners of a Murch Transmatch may want to apply silicone grease to the aforementioned area *before* the malady becomes manifest.

Who Needs a Transmatch?

For the newcomers to Amateur Radio, Transmatches are known loosely as "antenna tuners" and "antenna couplers." Some even borrow the E. F. Johnson trade name and call them "Matchboxes." Transmatches provide a matched condition between the *transmitter* and the feed line, but do not correct for a mismatch at the antenna feed point. It is important to remember this basic rule.

What a Transmatch will do for you is permit the transmitter or amplifier to look into a 50-ohm load. Most transmitters are designed for that ouput impedance. A proper match for the transmitter is especially important when using solid-state rigs, as most of them have an SWR shut-down circuit which lowers the power output as the SWR increases. Thus, if you have an antenna that has a low SWR on one end of the band, but has high SWR in some other part of the band, a Transmatch can be used to "fool" the transmitter into delivering full rated power output. I need a Transmatch at my station to work both the cw and phone bands with my tri-band trap Yagi beam. I like to think that I'm getting a bit of additional TVI protection in the process! However, there is no need for a Transmatch if you're using a properly matched antenna system. — *Doug DeMaw, W1FB*

Murch UT-2000-B Specifications

Size (HWD): 5 × 12 × 15 inches (127 × 305 × 380 mm).
Weight: 10 lbs (4.54 kg).
Color: Two-tone gray and black.
Frequency range: 1.8 to 30 MHz.
Power rating: 2-kW PEP.
Price class: $220.
Manufacturer: Murch Electronics, Inc., Box 35, Franklin, ME 04634. Tel. 207-565-3312.

THE AEA ISOPOLE* 2-METER ANTENNA

Let's face it: The ISOPOLE is one of the most unusual antennas this reviewer has ever seen. All the more reason to take it home and put it together.

What makes it look so different are the twin, resonant decoupling sleeves. What makes it work so well is a lot of thought given to decoupling. It is virtually impossible to sufficiently decouple an antenna feed line (and the mast on which a vertical antenna is mounted) from the antenna and thereby preserve the ideal pattern the designer had in mind. In the case of a vertical antenna mounted on a vertical mast and fed with a long vertical run of coax, it is difficult, at best, to prevent distortion of the pattern toward the horizon. Furthermore, a vertically polarized antenna that is poorly decoupled will provide horizontally polarized radiation from any horizontal components in its field, including runs of coax cable.

Each of the above factors tends to reduce the vertical gain toward the horizon, just the opposite of what one hopes to achieve with a vertically polarized 2-meter antenna. Enter the ISOPOLE.

A drawing of the ISOPOLE appears in Fig. 2. The twin, resonant decoupling sleeves are responsible for the decoupling of the antenna from its supporting mast and coax feed line. The decoupling sleeves are conical in shape (something like a small megaphone) and are mounted firmly on the supporting mast.

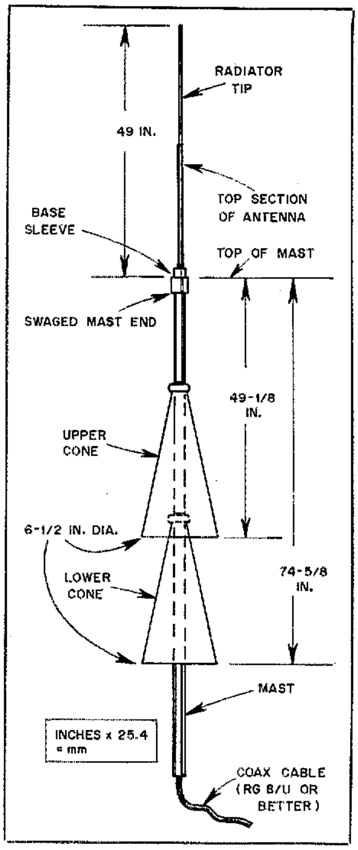


Fig. 2 — A drawing of the AEA ISOPOLE antenna. The purpose of the two cones is discussed in the text.

*ISOPOLE is a registered trademark of Advanced Electronic Applications.

In fact, part of the supporting mast functions as part of the antenna. Look at it this way. The coax passes up through the mast and terminates in a female coax receptacle at the bottom of the 49-inch, two-section tube and rod that is fastened by set-screws to the top of the mast. This 5/8-wavelength section is the top part of the antenna. Above the coax connector (and part of the same weather-insulated housing) is a sealed matching network, factory adjusted, which provides broadband matching from 142 to 150 MHz. The manufacturer claims that the antenna will exhibit less than 2:1 over this bandwidth. This reviewer measured a VSWR of no more than 1.4:1 over the 144- to 148-MHz amateur band.

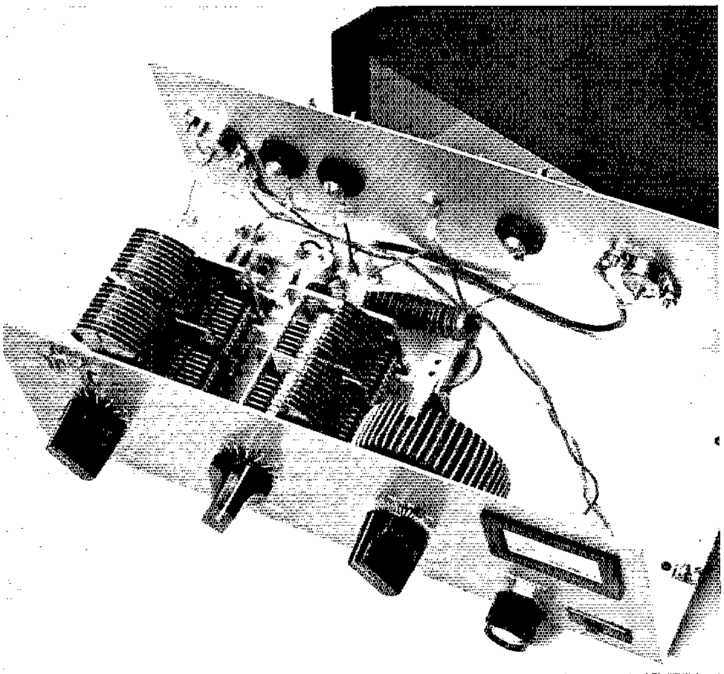
The first decoupling sleeve is adjusted so that the bottom of the sleeve is exactly 49-1/8-inches below the top of the mast. The radiating part of the antenna consists of the top 5/8-wavelength long, two-section rod and tube and the top portion of the mast down to the bottom of the first decoupling sleeve. Essentially, the active radiating part of the antenna, as described, may be looked upon as a 1-1/4-wavelength dipole. The manufacturer says it may also be referred to as "two 5/8-wavelengths in phase." The flared end (bottom) of the decoupling sleeve starts the isolation of the radiating part of the antenna from the mast. The second decoupling sleeve, fitted just below the first, completes the decoupling and effectively isolates the radiating part of the antenna from anything below it.

The ISOPOLE assembles in a few minutes on a 1-1/4-inch mast (not supplied). Maximum mast length is unlimited, though the minimum length should not be much less than 8 feet so that the antenna may be attached to its supporting structure.

As usual, this reviewer couldn't wait to mount the antenna on roof or tower. As soon as the brief assembly was completed, the mast was strapped to the railing of the rear deck of the house, about 8 feet above ground. A quick check with a quality VSWR bridge good to 150 MHz indicated no more than 1.4:1 over the entire 2-meter band. Armed with the ARRL *Repeater Directory*, and with the antenna at its commanding height of 8 feet, I proceeded to raise 29 repeaters in Connecticut from my centrally located point, along with several in Massachusetts and even a few on Long Island, approximately 50 miles distant. The remaining repeaters in Connecticut were either "down" or private. Most of the repeaters were raised with 5 watts output. Access to a few required 25 watts output for reliable contacts.

The antenna does not appear to be designed to withstand 6-inch ice loads on 10,000-foot mountains, but if you have need for an effective omnidirectional, horizon-oriented antenna you may wish to look into the AEA ISOPOLE. It appears to be ideal for modest repeater and home locations. The antenna offers a projected surface area of 1.75 sq. ft., weighs less than 3 pounds and sells for $49.95.

The ISOPOLE is available from Advanced Electronic Applications, P. O. Box 2160, Lynnwood, WA 98036. — *Lee Aurick, W1SE*



The Ten Tec model 277 Transmatch shown above employs the popular W1ICP Ultimate Transmatch circuit. Provision is made for feeding both balanced and unbalanced loads. The balun is located immediately behind the center capacitor. At the left of the SWR meter is the variable inductor. All terminals are on the rear panel.

TEN-TEC 247 AND 277 ANTENNA TUNERS

Ten-Tec is currently marketing Transmatch models 247 and 277 which are designed to match the 50- to 75-ohm unbalanced outputs of transmitters and transceivers to both balanced and unbalanced loads. What distinguishes the 277 from the 247 is that the model 277 contains a built-in SWR bridge and meter.

These Transmatches are compact and lightweight (only 3 pounds), factors that should interest the vacationer or Field Day operator. Cabinet dimensions (HWD) are 3-1/2 × 10-1/4 × 6-1/2 inches (89 × 260 × 165 mm) for the model 277. Measurements for the model 247 are 2-15/16 × 7-3/4 × 6-11/16 inches (75 × 197 × 170 mm).

The attractive enclosures make either unit a suitable desk-top accessory. Front and rear panels are finished in metallic gray. Both covers (sides and tops) are dressed in a black textured material. Operating controls for the main variable capacitors and the variable inductor are on the front panel.

Mounted on the rear of the cabinets are the PL-259 coaxial connectors which accommodate the transmitter and antenna transmission lines. Terminals are also furnished on the rear panel for a balanced transmission line, a single-wire antenna and a ground.

A decade ago, Lew McCoy, W1ICP, introduced the Ultimate Transmatch circuit. Without doubt, this configuration is the most popular antenna tuner design today. Both the 247 and the 277 Ten Tec tuners follow the W1ICP format, with the exception that Ten Tec elected not to use a differential capacitor in the input. Instead, the differential capacitor is replaced by a ganged, dual-section unit. This capacitor, however, does seem capable of handling most matching requirements.

The shunt inductance of the T-network is wound in a manner that reminds one of a rheostat, especially inasmuch as it is equipped with a rotary slider similar to that on a rheostat. By means of the slider, the operator can select the amount of inductance required for matching.

Although both Transmatch models are designed to match a variety of loads, there are some restrictions. The maximum *balanced* load from 1.8 MHz to 4.0 MHz is 600 ohms. In laboratory tests with *unbalanced* loads, 500 ohms appears to be the upper limit on 160 meters. On the other hand, tests on 80, 40 and 20 meters indicated that on these bands, unbalanced loads as high as 2000 ohms could be accommodated. Loading on 10 and 15 meters at 2000 ohms was not satisfactory. On these bands, loads of 1500 ohms and less presented no problem. After all, not many amateurs would seek to match such high impedances on these bands. Feedpoint impedances of popularly used antennas for 10 and 15 meters are well within the range of either tuner.

Being a 160-meter buff, I rather naturally tried both of these Ten Tec Transmatches on the "top band" first. Antennas that have low-impedance feedpoints (30- to 150-ohm range) proved to be no obstacle. But for the chap who wants to end feed a single-wire half-wavelength antenna on 160, use of the Ten Tec networks is out of the question. Perhaps the manufacturer will, in the future, modify the circuit to overcome this disadvantage. One competitive Transmatch producer does furnish an accessory coil that compensates for a similar shortcoming.

In order to determine the insertion loss of the

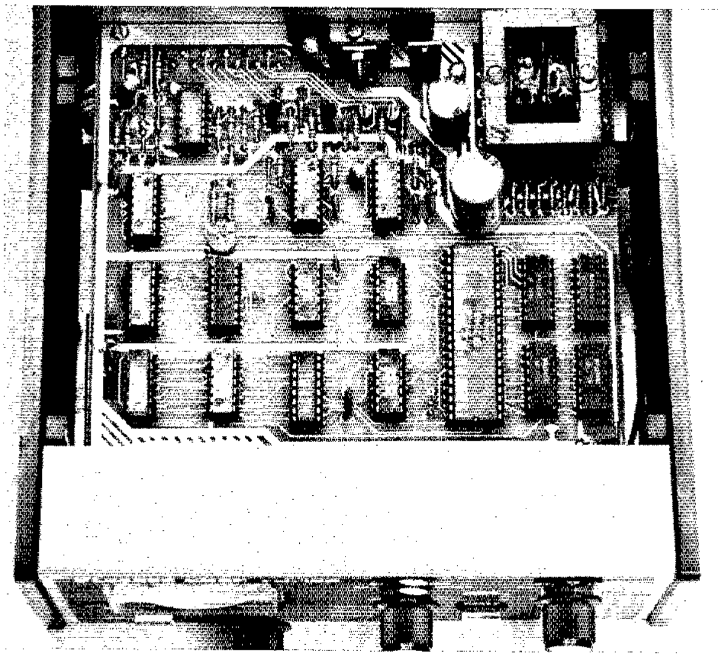
Ten Tec tuners, the test circuit included two Bird Wattmeters and a laboratory type dummy load. From 10 through 80 meters, the loss was constant at 0.46 dB, a value considered normal. The loss was somewhat higher on 160 meters, 0.79 dB.

Ten Tec made an improvement following the examination of an initial pair of these Transmatch units submitted for lab checking last year. We reported back to Ten Tec that the balun severely overheated when subjected to the full rated power, as did the variable inductor. Also, as a result of further discussions with their engineering department, it was agreed that listing the continuous-carrier power rating of these tuners at 100 watts instead of 200 watts would be more appropriate for the specifications.

As a matter of personal preference, I would like to see the model 277 equipped with an SWR meter that has a zero-set adjustment, a feature lacking in the current model. Other than that, I do find that the type of meter Ten Tec employs serves the purpose and agrees fairly well with the Bird Wattmeter.

I wish to commend Ten Tec for the fine set of instructions supplied with these units. Indeed, they form a concise review of transmission-line and antenna theory that is clearly presented in a well-organized manner.

Price class for the model 274 is under $70; the model 277 is in the $85 range. Ten Tec products are available from authorized dealers or from the manufacturer in Sevierville, TN 37802. — *Stu Leland, W1JEC*



The top cover of the Flesher TR-128 has been removed to disclose the neat interior layout of the unit. All ICs are socketed.

FLESHER TR-128 BAUD RATE CONVERTER

Stuck at one RTTY speed? Ever feel frustrated because your printer has only 60-wpm gears while somebody is sending some Star Trek art at 100 wpm? Or, after picking up that model 28ASR at a bargain price, you find it has 100-wpm gears and you now have to spend $50 for 60-wpm gears to slow the machine down to copy everyone else? Maybe you are a hunt-and-peck typist — wouldn't you like to smooth out your transmissions? Well, the Flesher TR-128 is the solution.

Speedy Relief

With the TR-128 on line, one can tune in any RTTY station transmitting at any standard amateur speed (60, 67, 75, or 100 wpm) as well as the commercial speed of 110 wpm. The TR-128 will convert that speed to your local equipment operating speed. Similarly, in the transmit mode, your local equipment speed can be changed to be transmitted at any of the four legal amateur speeds. For example, if you tune in a station transmitting at 75 wpm and your teleprinter is a 60-wpm machine, with a couple of twists of the TR-128 controls the 75-wpm transmission is reduced to your teleprinter's 60-wpm speed, and when you are ready to transmit, your 60-wpm transmission is altered to 75 wpm.

The TR-128 also transfigures a hunt-and-peck typist into a smooth operator. Simply set the SPEED control as high or low as you wish (one character per second is the lowest, while the top speed is the highest operating speed of your keyboard), and start typing. If you hunt and peck at an average speed of 30 wpm, set the SPEED control for approximately 30 and your erratic hunting and pecking is reshaped into a smooth and consistent 30 wpm. You'll be known on the air as "slow and steady."

Building the Kit

You may purchase the TR-128 assembled and tested ($239.95) or as a kit ($179.95). This reviewer built the kit in less than 8 hours; no problems were encountered. Nearly all the components are mounted on one circuit board and sockets are included for all 23 ICs.

Testing and calibrating the unit is an involved process — the manual has six and a half pages of assembly instructions and nearly five pages of testing instructions. Patience and care in testing and calibration procedures will be rewarded by a flawlessly operating unit.

Buffer and UART

A 128-character memory buffer is the "heart" of the TR-128; a UART is its "soul." The UART converts the incoming serial data into parallel data, and reconverts the parallel data to serial form. Normally, the buffer is a temporary holding register through which data passes. However, in the PRELOAD mode, 128 characters of data may be stored in the buffer to be released for transmission or reception at will. Also, this stored message may be restored and be repeated if necessary. A meter indicates just how full the buffer is at all times.

The '128 is built into a neat little package and is a perfect match for the Flesher TU-170 demodulator/afsk unit (reviewed in March 1979, *QST*, pages 42-43). The front panel contains all of the controls and metering, while the rear panel contains screw terminals for all interconnections — signal connections are TTL-compatible.

If you are interested in controlling the speed of your RTTY station, the TR-128 provides the means. It is available from the Flesher Corporation, P. O. Box 9760, Topeka, KS 66601. — *Stan Horzepa, WA1LOU*

TET 3F35DX TRI-BAND ANTENNA

The TET 3F35DX is an unusual triband antenna — and from all appearances, it is an efficient one as well. At this writing, the antenna has been installed and in use for two months. During that time, the antenna has not been in constant use; it is one of several available to this reviewer. However, it has been the *only* antenna used on 10, 15 and 20 meters. An examination of the station log indicates that, under very casual operating conditions, some 17 different countries on five continents have been worked, some of them many times. Input power was never more than 150 watts, and both cw and ssb were used. DX contacts ranged from the Pacific area to Africa, Europe and Asia; excellent reports were received at all times.

The 3F35DX functions as a 3-element Yagi on each of the three bands. There is a separate driven element for use on each band; these elements have no traps. The traps are confined to the reflector and director. It is because there are no traps in the driven elements to "soak up" transmitted power that the manufacturer makes high-performance claims for this antenna. Testing under actual operating conditions without the benefit of an antenna measuring range makes it difficult to maintain an objective approach and impossible to obtain qualitative answers. However, there is one method of testing at our disposal — that of comparison. That is: How does the 3F35DX fare when compared with a previously installed antenna? The comparison antenna is a 4-element, fully trapped tribander with a much larger (26-foot) boom that had been taken down several weeks earlier. This was to be a test of the antenna's ability to produce results. Here's how they stacked up.

Using the trapped tribander, I needed but one or two calls to snag a DX station. The 3F35DX usually produced such replies on the second or third call, with other replies on either the first or fourth call. Assuming all other conditions were the same, one would have to conclude that the larger antenna had an edge over the 3F35DX — but not much. There are some real advantages afforded by the '35DX, too. Estimated weight is under 25 pounds; about half the weight of the comparison antenna. Boom length is considerably shorter, just 16 feet. These two factors are definite advantages if one contemplates mounting such an antenna on a modest tower.

Perhaps the greatest advantage that this antenna has to offer is that it is relatively "flat" over both the cw and ssb segments of each of the three bands. With the larger antenna, one selected a portion of the band most frequently worked (either the lower or upper end) during the initial adjustment of the antenna. The high-Q traps in the driven element would not permit one to operate both band segments without a resultant high SWR occurring in the lesser-used portion of the band. The 3F35DX, as a result of the full-length driven elements (and resultant lower Q), offers full-band operation with a modest VSWR. On 20 meters, the maximum VSWR is 2.25 to 1 at 14.35 MHz. On 15 meters, the VSWR is 1.3 to 1 at both band edges, and on 10 meters it is below 1.3 to 1 to beyond 29.5 MHz, rising to 1.6 to 1 at 29.7 MHz.

The assembly instructions are better than many this reviewer has seen; dimensions are given in both inches and millimeters. One piece, a swaged section, has only one hole and one screw, despite the instructions which insist it has two holes and screws. Fig. 5 is supposed to be an assembly drawing of the director and reflector; it isn't. The drawing refers to the assembly of the driven elements and feed system and attachment to the boom. Some day the instructions for all antennas will catch up with reality. (Of course, on that day horses will fly!) Despite the aforementioned annoyances, the beam goes together very easily and there are no complications.

The 3F35DX triband antenna offers wide bandwidth and usual gain in a reasonably compact, lightweight construction. It is manufactured by TET U.S.A., Inc., 425 Highland Pkwy., Norman, OK 73069. Price class: $190. — *Lee Aurick, W1SE*

OPTOELECTRONICS, INC. DIGITAL THERMOMETER

Question: "Where in the world would a radio amateur use a precision digital thermometer?" Well, how many QSOs have you heard start out with the RST report, QTH, name and local weather report? Plenty, for sure, even though that type of QSO is pretty mundane. Those who feel compelled to report local temperatures to other hams must certainly need a good outdoor or indoor/outdoor type of thermometer. The Optoelectronics PDT-590 precision digital thermometer can be used as an indoor/outdoor temperature indicator. It reads temperature in Fahrenheit and Celsius scales with the flick of a switch.

But what if you don't give a hoot about passing out weather data to those you work? Well, think how handy it would be for the amateur experimenter to measure transistor case temperatures, tube-envelope temperatures or the ambient temperature in a VFO compartment. Another application is the monitoring of etchant-bath temperatures, if you make your own pc boards.

The Optoelectronics PDT 590. This precision digital thermometer provides an LED temperature readout in either Fahrenheit or Celsius scales. The probe cable length may be made quite long for remote temperature-sensing applications.

Instrument Features

The PDT-590 comes in kit form. It employs large-scale integrated circuitry (LSI) and utilizes two switch-selected temperature probes which can be connected via many feet of cable for sensing at remote locations. The accuracy is ±0.5°C (0.9°F) from −50° to +150°C. This equates to a range of −60° to +200°F. Resolution of the digital readout is 0.1°C or 0.1°F.

The sensor probes function as temperature-dependent current sources. Response time is 3.4 seconds to reach 63.2% of an increment change in temperature, as determined in an agitated liquid bath. The stock cable length for each probe is 10 feet (3 m), but they can be extended to several hundred feet if the need arises.

The selected temperature probe Celsius or Fahrenheit output voltage is measured by means of a 3-1/2-digit DVM (digital voltmeter). The DVM has a −1.999 to +1.999 voltage range. Hence, when the scaled output voltage falls below the internal reference voltage a negative temperature is displayed. Because the input voltage is 10 mV per degree C or F, the decimal point is placed between the 1- and 10-mV position to obtain a readout in degrees C or F.

A complete diagram of the digital thermometer is provided in Fig. 3. It has been reproduced directly from the Optoelectronics operating manual ($2 per copy). Therefore, the symbology of the diagram does not match the IEEE symbology used by the ARRL. The

Optoelectronics PDT 590 Precision Digital

Specifications

Dimensions (HWD): 1-1/4 × 4-1/4 × 5-1/4 inches (32 × 108 × 133 mm).
Weight: 14 ounces.
Operating temperature environment: 0 to 50°C.
Power requirements: 9 to 14 volts ac or dc at 175 mA (1.7W).
Readout range: −50° to +150° Celsius, −60° to +200° Fahrenheit.
Readout resolution: 0.1°C and 0.1°F.
Price Class: $100.
Manufacturer: Optoelectronics, Inc., 5821 N.E. 14th Avenue, Ft. Lauderdale, FL 33334. Phone: 305-771-2050.

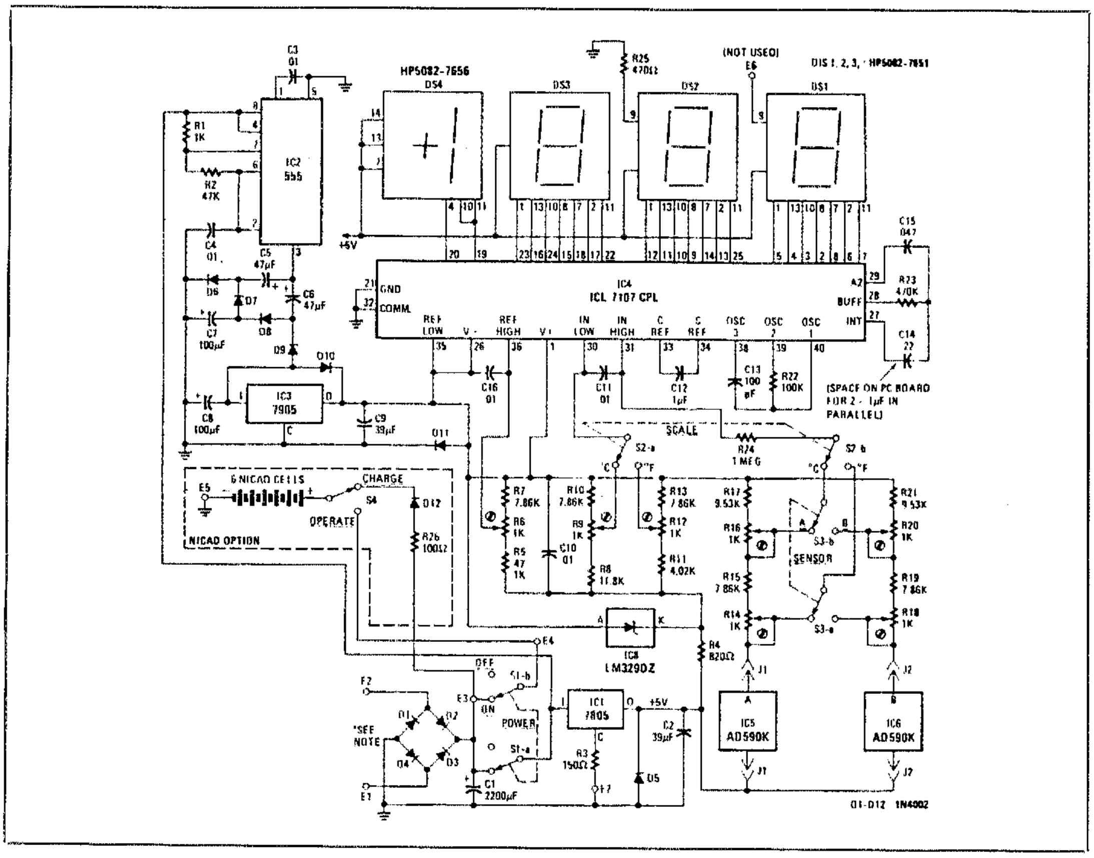


Fig. 3 — Exact reproduction of the manufacturer's schematic diagram for the PDT-590. The symbols differ in style from those used in ARRL publications.

diagram is, however, very clean and easy to follow.

Assembly of the Kit

This kit may be slightly beyond the capability of an inexperienced amateur. A modicum of technical knowledge and experience is needed to comprehend some of the step-by-step assembly instructions. The dialogue is a bit terse in spots, requiring some "decision logic" which is based necessarily on practical experience with circuits. Also, the assembler needs to have good vision to read the parts numbers and the labeling on the pc board: The unit is fairly miniature, and so seems the aforementioned printing to those (like the reviewer) with aging eyes! A magnifying glass is highly recommended for this project. One of the greatest aids to assembly of this kit was the black-and-white matte-finish photograph of an assembled kit (pc-board view with compartments in place). Apparently, the photograph is part of the instruction manual. It helped in determining where some of the parts belonged.

A double-sided pc board is used, but without plated-through holes. Instead of through-hole plating, the component leads are soldered to pads on each side of the board, where applicable. Yellow squares or rectangles are painted on the pc board at each location where soldering on both sides is required. In the long term this technique may prove better than that of the plated-through hole. Many "through-hole" boards seem to be failing these days as a function of time and heat cycling. Assembly time for an experienced kit builder should be approximately 10 hours, inclusive of calibration.

The calibration procedure is interesting. First, the builder must prepare a pot of boiling water, insert the probes, then adjust a Trimpot to obtain a reading of 100.0°C. There is a Trimpot for each probe. Next, a bowl of ice cubes and an equal volume of water is stirred until it stabilizes. The probes are inserted in the ice water and allowed to stabilize. Two more Trimpots are tweaked so that each sensor provides a readout of 0.0°C. The Fahrenheit calibration is done after the probes are dry and allowed to stabilize at room temperature. A pair of Trimpots are used to accomplish this. The Celsius reading is simply converted to Fahrenheit during this final adjustment step. The constructor must have access to an accurate digital voltmeter. The initial calibration calls for adjusting the voltage references by means of internal Trimpots. Since decimal-value voltages are involved (2.73 and 4.59 volts), resolution and accuracy are vital.

Using the Instrument

Both sensor probes must be plugged in at all times in order for the remainder of the circuit to function correctly. Furthermore, one must keep track of probes A and B with respect to the A and B jacks on the thermometer. This is so because the calibration is done with specific probes in the jacks. Differences in sensor characteristics dictate that A and B probes always be used with the inputs for which they were calibrated.

For use as an indoor/outdoor thermometer one probe can be placed out-of-doors while the remaining one is located in the shack. Since the sensor ends are the cases of small ICs (metal), they can be placed in contact with tube envelopes, transistor cases, IC cases or whatever is being checked by direct-contact means. I even measured my body temperature by placing one of the sensors under my tongue — however unrelated to radio that might have been.

If the sensors are placed in etching solution, be sure to clean them thoroughly after use — preferably before any of the etchant can dry on the probes. — *Doug DeMaw, W1FB* QST

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

REMOTE SWITCHING FOR 3-BAND QUAD

Recently I built a two-element, 3-band quad antenna now installed atop a 54-foot tower. Being an avid QRP operator, I used a 7/8-inch (22-mm) Heliax cable to avoid losing those precious milliwatts. The remotely controlled switching arrangement I've illustrated permits the use of a single transmission line that is extended to the top of the tower. Push-button control with pilot lights provides positive indication of which band has been selected.

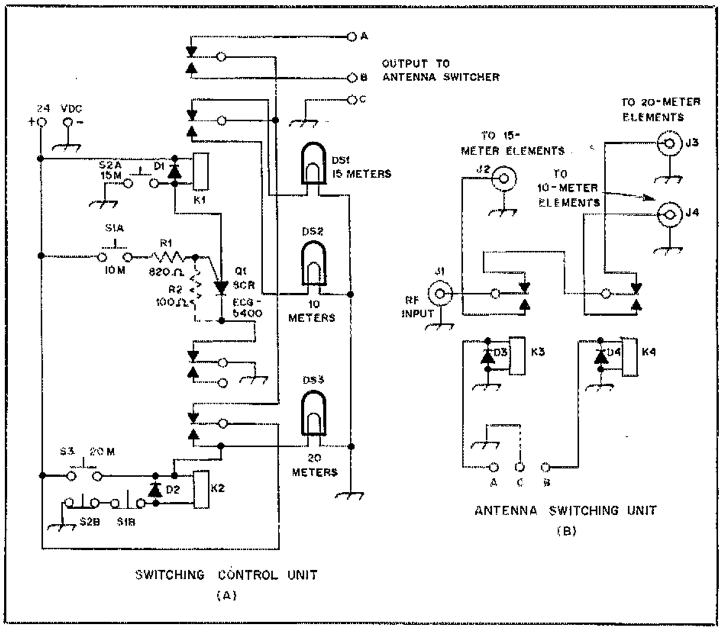
The switcher and remotely controlled unit are both constructed mainly from junk-box parts. Suitable enclosures for the control box and the switcher are choices for the builder. A means of weatherproofing should be provided for the antenna switcher inasmuch as this unit is to be placed at the top of the tower.

There is a set of normally open and normally closed contacts in each of the Dialco push-button switches selected for this project. When S3 is pushed, K2 is latched; voltage is removed from the wiper contacts of K1 and the ground is disconnected from the SCR, opening K1. As a result, there is no voltage going to the switcher. Therefore, the 20-meter circuit is, in broadcast industry terms, "normaled through."

When S1 is pressed, the normally closed contacts open and relay K2 is unlatched, supplying voltage to the wiper contacts on K1. The normally open contacts in S1 close causing K1 to latch. The normally open contacts of K1 are closed, placing voltage on terminal B. Voltage at B in the switcher activates K4 of that unit and connects the rf input to the 10-meter connector.

Pressing S2 once again opens the normally closed contacts and K2 is unlatched applying voltage to the wiper contacts of K1. Contacts that are normally open in S2 short the low side of K1 to ground, cutting off the flow of current through the SCR which is then unlatched. As S2 is released, K1 relaxes supplying voltage to terminal A. Voltage at A in the switcher causes K3 to activate, providing connection to the 15-meter antenna.

This arrangement can be adapted to other antennas. It is well suited, for example, to the installation of three half slopers extended from the top of a tower. Any one of these may be selected by the push of a button. — *Girard Westerberg, NØAFI, technical director of KLAK and KPPL, Denver, Colorado*



NØAFI uses this band-switching method for selecting the proper elements of this triband quad. Three wires are required to interconnect the control box with the switching unit. If the shield of the coaxial cable is used for the common lead, the third wire can be eliminated. Parts are available from Newark Electronics, 500 N. Pulaski Rd., Chicago, IL 60624.

Control Unit Parts:
D1, D2 — 1N4004 diodes.
DS1-DS3, incl. — Dialco push-button lamps, no. 387.
K1, K2 — Dpdt relays, 24 V.
Q1 — ECG-5400, SCR.
R1 — 820 ohms, 1 W.
R2 — 100 ohms, 1 W. For small relays with high-resistance coils, this resistor is not required.
S1-S3, incl. — Dialco two-circuit switches, no. 513-0601-604.

Antenna Switcher Parts:
D3, D4 — 1N4004 diodes.
K3, K4 — Spdt relays, 24 V.

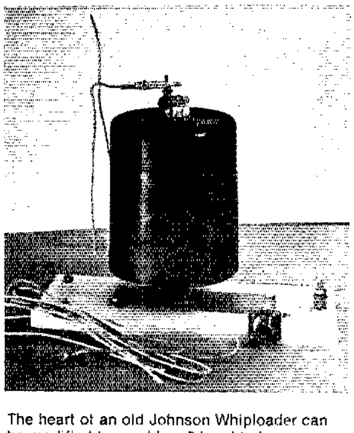
AN EFFECTIVE INDOOR ANTENNA

The five dollars you may have to spend at a flea market to acquire an old Johnson Whiploader antenna can be worthwhile. It can provide you with the hardware to make a reliable 5-band indoor emergency antenna.

Begin modification of the Whiploader by removing the 75-pF air-variable capacitor which allowed coverage of the entire 80-meter band. This feature will be retained by a different method. Removal is necessary because the capacitor otherwise would limit the power-handling capability of the coil to 75 watts. Because the capacitor was installed before the coil, there is no other choice but to destroy the capacitor, removing the parts piece by piece with the aid of a pair of hefty longnose pliers.

The Whiploader is mounted on a piece of bakelite or plastic measuring 4 × 10 × 1/2 inch (100 × 250 × 12 mm) by means of a 3/8-24 hole tapped into the approximate center. A piece of sheet metal or a large solder lug is placed between the nut and the board to provide electrical contact with the coil. A 10-32 screw is put into the side of the board for an external ground. This machine screw is connected to the shield side of the SO-239 connector by a short piece of wire.

Replace the 8-foot steel whip which normally protrudes from the top of the coil with a 3/8-24 nut-bolt-washer combination with a 3/8-inch solder lug sandwiched between. A 6-32 screw is threaded into the outer end of the large solder lug to allow connection of the antenna (shown



The heart of an old Johnson Whiploader can be modified to provide a 5-band indoor emergency antenna. See text.

*Assistant Technical Editor, *QST*

folded in the foreground of the photograph). The antenna is simply an 8-foot (2.44-m) length of hookup wire. It is connected to the top of the coil and then suspended from the ceiling or any nonmetallic object. The wire may slope as much as 45 degrees from vertical. I have found that a 6-foot (1.8-m) length of wire connected to a cold water pipe will provide a satisfactory SWR on 80, 40 and 20 meters. In some cases a Transmatch may be necessary on 15 and 10 meters.

A 1-foot (305-mm) piece of wire, connected by an alligator clip to the coil assembly, serves to tune the antenna across the entire 80-meter band (see photo). When this wire is removed, the antenna resonates at 3960 kHz. For in-between frequencies, the wire is bent away from the fiberglass cover.

Dozens of stations have been worked on 40-meter phone with the antenna sitting on my operating table. Power output at W4YOK is about 100 watts. W6 stations have been worked on 20 cw and a DL station on 15 cw gave me an RST 569. I have checked into the Kentucky phone and cw nets on 75 and 80 using this set-up for traffic handling.

In order to construct the coil from scratch, here are the specifications:

32 turns, no. 12 wire, air wound
Diameter — 3-1/2 inches (89 mm)
Coil height — 3-1/2 inches (89 mm)
Turn spacing — 0.030 inches (0.76 mm)
Location of taps — 0 turns for 10 meters; 2 turns for 15 meters; 4-1/2 turns for 20 meters; 19 turns for 40 meters and 31 turns for 80 meters.

The location of the 80-meter tap is quite critical. It may be necessary to move the tap along a particular turn an inch or so at a time until the right spot is found. Use of a dip meter can be helpful. A Transmatch should be placed as close to the coil as possible. — *T. W. Webb, W4YOK, Henderson, Kentucky*

GROUNDING GUY WIRES ELIMINATES QRM

While trying to get a set of duplexers working on the Wilson, Kansas, 37/97 repeater, we were picking up fm signals from broadcast stations besides other interference. The difficulty was solved by bonding the tower guys together and grounding them. A ground rod was installed at each anchor. This cured the interference problem. Desensing of the repeater receiver was also eliminated.

Tension on the guy wires apparently had not been sufficient to allow the turnbuckles and anchors to furnish good connections. A combination of high resistance and some diode action was responsible for the interference.

Installing ground rods is easier in many cases if you follow this advice. Soak the earth thoroughly with water first. — *Paul Grauer, WØFIR, Wilson, Kansas*

STACKED ANTENNAS, KILOWATT TRANSMITTERS CAUSE RECEIVING PROBLEM SOLVED BY TRAPS

While I was helping to operate HH2MC during a recent cw contest, severe QRM affected the receivers when one transmitter was operated on 10 meters and the other on 15. The antennas were stacked on the same tower with only a few feet of separation. Furthermore, both transmitters were running 1-kW input.

Quarter-wave, open-ended traps, constructed from RG-58/U coaxial cable, provided the solution to the problem. The formula for the traps is 246 V/f. V, the velocity factor, is 0.66 for RG-58/U, so the lengths (for the cw band) were 5 feet, 5 inches (1.65 m) for the 10-meter trap, and 7 feet, 9 inches (2.36 m) for the 15-meter trap. Putting the 15-meter trap at the receiver input on the unit for 10 meters and the 10-meter trap on the 15-meter unit completely eliminated the interference.

The particular transceivers used were FT-101ZDs. These have a phone-plug input for connecting an auxiliary receiver. That made the installation very simple. Other sets may have similar facilities. For those that are not so equipped, use of a T connector at the antenna terminal with a trap attached to one of the T posts is a good alternative.

This method can, of course, be extended to other bands. The procedure may help alleviate problems specifically associated with multi-transmitter installations at Field Day sites or DX test locations. WA4DRU and W2SR brought this method to my attention. I feel it is worthwhile to pass along to others. — *H. Dale Strieter, W4QM, Cocoa Beach, Florida*

A HYBRID MULTIBAND ANTENNA

Wanted — an all-band auxiliary antenna requiring little space, having some gain on the high frequencies, but simple enough for a Novice. With the aid of *The ARRL Antenna Book*, I constructed an antenna that met these requirements by combining a 10-meter extended double Zepp with an open-wire transmission line in an L configuration. Not only did this antenna seem feasible for low-band operation, but I also realized that an extended double Zepp for 15 meters can become approximately two half waves in phase on 10. On 80 and 160 meters you can use one wire of the feeder connected to the tuner, thus forming an inverted L antenna. Or, by tying the two wires of the feeder together and connecting both to the single wire terminal on the tuner, the antenna is converted into a T-type radiator.

An antenna-matching network is essential for this antenna. Not only does it provide necessary impedance matching, but also the network will attenuate any harmonics from the transmitter.

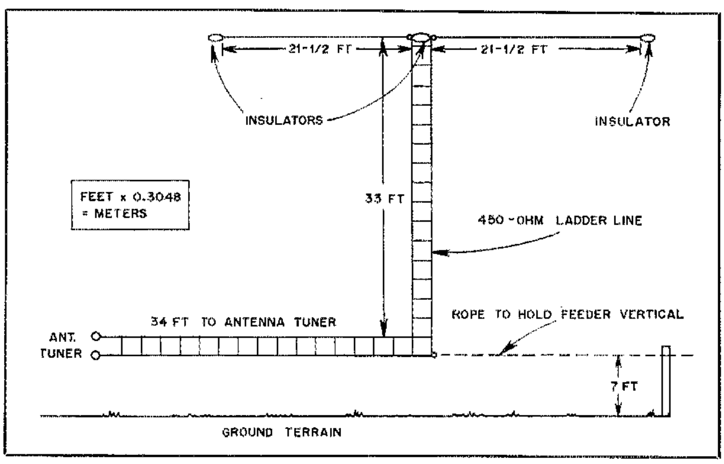
For the 10-, 15-, 20- and 40-meter bands, the feeder wires are individually connected to the balanced output terminals of the tuner in the normal manner. For 80 and 160 meters, the feeders are tied together and attached to the single wire terminal. A good ground, preferably in the form of radials, is needed for operation on these two bands. Ground leads should be connected first to the tuner and then to other equipment. From the standpoint of electrical safety, proper grounding of both the antenna and station equipment is required.

The following comments are for newcomers. The cost of the antenna is under $12. Feeder lengths shown in the drawing are not the only ones that may be used. Some lengths, however, may result in poor SWR readings. You can compensate for this by adding a few feet of line at a time until a suitable SWR is attained. On 80 meters, with radiation mostly in the vertical plane, there is little directional effect. On 160 the antenna is both short and low. Communication will not be optimum, but the antenna will allow your equipment to operate on this band.

As for overall performance, with a transmitter output of 100 watts, I get an answer to almost every call or CQ except perhaps in a DX pileup. Most foreign reports on 10 and 15 meters are S9. On 20 meters, the antenna seems slightly better than a half-wave dipole. The approximate gain over a half-wave dipole on 15 meters is 1.5 dB, and on 10 meters 3 dB. — *Merrick (Red) A. Counsell, W1BNS, Medfield, Massachusetts*

TIPS FOR MOSLEY CL-33 AND CL-36 TRIBAND ANTENNAS

Mosley Electronics furnished me with useful information that may help other amateurs who, like me, experienced difficulty in obtaining suitable SWR indications after installing a CL-33 or CL-36 antenna. First, I was advised



A hybrid multiband antenna for 10 through 160 meters. The feeder is 450-ohm ladder line. Light weight of the line avoids sagging at the center of the antenna. For good radiation from the vertical portion of the line when used as a T antenna on 80 and 160 meters, the antenna should be at least 40 feet above ground. The author recommends this as a good beginner's antenna.

to check the matching-tube assembly. The two insulated wires attached to the connector on the assembly are for capacitively coupling the coaxial transmission line to the radiator element. Sometimes the insulation on these wires shrinks back, allowing the center wire to short against the inside of the radiator element tubing. This could lead to weird SWR readings on all bands. Check the ends of these wires. Second, mounting other types of antennas above or below triband beams is frowned upon because of the detuning effects which may result. Where other antennas are so installed, they should be at least 10 feet apart. Even close-proximity 2-meter beams and ground-plane antennas can be troublesome. A third bit of advice is to be sure the traps are properly installed and placed in the right direction. — *Tom Frenaye, K1KI*

NONCONDUCTIVE GUY LINES

By choice or by chance, many licensed Amateur Radio operators are trapped in urban environments that provide little space for antennas. Where space does exist, the use of conductive guy wires can often create havoc with low-level beam antenna installations.

The use of metallic guy wires with appropriate installation of insulators has long been the approved practice. But even under the best of such conditions, amateurs who are forced to install beam antennas close to the rooftops of apartments and condominiums are likely to note severe SWR skewing as the antenna is rotated. This effect can be reduced, if not eliminated, by the use of nonconductive, nonstretch guying material.

Such material has recently been introduced for use as sailboat halyards for raising sails. The line, manufactured from Dacron and other trademarked materials, is sold at many stores handling marine supplies. Because it is strength and stretch rated, I find it well suited for Amateur Radio installations. This information makes the choice of diameter easy.

Amateurs who are familiar with techniques for splicing line can include terminating thimbles and turnbuckles in their guys. Those not capable of making splices can apply easily learned knots. These, however, will require periodic inspection for wear.

Either way, the use of nonconductive guy lines serves the purpose reliably. In my restricted situation, I use a Model HQ-1 Mini-Quad on a mast that's only 31 feet above ground and only eight feet above the roof of a 2-1/2 story condominium. The total roof space available is 18 × 36 feet (5.5 × 11 meters).

Admittedly, my maximum power output is no more than 120 watts on 10, 15 and 20 meters. But with the use of nonconductive guy lines plus all essential filters, I run a clean station. The nearest neighbor's TV antenna is less than 18 feet from my Mini-Quad! — *Jay Reisman, KB6IZ, Marina del Ray, California*

MORE ON REMOVING TOWER SECTIONS

While reading your September 1979 *QST* article, "Simple Technique for Tower Separation," I thought of the following comments which might be of use to other readers. Using silicone grease or a good grade of water pump grease to completely grease the flared portions of a tower leg before assembly will make the work of installing and dismantling a tower easier. Bolts that secure mating sections should not be over tightened, a precaution that will prevent compression of the tubing. Old bolts can be knocked out easily by using a small center punch. Leg hardware is available from Rohn tower distributors. Use of new hardware is recommended when reinstalling a used tower. — *James H. Hayes, W4XS, W1ZO Radio, Franklin, Tennessee*

ROTOR CONTROL CABLE QUICK DISCONNECT

There are times when it would be convenient to disconnect the control unit of rotators from the tower-mounted equipment for reasons such as relocation or station modification. Although the terminal strip on the rear of most rotor control units is substantial, neither the terminal strip nor the wire ends (even if soldered or otherwise terminated) will stand too many loosenings or retightenings. Also, it is possible to make an improper reconnection (Murphy's Law!).

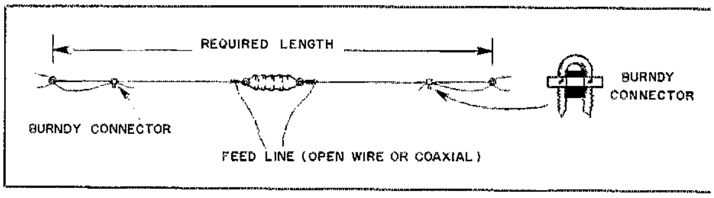
A very convenient, safe and positive way of solving this problem is to install a male/female 8-pin connector assembly in the line conveniently close to the control unit. Exercise caution, though. Connect the wires of the control cable to the connector pins in the same sequence as was done on the terminal strips for both the tower-mounted rotator and the control unit in the shack. Doing so will save many headaches later during trouble shooting sessions.

If the cable run is at a maximum length for a particular rotator in use, then any additional resistance offered by adding a connector may lead to troublesome operation of the rotator. Some rotators are susceptible to operating problems if an overlength control cable is used. In the case of the Ham-M II, for instance, the maximum cable length is 150 feet. — *John F. Marthens, W6SE, Encinitas, California*

BURNDY CONNECTORS AID LENGTHENING OR SHORTENING A DIPOLE ANTENNA

All my active years as an amateur since 1928, I've practiced and passed on to others the following means of adjusting the length of an antenna. (Refer to the accompanying drawing.) Pass ends of the antenna wire through the insulator eyes. Clamp the ends with Burndy connectors as shown in the illustration. The advantage of this method is that the wire can be lengthened or shortened without cutting until the desired length is obtained. After the correct length is obtained with the aid of a dip oscillator or other means of measurement, the excess may be cut off after tying at the insulators. You may choose, however, not to cut off the excess — a good idea if you may decid later to resonate the antenna at a lower fr quency.

Use of a little graphite grease on the conne tor threads is suggested. The connectors, Burr dy no. KS-15, are obtainable through man electrical supply houses. — *Antonio G. C Gelineau, W1HHF, Burlington, Vermont*



Use of Burndy KS-15 connectors facilitate lengthening or shortening antenna wires. After correct length has been found the ends may be left as shown above or tied at the insulator with the excess wire being cut off.

ATTACHING COAXIAL CONNECTORS

I use a method of attaching PL-259 coaxi connectors that seems rather foolproof. Newe hams, and maybe a few older ones, may ap preciate help in this direction.

To prepare the PL-259 connector, disassem ble it. File off the nickel plating next to one c the holes normally used to solder the braic Repeat on the opposite hole. The reason fc this is that the base metal brass is easier t solder to than the nickel. Tin the filed area with a hot iron (up to 200 watts). Use minimal amount of solder. Apply heat n longer than necessary to make a good connec tion. Tin the center pin, leaving no exces solder.

In preparation of the coaxial cable, if RG 59/U, RG-58/U or the new Micro-8/U cable are to be used, slide the ferrule of appropriat size and the PL-259 knurled nut over the end o the cable. Tie a single overhand knot in th cable to capture them. Next remove 1-1/ inches (38 mm) of the outer vinyl sheath fror the cable. Comb out the braid into two bundle of equal numbers of strands (within reason) s the bundles are opposite each other. Twist th strands into a tight bundle, then carefully ir spect them for and remove any broken strand Cut 1/2 inch (13 mm) off each strand bundle Tin the ends for 3/8 inch (10 mm). Put 45-degree bend on the very end of the soldere area away from the center conductor. Remov all but 1/4 inch (6 mm) from the center condu tor insulation. Tin the full length.

Assembly begins with squeezing the brai bundles together against the center conducto and inserting them into the connector body The center conductor should enter the pi Then you jockey the shield ends until they ap pear in opposite holes. To get the center con ductor to pop out of the pin, grab the shiel ends and pull them in opposite directions.

Proceed next to slide the ferrule up the cabl and screw it into the connector body using tw pairs of pliers to make sure that seating is firm The shield ends will retract slightly.

At this point of assembly, make an ohm meter check for possible shorts between shiel and center conductor. If no correction i necessary, follow the ohmmeter test by com pleting the assembly. Cut the shield bundle leaving about 1/4 inch (6 mm) protruding fror the holes. Solder the braid to the body whil pushing the braid against the body. Remove any excess solder below the threaded area. Cut off the center conductor flush with the end of the center pin and solder. Remove any excess solder that appears on the side of the pin. Now slide the connector nut up and thread it over the connector body.

The job isn't completely done until the cable is checked out! Use your ohmmeter, set for the low-ohms scale, to check for near zero ohms, one end of the shield (connector body) to the other end. Do likewise for the center conductor. The final test is to set the ohmmeter on the high-ohms scale and test again for any resistance between shield and center conductor. Properly, the reading should be infinite.

For RG-8/U I suggest combing the shield into four bundles. File off the nickel plating all around and tin the same area all around. Following the steps outlined will provide excellent mechanical and electrical bonds that will ensure trouble-free life. — *E. Raymond Hardy, W3BSS, Delmar, Delaware*

SHOOTING A FISHING LINE OVER A TREE

Maybe this has been tried before, but it was a first time for me and surely saved a tangled fishing line! In preparation for installing an antenna I needed to get a line over the top of a tree. My gimmick was to use a Zebra 202 closed-face spinning reel attached to a fishing rod. The procedure is to lay the lower part of the fishing rod on the ground. Fasten the line to the arrow. Push the reel release button, grab the bow and arrow and fire away. The method sure works! — *Larry Briggs, W3MSN, Oxon Hill, Maryland*

MODIFIED CAPACITOR FOR THE UNIVERSAL TRANSMATCH

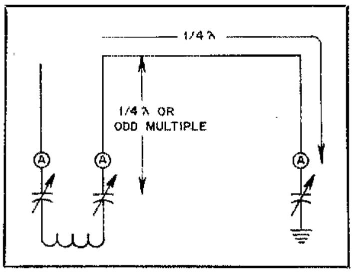
To provide a differential capacitor for the Universal Transmatch described in the 1975 edition of *The Radio Amateur's Handbook* I removed the rotor from a Millen 16250 variable capacitor, loosened the clamping nuts and rotated one set of the plates 180 degrees to give a differential action. The circuit adjustment is now much smoother and matches a wider range of impedance than I was able to obtain with the two-section variable suggested in the parts list.

A good initial adjustment procedure is to start with C2 fully meshed and C1 at midrange. C1 and L3 are then varied for a minimum SWR reading. If a null cannot be obtained, open C2 about 10 degrees and again adjust C1 and L3. Repeat until a perfect match is obtained. — *Frank C. Getz, N3FG, Newark, Delaware*

THE OLD TIMER'S NOTEBOOK: A MARCONI-ZEPP ANTENNA

With this system, a Zepp designed for 80 meters can be used on 160, or one designed for 40 can be used on 80. Plenty of amateurs with small backyards can use it to advantage since the flat-top is only a quarter-wave affair.

Since accurate tuning of the flat-top is a little ticklish, it calls for a bit more care than with an ordinary Zepp. First, the system should be tuned at the transmitter end with the condenser (capacitor) set about midway. Observe the current in each feeder. If the currents balance, everything is okay. If not, the flat-top will call for some tuning of C1. C1 should have a fairly high capacitance (350 pF). Adjusting this capacitor moves the current loop around. When the loop is in the center of the coupling coil (where it should be) the currents will balance and cancellation results.



Grounding the far end of a Zepp antenna permits using it as a quarter-wave Marconi with end feed. With this arrangement the antenna may be operated on a lower frequency than the fundamental.

The idea can be carried a bit further by making the length of the antenna between the end of the feeder and the connection to C1 equal to a half wave for the next-higher frequency band. Then install a switch at C1 so that the condenser and ground connection can be opened when the antenna is to operate as a half-wave Zepp. The length of lead between C1 and ground can be any convenient length, provided that the total length is not more than three-eighths of a wavelength since the series condenser will shorten the electrical length. — *George Underwood, W1GPE, North Providence, Rhode Island,* "For the Experimenter," August 1934 *QST*.

THE OLD TIMER'S NOTEBOOK: REMEMBER THE WONDER BAR ANTENNA — A 10-METER BOW TIE?

We receive many requests at the ARRL for information about the simple loaded dipole, only 8 feet long, that was described by Dr. Edwin T. Bishop, K6OFM, in November 1956 *QST*. This miniature 10-meter antenna, made from the elements of a conical TV antenna, became a hit because of the low cost and good performance. In summarized form, therefore, here are the details.

If you can obtain a conical television antenna, you will have all the parts needed except two standoff insulators, a B & W Miniductor no. 3013 (12 turns no. 16 wire, 1-inch dia, 3 inches long) and a few nuts and bolts — it's that simple! If a TV antenna is not available, 1/2-inch OD aluminum tubing can be substituted. Dimensions are shown in the drawing.

The outer ends of the four 48-inch antenna elements and the ends of the 30-inch bars are flattened for a distance of 1 inch. These ends are then drilled to accept whatever size machine screw you choose to use.

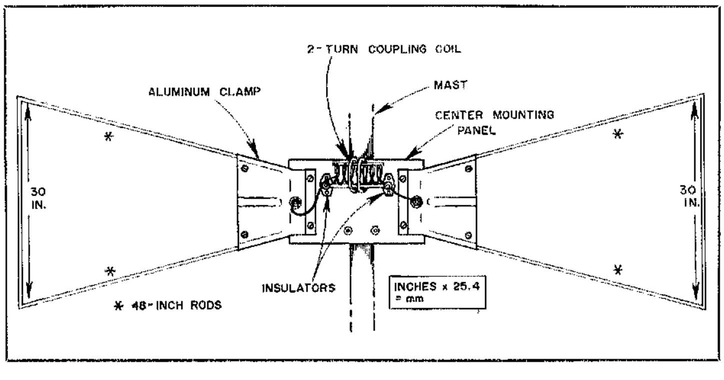
Any nonconducting weatherproof material may be used for the center panel. The dimensions are not critical, but should be large enough and strong enough to accommodate the antenna and mounting hardware.

Two of the original clamp mountings hold the halves of the revamped TV antenna. The aluminum clamps and the antenna should be well cleaned before assembly. Application of Mosley's Penetrox at all connecting joints will ensure good continuity. In order that both sections of the bow tie lie in the same plane, mounting plates should be straightened for that purpose.

The Miniductor coil is supported by two 1-inch standoff insulators placed 3 inches apart on the center mounting panel. One end of this coil is connected directly to one of the antenna sections by means of a short length of no. 12 wire. Another short length of no. 12 wire, connected to the other section of the antenna, is tapped onto the coil so that there are approximately 10-3/8 turns between the connections. The transmission-line coupling coil consists of two turns of plastic-covered solid no. 14 electricians wire, loosely coupled around the center of the loading coil. The coils should be adjusted for minimum SWR.

Either RG-8/U or RG-58/U may be employed for the transmission line, which may be terminated at the antenna by means of coaxial connectors or simply wired directly to the coupling coil. In any case, the end of the line should be waterproofed. One means of waterproofing is Duxseal, available at some plumbing and heating supply houses, and also from Motorola Communications equipment branches.

In order to maintain the centered position of the coupling coil, the author elected to cement the leads to the mounting panel with water-



The Wonder-Bar 10-Meter Antenna. This bow-tie was originally described in November 1956 *QST*. In response to continued reader interest, it is presented once again. This antenna is fashioned from a conical TV antenna.

proof cement. This was done at the point where the leads pass through holes in the panel. Several light coats of Krylon spray, applied to the antenna, help resist the effects of weather.

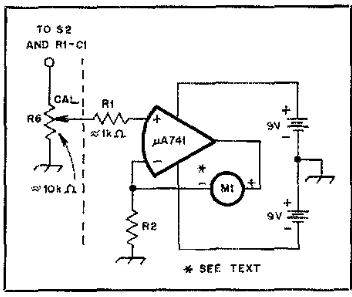
Keep in mind that this is not a form of folded dipole. The rods for each section of the bow tie converge at an electrically common point — a common point for the right section and a common point for the left. In this respect, the construction is the same as a conical TV antenna.

To conclude his article, Dr. Bishop said: "Signal reports really bring home the bacon to the ham! Try it and I do believe you'll agree with me!" — *Stu Leland, W1JEC*

A USEFUL METER AMPLIFIER

K4KI's tune-up bridge, described in December 1979 *QST*, is an outstanding circuit. Every amateur station should have one or something similar to relieve tune-up QRM. His circuit calls for a 50 μA meter. Other circuits in *QST* have specified various meter values. I frequently do not have the proper value meter in my junk box, and since I am not a wealthy person, my hamming is done on a very modest budget. My solution is to use the simple meter-driver circuit shown in the accompanying drawing. With it you can adapt a meter of any value to practically any circuit.

Basically this amplifier is a voltage-to-current converter that is well described in many IC handbooks. It has a very high input impedance that will not load the sensing circuitry. A 1-mA movement can therefore be used in place of a 20-μA movement. Low current drain permits the use of inexpensive batteries for power. Voltage is not critical.



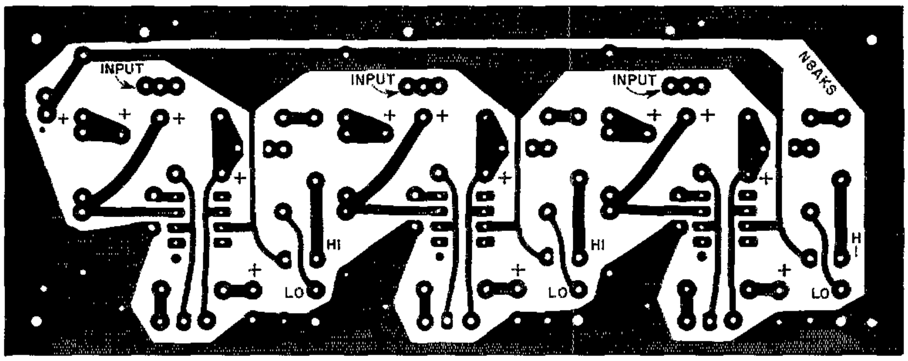
This circuit, provided by KA7CDR, permits the substitution of meters other than the one specified for a given project. The circuit as shown will adapt a 0-1 mA meter to the K4KI tune-up bridge described in December 1979 *QST*. The value of R2 is determined by dividing the maximum voltage at the + terminal of the 741 by the meter current required. R6 may be as little as 2 kΩ but higher values decrease the loading effect. The upper limit is about 100 kΩ.

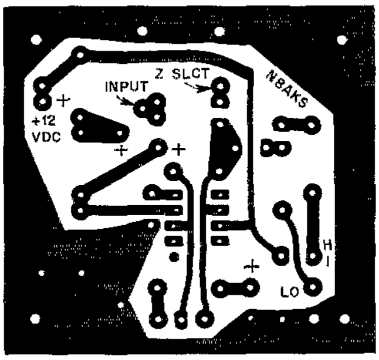
The circuit, as shown, will adapt a 0-1 mA meter to K4KI's circuit. Resistor values are also not critical and are selected according to the value of whatever potentiometer is on hand. R1 should be no more than 1/10 the value of R6. The voltage "felt" at the + terminal of the μA741 will also be found across R2. The μA741 will supply whatever current is required to maintain that voltage balance (limited to about 25 mA). A good choice for R2 is to use a 1-kΩ pc-board style potentiometer that can be adjusted during assembly and checkout and then ignored. Different meters have different V-I characteristics. Therefore use of a one-time-adjusted potentiometer will eliminate any design calculations with this circuit. Any meter movement can be used by simply experimenting with a few resistors. If the maximum input voltage is known, just divide that voltage by the meter-current requirement to obtain the value for R2. If the voltage is not known, then a potentiometer or some experimenting is in order. The entire driver circuit, including batteries, can be glued to the back of the meter. A dpst switch can be included to conserve the batteries if desired. The 741 is an experimenter's delight. I can burn dozens of them up for the price of one good meter. — *Michael C. Trull, KA7CDR, Las Vegas, Nevada*

[Editor's Note: Also see "A Tune-up Bridge Note" in the "Technical Correspondence" section of this issue.]

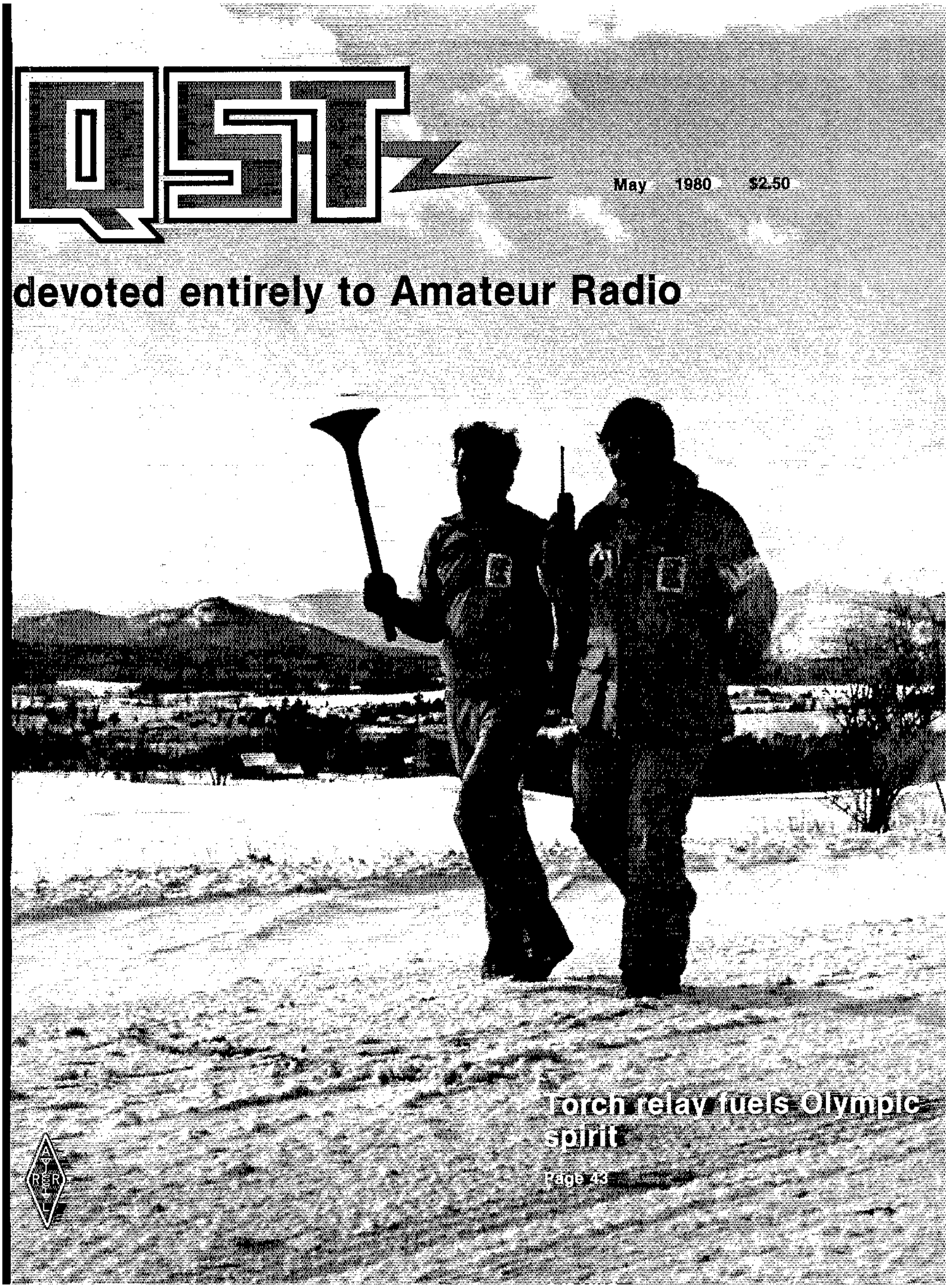
ANTENNA HINT FOR DXERS

A word of caution on special low-noise receiving antennas — put them as far away from your vertical or semi-vertical transmitting antenna as possible. The distance should be one wavelength or more. If there is insufficient separation, the receiving antenna will pick up the same noise and crud you've tried to avoid. The noise can be reradiated from the transmitting antenna. — *Stewart Perry, W1BB, Winthrop, Massachusetts*





Circuit-board etching patterns for the adjustable-gain microphone amplifier (see Figs. 3 and 4, pages 13 and 14 of this issue). Patterns are shown at actual size from the etched side of the board, with black representing copper. The pattern at A is for the 3-channel amplifier, and that at B for the single-channel amplifier. Boards have copper on one side only.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THE COVER

Armand Canestraro, WA2EQW, was among the scores of volunteer amateurs who helped smooth the way for the Olympic torch run. Their story begins on page 43. *(photo courtesy Gary J. McPherson)*

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Circular Polarization and OSCAR Communications

OSCAR users are switching to circular polarization to lessen signal fading. Build this low-cost antenna system and hear what you've been missing.

By Bernie Glassmeyer,* W9KDR

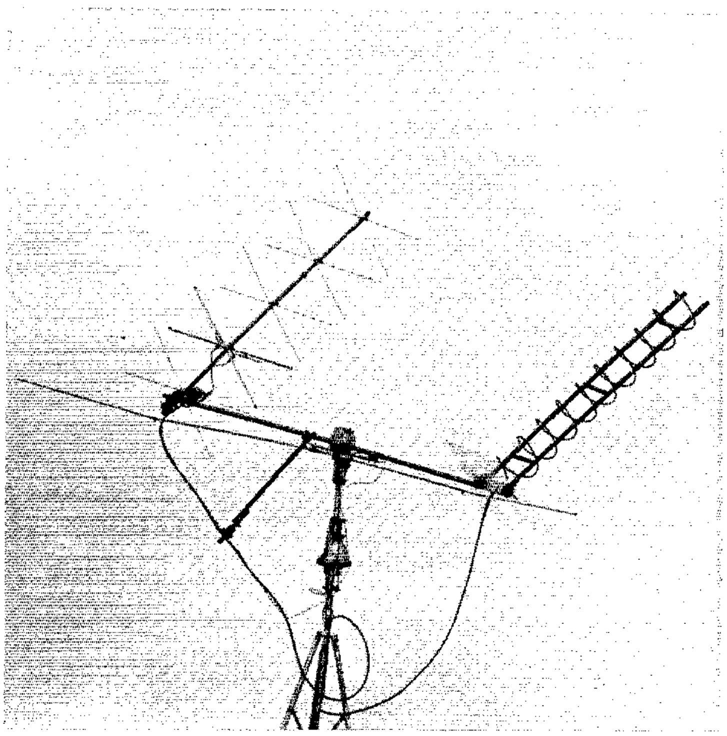
Most amateurs use either horizontal or vertical polarization because no other types are needed for terrestrial communication. In space communication certain polarization changes must be accounted for. This may be simply done with a basic understanding of what to expect and how to compensate for it.

Skywave communication involves the use of the mysterious ionosphere to reflect the waves of high-frequency signals. The ionosphere consists of ionized particles that extend from about 30 to 300 miles above the earth. See Fig. 1. Because the particles are in a constant state of flux, the effect on the radio signal passing through the ionosphere is random and ever-changing. Signals to and from a satellite are affected to varying degrees depending on the frequency, time of day, and location of the receiver and transmitter. The major effect is contributed by Faraday rotation, which causes changes in the polarization of electromagnetic waves as they pass through the ionosphere. Frequencies up to approximately 1 GHz (1000 MHz) are subject to Faraday rotation when they traverse the ionosphere. Since the present OSCAR satellites operate in this frequency range, we have an opportunity to observe the phenomenon of Faraday rotation.

Orbital Perspective

To track the satellite we must know its

*OSCAR Operations Manager, ARRL



The author's satellite communications antenna system. On the left is a commercially made crossed-dipole Yagi antenna for 2 meters. On the right is a 9-turn 70-cm helical antenna. Note the counterweight mounted on the elevation boom.

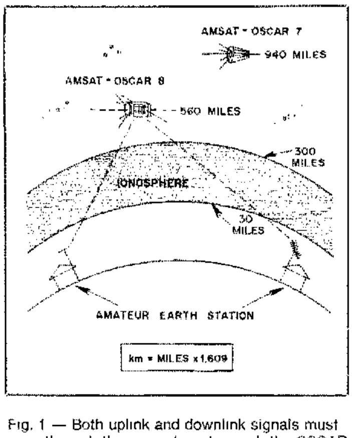


Fig. 1 — Both uplink and downlink signals must pass through the ionosphere to reach the OSCAR satellites. Approximate distances from the earth's surface are shown.

location relative to our position on earth. This is easy to do using tracking devices available from ARRL hq.[1] and other sources, and the OSCAR operating schedule, published monthly in *QST*. Once the position of the satellite is established, it is time to consider another unknown: spacecraft rotation. A perspective may be gained by studying Fig. 2. The direction of orbit for OSCAR 8 on a south-to-north evening (ascending) pass is indicated by the positive z-axis (top of spacecraft). For a north-to-south morning (descending) pass, the direction of orbit is indicated by the negative z-axis. Therefore, the positive z-axis points in the direction of the earth's geomagnetic north pole, and the negative z-axis points in the direction of the south geomagnetic pole. The north and south geomagnetic poles, distinct from the more familiar geographic poles, define the earth's magnetic field. Because this axis inclines about 12 degrees from the geographic axis, the geomagnetic poles lie 798 miles from the geographic poles. The stabilization system aboard OSCAR 8 consists of four permanent magnets aligned along the z-axis. These magnets allow the spacecraft to remain parallel to the earth's magnetic field.

The OSCAR 8 spacecraft currently makes one 360-degree rotation about its z-axis every five minutes. The 2-meter antennas (four canted turnstiles) mounted on the negative z-axis (bottom of the spacecraft) and the 10-meter dipole mounted on the x axis both rotate on the z-axis. Result: additional polarization rotation and fading.

Circular Polarization

Now that we have some idea of the orbital mechanics of the spacecraft, let's

[1]A simple tracking device, the OSCARLOCATOR, is available from ARRL.

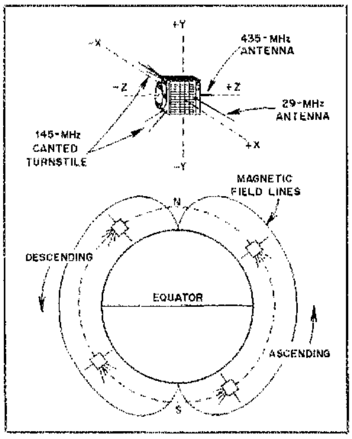


Fig. 2 — The path and orientation of OSCAR 8 as it orbits the earth.

take a look at the types of polarization used in space communications. The two most likely polarization candidates are right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP). To understand these two forms, we must choose one of the two conventions of circular polarization theory. One theory is the 1942 classic physics definition; the other is the definition of the Institute of Electrical and Electronics Engineers (IEEE). Arguments lasting to the wee hours of the night have occurred between these two schools of thought. I chose the IEEE convention, since all recent work done in the field uses it. Let's accept it and proceed. The IEEE convention is taken from a viewpoint at the rear of the antenna looking in the direction of travel of the wavefront, as shown in Fig. 3. As we look in that direction, an RHCP wave will turn *clockwise*. An LHCP wave will turn *counter-clockwise*.

Most vhf operators know that vertical and horizontal polarization are not compatible; about 20 dB of signal strength is lost when the transmitting station uses one polarization and the receiving station uses the other. But circular polarization can be used with vertical and horizontal polarization, and any form in between.

Because of Faraday and satellite rotation, the polarization of the rf energy from space is indeterminate. Observing the intense fading of a received signal such as the 435.095-MHz beacon from the OSCAR 8 spacecraft has changed the thinking of many recent OSCAR converts who would rather switch than fight Faraday rotation. If you tune in the beacon and get QSB (fading of the received signal), that's it — polarization rotation — unpredictable and ever-changing. Regardless of the polarization at the spacecraft or earth station antenna, whether uplink or downlink, when the signal passes through the ionosphere its

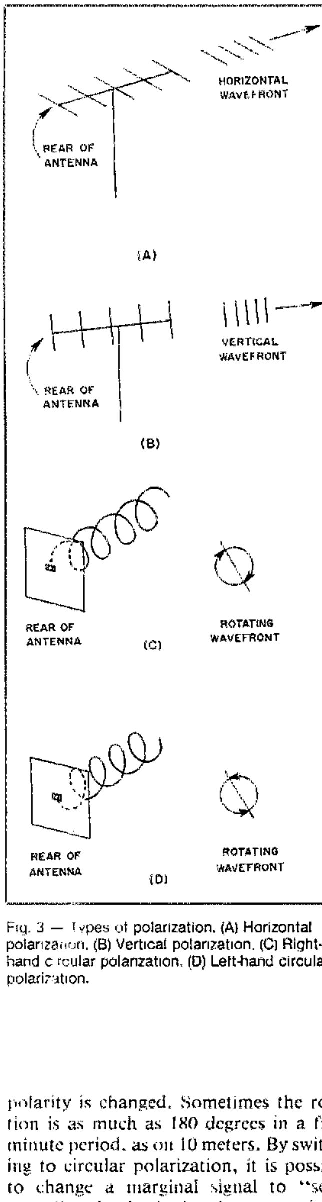


Fig. 3 — Types of polarization. (A) Horizontal polarization. (B) Vertical polarization. (C) Right-hand circular polarization. (D) Left-hand circular polarization.

polarity is changed. Sometimes the rotation is as much as 180 degrees in a five-minute period, as on 10 meters. By switching to circular polarization, it is possible to change a marginal signal to "solid copy," and gain the hands-on experience you will need to become proficient in space communications.

The best possible system would be switchable RHCP and LHCP on both the uplink and downlink frequencies. Both RHCP and LHCP are useful because the effects of Faraday rotation may be so severe that the polarization sense may actually become reversed!

Assembling such an antenna system is not difficult. Fig. 4 shows four Yagi antennas, a pair for 144 MHz and a pair for 432 MHz. Note how each antenna is mounted at a right angle to its counter-

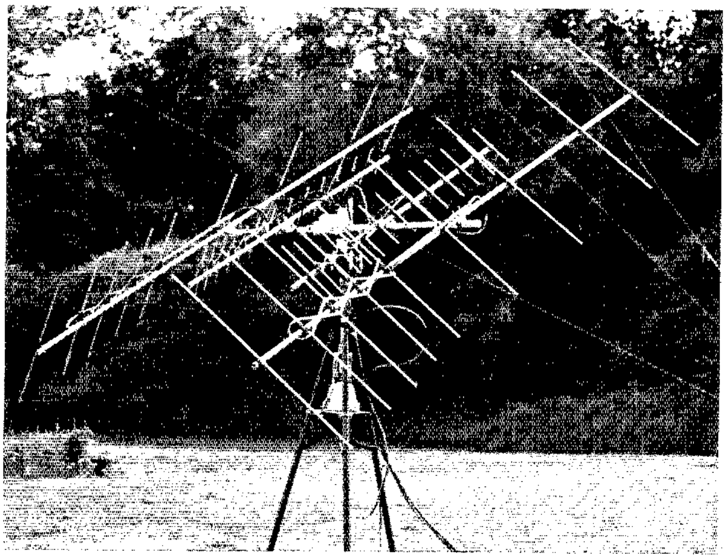


Fig. 4 — An OSCAR array, built by W1VD and assembled from KLM log-periodic Yagis (featured in the 1980 ARRL *Handbook*, page 14-8).

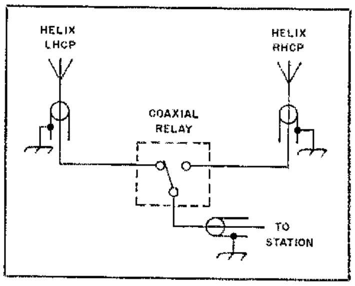


Fig. 6 — A switchable-sense antenna system for satellite communications.

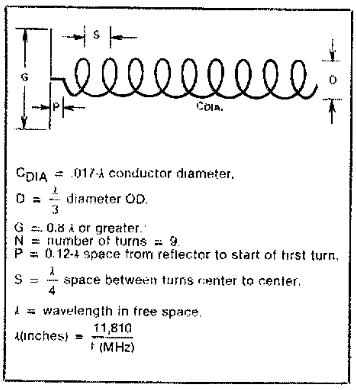


Fig. 7 — A 70-cm, 9-turn helix, with formulas for determining the critical dimensions. For a 430-MHz design frequency, C_{DIA} = 0.47 inch, D = 9.16 inches, G = 22.0 inches, P = 3.3 inches and S = 6.9 inches (mm = inches × 25.4).

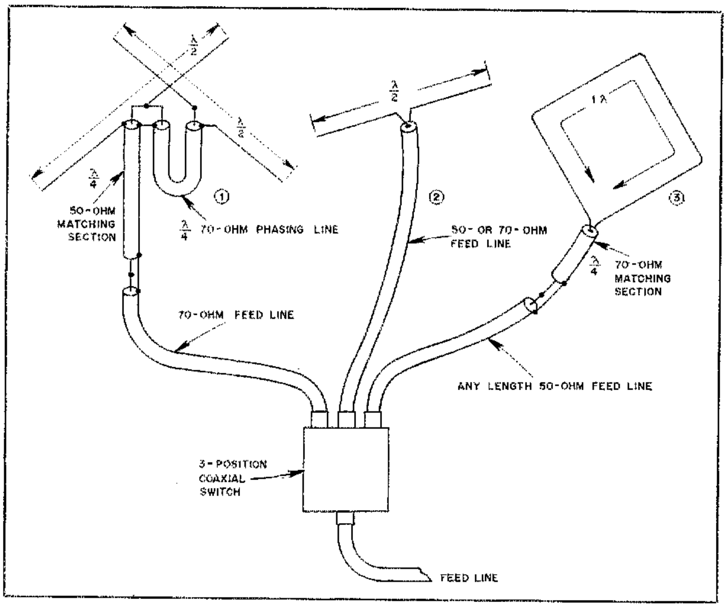


Fig. 5 — Any one of three 10-meter antennas — a turnstile (1), rotary dipole (2), or horizontal loop (3) — may be selected for OSCAR downlink reception.

part. This is an effective means to generate circular polarization. Fig. 5 illustrates a scheme that a Mode A user might employ to recover maximum signal from the 10-meter downlink.

A Switchable-Sense Helical Antenna

A helical antenna is another effective means to generate circular polarization. Constructing a set of helix antennas for the 70-cm band is very easy. One antenna wound for RHCP, the other LHCP, a uhf spdt antenna switch or relay, and some good hardline is all that is needed to complete the system. Such a setup is shown in Fig. 6. Only readily available, inexpensive materials are used for construction, and the most comforting part is that the dimensions are not critical. Fig. 7 shows the helix formulas and dimensions. This broadband beauty, with a 1.8-to-1 bandwidth ratio, is ideal for a high-gain, broad-beamwidth satellite-tracking antenna. With this switchable antenna system and 50 to 100 watts of rf output, you should have a respectable signal on the new Phase III satellite.

A close-up detail of the complicated portion of the helix is shown in Fig. 8. A good starting point for construction is the reflector, made of heavy wire mesh. This type of wire mesh is used in most uhf TV "bow tie" antennas. Hardware or wire companies can supply this material in four-foot widths. It is no. 14-gauge galvanized steel and sells at approximately $1.60 per foot. To build two antennas you will need a piece of mesh two by four feet. Trim the mesh so that no sharp ends stick out, or you may end up with a four-sided porcupine.

The next step is to make the reflector mounting plates and boom brackets.

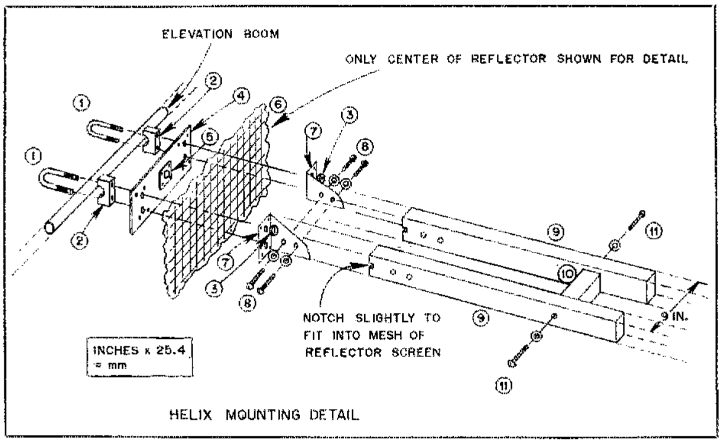


Fig. 8 — The details of the helix-mounting arrangement. See Table 1 for a number-keyed parts list.

Table 1

Parts list for the helix mounting detail shown in Fig. 8.

Piece No.	*Description*	*Comments*
1	U bolt, TV type	Use to bolt antenna to elevation boom
2	U bolt spacer	As above
3	U bolt nut with lock washer	As above
4	Reflector mounting plate (see Fig. 9)	Rivet through reflector to boom brackets
5	Coaxial receptacle, N type	Rivet to mounting plate
6	1- × 2-in. heavy gauge wire mesh	Reflector, cut approx. 22 in. square
7	Helix boom-to-reflector brackets	Rivet through reflector to mounting plate
8	No. 8-32 bolts with nuts and washers	Bolt boom brackets to boom
9	Boom, approx. 1- × 1-in. tomato stake, 6 feet long	
10	Boom spacer, 1- × 1-in. tomato stake	Bolt to boom; cut to give 9-in spacing
11	No. 8 wood screws with washers	Attach spacers to boom (three places)

Notes: 1) Mount reflector mounting plate to boom brackets observing 9-inch clearance for boom.
2) Wire mesh may be bent to provide clearance for U bolts.
3) When positioning the reflector mounting plate, try to center the coaxial receptacle in the wire-mesh screen.

Follow the dimensions shown in Fig. 9. Heavy aluminum material is recommended; 0.060 inches (1.5 mm) is the minimum recommended thickness. Thicker material will be more difficult to bend, but two bends of 45 degrees spaced about 1/4 inch (6.4 mm) apart will work fine for the brackets in this case. The measurements shown are for TV-type 1-3/4 inch (44.5-mm) U-bolt clamps. If you use another size, change the dimensions to suit. Drill the four holes in the reflector mounting plate and mount the coax receptacle, using pop rivets or nuts and bolts. It is advisable to check clearance between the coax receptacle and the elevation boom before final assembly. The thickness of the U-bolt spacers will affect this clearance. Mount a short piece of pipe, the same size as the elevation boom you will be using, to the U bolts, wire mesh reflector, reflector mounting plate and boom brackets, as shown in Fig. 8. Position the plate in the center of the wire mesh reflector. It will be necessary to bend some of the mesh to clear the U bolts. Loosely tighten the U bolts so the plate can be adjusted to fit the mesh.

The wood boom assembly shown in Fig. 8 is two six-foot lengths of tomato stake joined together in three places. Mount one spacer in the center and the other spacers one foot in from each end. Position the notched ends of the boom to fit into the mesh. When the correct alignment is obtained, clamp the assembly together and drill holes for rivets or bolts through the reflector mounting plate, brackets and wood boom assembly. When drilling the boom holes, place the reflector flat on the floor and use a square so the boom is perpendicular to the reflector. Mark the boom through the holes in the boom bracket. When the assembly is complete, give the wood boom a coat of marine varnish.

The most unusual aspect of this antenna is its use of coaxial cable for the helix conductor. It is readily available, inexpensive, light in weight, and easy to shape into the coil required for the helix. Nine turns will require about 22 feet (6.71 m), but allow 25 feet (7.62 mm) and trim off the excess. The author used an FM-8 type of coaxial cable, but any type may be used that is near the 1/2-inch (12.7-mm) diameter required, and has a center conductor and shield that can be soldered together. Strip about four inches (102 mm) at one end of the cable down to the center conductor, but leave enough braid to solder to the center conductor. This will become an electrical short. The exposed center conductor should be measured 3.3 inches (84 mm) from the short and the excess cut off. This is the dimension P in Fig. 7. Wind the 25-foot length of coax in a coil about 10 inches (254 mm) in

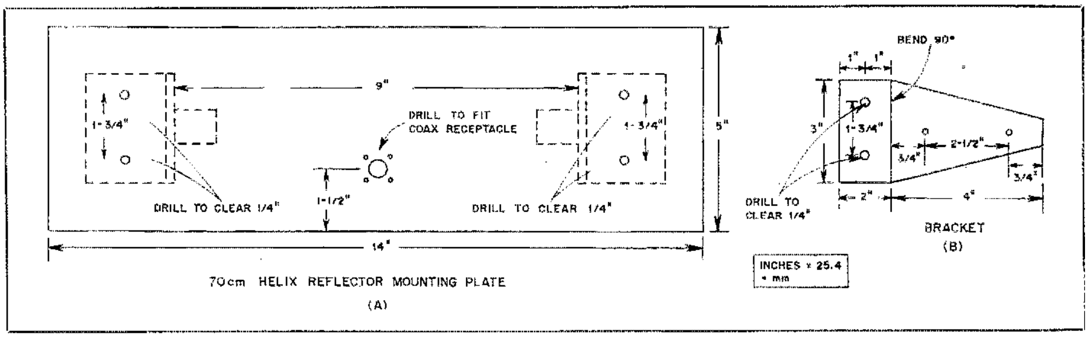


Fig. 9 — (A) The helix reflector mounting plate (part no. 4 in Table 1). (B) The boom brackets (part no. 7 in Table 1).

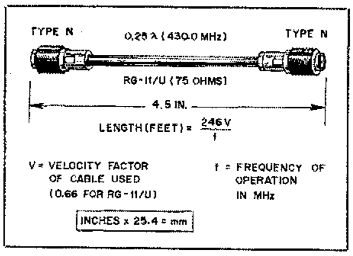
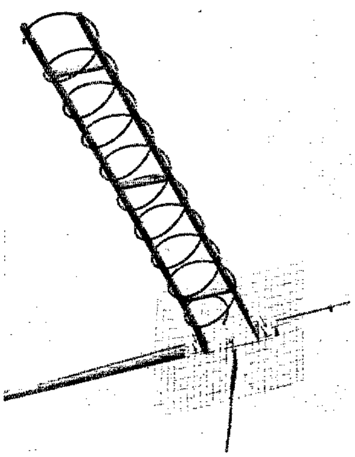


Fig. 10 — A coaxial matching section of 75-ohm cable matches the 140-ohm impedance of the helix to the 52-ohm feed line.



A close-up view of the author's 70-cm helical antenna.

diameter. Check Fig. 3 to determine which way to wind the coil for RHCP or LHCP. Slip the coil over the boom and move the stripped end of the cable toward the coax receptacle, which will become the starting point of the nine turns. Solder the center conductor to the coax receptacle, and start the first turn 3.3 inches (83.8 mm) from the point of connection at the coax receptacle. Tie-wraps are used to fasten the coax to the wood boom. Mark the boom using dimension S in Fig. 7. The first tie-wrap will be only half this distance when it first comes in contact with the boom, then each successive turn on that side of the boom will be spaced by dimension S. Use two tie-wraps so they form an X around the boom and coax. Once the first wrap is secure, wind each turn and fasten the cable one point at a time. Before each turn is tightened, make sure the dimensions are correct. When you reach nine turns, check all dimensions again. Cut the coax at the ninth turn, strip enough of the end to solder a short. The exposed solder connections at each end of the coax conductor may be taped and sprayed or covered with a RTV-type covering to weatherproof them.

The coaxial 75-ohm quarter-wavelength matching section shown in Fig. 10 is connected in series with the feed line at the antenna feed point. The formula for determining the correct impedance value for a coaxial quarter-wave matching transformer is

$$Z_0 = \sqrt{Z_s Z_r}$$

where

Z_0 = desired transformer impedance
Z_s = transmission-line impedance
Z_r = antenna impedance

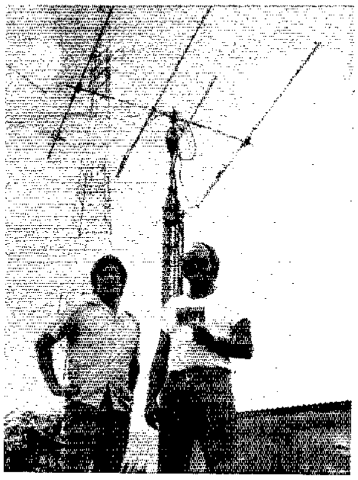
The impedance of the helix is approximately 140 ohms. To match the 52-ohm transmission line, a transformer of 85.3 ohms is required. The 75-ohm cable used here is close enough to this value for a good match. The transformer should be connected directly to the female connector mounted on the reflector mounting plate. Use a double-female adapter to connect the feed line to the matching transformer. Wrap the connectors with plastic electrical tape, then spray with an acrylic resin for waterproofing.

To mount these antennas on an elevation boom, a counterbalance is required. The best way to do this is to mount an arm about two feet (610 mm) long to the elevation boom, at some point that is clear of the rotator, mast and other antennas. Point the arm away from the direction the helices are pointing in, and add weight to the end of the arm until balance is found.

Do not run long lengths of coax to this antenna, unless you use hardline. Even short runs of good RG-8/U coax are quite lossy: 50 feet of foam RG-8/U at 430 MHz has a loss of 2 dB. There are other options if you must make long runs and can't use hardline. Some amateurs mount the converters, transverters, amplifiers and filters at the antenna. This could be done with the helix antenna very easily; the units could be mounted behind the reflector, which will also add counterbalance. If this approach is used, check local electrical codes before running any power lines to the antenna.

Many theoretically minded amateurs will argue that polarization sense does not change as the signal passes through the ionosphere. So far, only a few active OSCAR 8 Mode J users have discovered that it pays to switch polarization sense. With one RHCP, one LHCP helix and a remote uhf spdt switch, you will be able to determine for yourself if this phenomenon exists. With active satellites equipped for 70-cm transmission and reception orbiting the earth every day, we only need point our antennas skyward to enjoy and learn from the exciting world of satellite communications. QST

Strays



These two OSCAR DXpeditioners, Herb Schoenbohm, KV4FZ, of Christiansted, Virgin Islands, and Bud Ansley, W6VPH, of Pasedena, California, have put many new spots in the Caribbean on the air for OSCAR DXers. This photograph was taken at the KV4FZ antenna farm.

"HAMFEST CALENDAR" RULES AND REGS

☐ *QST* will list your hamfest in its monthly "Hamfest Calendar," free of charge. There are certain guidelines, however.

Hamfests will be listed only once. Sponsors may specify the issue in which the announcement should appear. Normally, if the event will occur before the 10th of the month, we recommend listing it in the previous month's issue. The deadline for *receipt* of hamfest information is the 15th of the second month preceding publication. In other words, if an event is August 5, the announcement should be in the July issue, and will need to arrive in Newington by the 15th of May at the very latest. For an August 19 event, the sponsor could choose either the July issue, with the May 15 deadline, or the August issue, with a June 15 deadline.

We will acknowledge all information received at Hq. for "Hamfest Calendar" with a postcard stating the date of publication. If you do not receive an acknowledgement within two weeks, your letter may not have arrived at Hq., so please send us a duplicate copy.

Oh, yes, "Hamfest Calendar" is separate from the hamfest section of the Ham Ads. See the first page of the Ham Ads section in this issue for more information. — *Marge Tenney, WB1FSN*

Increasing Receiver Dynamic Range†

Noisy local oscillators and poor noise blankers can ruin the dynamic range of an otherwise good receiver. The techniques shown here are in the vanguard of the battle for high receiver dynamic range.

By Ulrich L. Rohde, Ph.D., Sc.D.,* DJ2LR

The demands we place on our hf receivers are ever-increasing. The hf spectrum is becoming more and more crowded, and the current sunspot maximum is making that crowding even more evident. This has pushed the performance of hf receivers to new highs, especially in the area of dynamic range.

While the dynamic range has been increased by redesigning rf amplifiers and mixers for better intermodulation-distortion performance,[1-4] two common faults have received less attention. The local-oscillator signal in a modern receiver is often generated by frequency synthesis and the noise sideband performance of such a signal source can be poor. In addition, a noise blanker that does not introduce in-band intermodulation distortion or degrade the receiver performance in other ways is a rarity.

Low-Noise Synthesizers for Receivers

Currently there are three different approaches used to generate the LO signal for synthesized receivers. Direct synthesis is extremely fast in switching speed, very bulky because of the enormous filtering requirements and fairly large in power consumption. A second method is a combination of various phase-locked loops, sometimes used with the mix-and-divide principle. The third method is the digiphase system, which allows infinite resolution. Only the last two methods are in common use.[5] The Hewlett-Packard HP-3335A synthesizer/level generator[6] and the Racal RA6790 communications receiver[7] are good examples of these design approaches.

One of the most complicated problems in frequency-synthesizer design is the trade-off between loop bandwidth, settling time and sideband noise. In a single-loop synthesizer, the phased-locked loop will improve the noise performance of the synthesizer. This reduction in noise output will occur around the synthesizer output frequency for a bandwidth equal to the loop bandwidth. For division ratios greater than 1000, the loop filter would probably need to be extremely narrow. Therefore, noise reduction would only occur for a few hertz on either side of the carrier. Such a loop would not compensate for microphonic effects and other turbulences. Since these effects *must* be compensated for, it is essential that the loop bandwidth be reasonably wide. If the output frequency is divided by 100 or 1000, the modulation index, and therefore the unwanted microphonics, will be reduced. Unless this is done, a loop bandwidth of less than 1 kHz should be avoided.

The noise contribution of the voltage-controlled oscillator (VCO) is usually greater than the noise contribution of the reference signal. If we assume that the ideal loop bandwidth is 1 kHz, it is apparent that we must design a VCO that has sufficient low-noise performance in the range from 1 kHz from the carrier frequency out to several megahertz from the carrier frequency. How far out from the carrier frequency the output must be clean depends on the requirements of the receiver.

The noise-sideband performance of any oscillator depends upon the Q of the tuned circuit and the noise contribution from other parts of the circuit, such as the transistor and other lossy devices. It is, therefore, apparent that the best noise performance will be obtained from a crystal oscillator, where the Q of the crystal is extremely high.[8-10] Such a circuit minimizes any pulling effects and makes the crystal itself the main reference element. A crystal oscillator cannot be used as a VCO, however. In a phase-locked loop, a steering input is needed: The frequency of the oscillator should be a function of the dc control voltage applied to the oscillator.

It is not uncommon that the amount of frequency shift required is as much as 10 or 15% of the center frequency. Therefore, the tuning diode will have a major influence on the noise-sideband performance. In most cases, tuning diodes used in synthesizers are the same as those

†This article has also been submitted in a slightly different form to IEEE for presentation at IEEE ELECTRO/80, Boston, Massachusetts, May 1980.

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[1]References appear on pages 20 and 21.

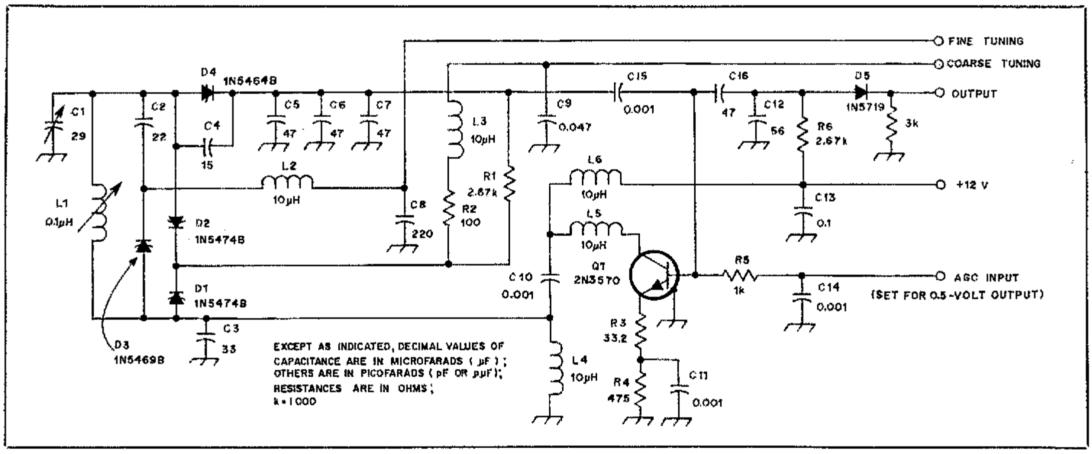

Fig. 1 — A 70- to 80-MHz VCO with coarse and fine tuning.

found in entertainment circuits. The noise contribution of those diodes, and therefore the degradation of VCO spectral purity, is excessive. There are special tuning diodes available, such as the Motorola 1N5464B/5474B series, that will fulfill the stringent requirements of low-noise VCOs.

Let us assume, for example, that the first i-f of a receiver is 72 MHz and that the entire shortwave spectrum should be tuned. This necessitates a VCO frequency of 72 to 102 MHz. While it might be possible to build a VCO that covers the entire frequency range, this would be an extremely poor design choice. Let us examine the reason for this statement.

Thermal Noise

The voltage gain K_v = 30 MHz/12 V or 2.5 MHz/V. The resultant noise voltage is generated according to Nyquist's formula

$$V_n = \sqrt{4kT_0R\Delta F}$$

where T_0 is the temperature in kelvins, and k is Boltzmann's constant (1.38×10^{-23}). R is the equivalent leakage resistance of the diode and ΔF is the bandwidth over which we want to examine the noise performance. The resistance, R, will typically range from 1000 to 10,000 ohms depending upon the diode and the reverse voltage supplied. A typical example will be a noise bandwidth of 10 kHz, an equivalent noise resistance of 3 kΩ and a temperature of 23°C or 296 kelvins. The calculation tells us that the value of the noise voltage is 0.7 μV. When we multiply this voltage by the voltage gain of the VCO, we determine the residual fm to be 1.75 Hz. This is caused by the effect of thermal noise modulating the VCO. In general, inexpensive varactor diodes are much worse in this respect: Their equivalent noise resistances are substantially greater. When using this type of diode, residual fm up to 1 kHz has been observed.

To improve the noise performance, the amount of influence the tuning diode has in the circuit should be kept as small as possible. Fig. 1 shows the VCO of the hf synthesizer used in a transceiver built by Rohde & Schwarz, and used in military communications. This VCO is tuned from 70 to 80 MHz and exhibits a signal-to-noise ratio of 90dB/Hz at 1 kHz off the carrier and 135 dB/Hz at 25 kHz off the carrier. The loop bandwidth of the synthesizer is kept in the vicinity of 1 kHz or less. The microphonic effects are well suppressed and the noise-sideband performance is determined only by the oscillator.

This oscillator has a number of unusual features. The influence of the transistor parameters is fairly small, as the collector circuit is kept at a low impedance by means of C3. The base is held at an even lower impedance by C5 through C7. The Motorola high-performance tuning diodes mentioned earlier are used. Fine tuning is accomplished via the 1N5469B diode, while the other tuning diodes are responsible for coarse tuning and linearization of the VCO gain. Since the receiver tunes the entire 30-MHz hf band, three of these 10-MHz VCOs are employed. Fast band switching is not important — more emphasis has been placed on the requirements for low noise.

To obtain low phase noise within the natural frequency of the loop, phase detectors rather than phase-frequency detectors were used. Since those have a limited capture range (not more than 1.5 MHz), coarse steering was required. Another reason to use coarse steering is to shorten acquisition time. The coarse steering is done with tuning diodes, which still have some noise contribution even when they are held at a constant terminal voltage. Outside the control loop frequency this noise voltage degrades the noise performance. Additional means had to be investigated to reduce this noise. The development of multistandard television tuners in Europe has spurred research activities in the field of switching diodes and the application in VCOs.

Rather than use tuning diodes for coarse steering, it is now much more elegant to use binary-coded inductors to coarsely preset the frequency in 1-MHz steps. When these diodes are conducting, their loss resistance is typically 0.4 Ω at 10-mA dc. This resistance degrades the Q of the coils very little. Intermettal, an ITT subsidiary located in Germany, has probably one of the best low-cost switching diode series. Type BA244 diodes require only 10-mA of switching current and should be used as shown in Fig. 2. Their differential forward resistance is a function of forward current, as shown in Fig. 3. The BA243 is recommended for lower frequency applications, while the BA244 should be used for our application. Fig. 4 shows a VCO that covers 40 to 70 MHz using such switching diodes for coarse steering. This VCO has the same noise-sideband performance as the oscillator shown in Fig. 1, but over a frequency range of 30 MHz.

An Exotic Example

A semi-fast frequency synthesizer using this type of VCO was developed for a commercial receeiver. Fig. 5 shows the block diagram of this novel approach. A single-loop synthesizer covering the range of 50 to 150 MHz with an internal reference of 1 kHz is divided by 100. This results in an output frequency of 500 kHz to 1.5 MHz. This division has increased the resolution from 1 kHz to 10 Hz, which is suitable for all practical applications. (Most receivers having 1-Hz resolution do not have adequate frequency standards to justify this resolution. The absolute

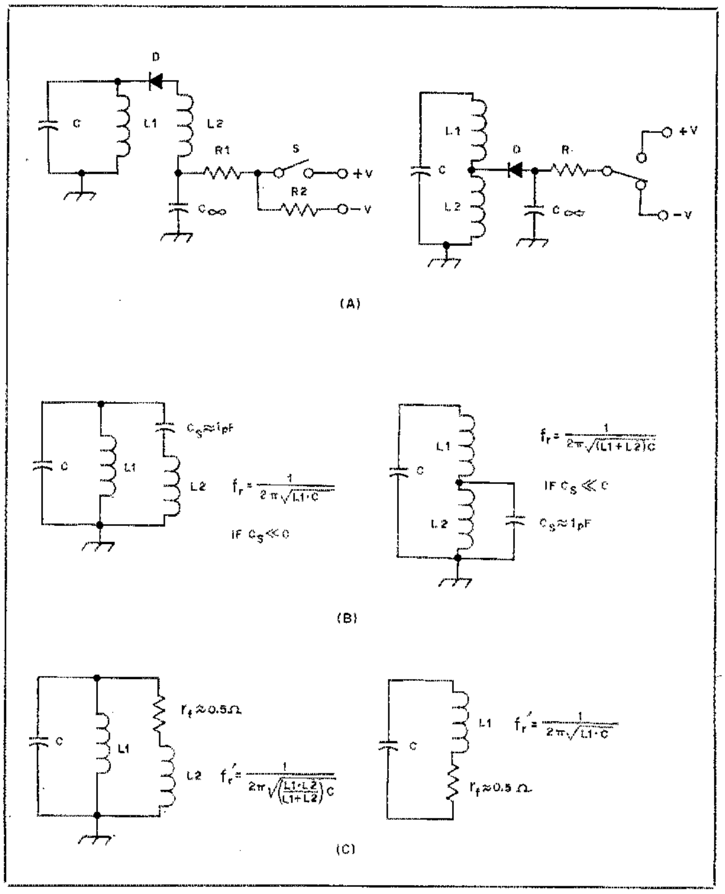

Fig. 2 — Shown at A are two methods of using a switching diode to change the resonant frequency of a tuned circuit (coarse steering). C_{∞} is a very large value of capacitance. At B is the equivalent circuit when the diode is biased off (open). C_S is stray capacitance which can be neglected when calculating the resonant frequency, F_r. At C is the equivalent circuit when the diode is biased into conduction; r_f is the forward resistance of the diode, which can also be neglected when calculating the new resonant frequency, F_r'.

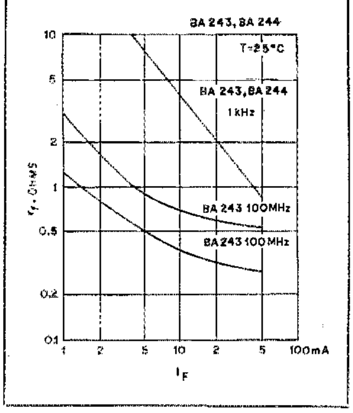

Fig. 3 — Forward resistance of BA243 and BA244 diodes as a function of forward current and frequency.

accuracy is typically between 10 and 100 Hz.)

Dividing the fine resolution loop by 100 also produces a noise improvement at its output of 40 dB. This noise reduction removes the stringent requirements on the loop oscillator, as the signal-to-noise ratio initially needs to be only 100 dB/Hz or slightly better. A third-order filter in the PLL permits very fast acquisition time. Because of the fairly wide loop bandwidth, a switching time of about 10 ms is possible. (The digiphase system may allow quasi-infinite resolution, but the receiver is almost never phase-coherent with the internal standard. The resulting noise sidebands are often barely 60-dB suppressed.)

The output loop of the synthesizer covers the frequency range of 40.455 MHz to 70.455 MHz. It is mixed with an identical set of oscillators used in a step loop. The step loop is locked in 1-MHz steps to the internal frequency standard and is very fast because of the small division ratio. This loop is called the high-gain loop and exhibits extremely low-noise performance. The coarse dc control voltage of this step loop is used to preset the output loop VCOs within a few hundred kilohertz. One VCO is fed the coarse control voltage only, while the other VCO has both coarse and fine inputs. The outputs of the two VCOs will differ in frequency by 200 kHz minimum to several megahertz maximum. The outputs are mixed and fed to a phase/frequency comparator and compared with the output of the fine resolution loop described above. The two auxiliary loops are not multiplied inside the phase-locked loop and therefore don't degrade the noise performance, but their noise contribution is added. The output loop has no divider chain and transfers the noise of both loops directly to the output. Because of this clever method the resulting noise is equal to the noise of the high-gain 1-MHz loop (highest multiplication, 70) while the internal reference is operating at 10 MHz. Therefore, the additional multiplication factor is only seven as far as the noise degradation is concerned. The dividers have a noise floor of about 160 dB/Hz, and therefore the sidebands of the 1-MHz loop ultimately remain at 140 dB/Hz. More than 100 kHz away from the carrier frequency, the close-in signal-to-noise ratio is never worse than 120 dB. For more information on local oscillators, references 11, 12 and 13 are recommended.

A High-Dynamic-Range Noise Blanker

As discussed previously, interference which is generated inside the receiver has been reduced by improving the performance of amplifiers and mixers. Undesired noise sidebands of the LO depend upon the spectral purity of the synthesizer. In the real world, however, there is another type of annoying interference. These are pulses, either manmade or made by nature.

The two most violent sources of pulse interference are discharges during a lightning storm and noise generated by jamming stations and pulse radar stations. A nuisance called the "woodpecker" is a several-megawatt over-the-horizon pulse radar system that apparently has its origin in the U.S.S.R. This system produces pulses up to several hundred microvolts at the receiver input and interferes with communications. LORAN is the bane of amateurs using the 160-meter band. Naturally occurring noise discharges such

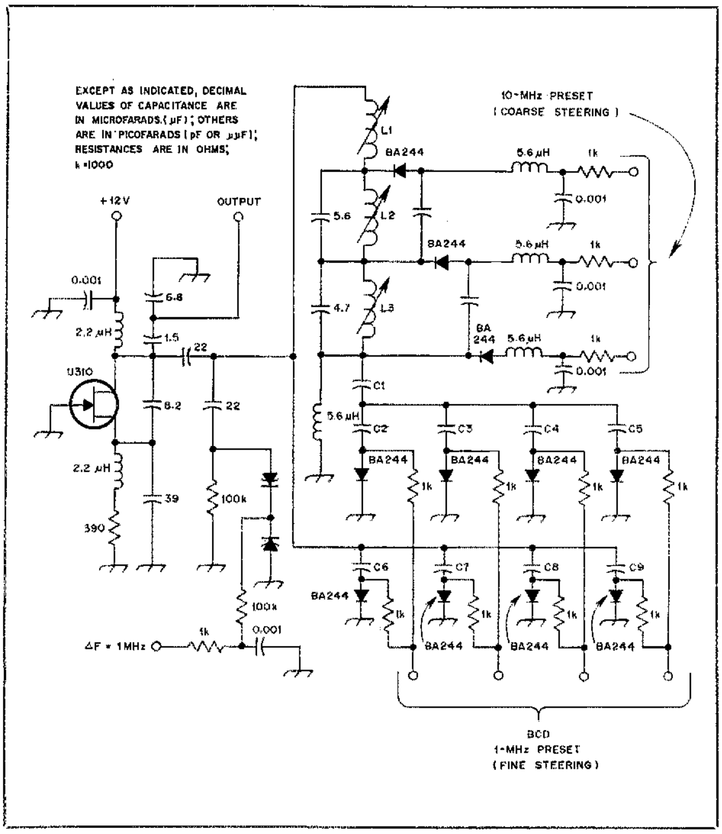

Fig. 4 — An ultra-low-noise VCO with coarse steering. The values of L1 through L3 and C1 through C9 depend on the frequency of operation chosen.

as lightning add to the man-made noise sources to make a noise blanker a necessity in modern communications receivers.

In general, the rise and decay times of man-made and naturally occurring noise pulses are substantially faster than the rise and decay times of desired signals. This phenomenon can be used to differentiate between the two types of interference. It is therefore desirable to build a pulse receiver that can become part of the existing receiver system without degrading the overall receiver performance.[14]

The noise blanker example of Fig. 6 is based on a publication by M. Martin, Hahn-Meitner Institute, Berlin, West Germany.[15,16] Martin's circuit is very involved and expensive. The simpler version published here can be added to any hf receiver with a first i-f between 9 and 70 MHz. It is assumed that the receiver has no rf preamplifiers and that the amplifier following the mixer has a low enough noise figure to make such a preamplifier unnecessary.

The noise blanker uses a Siemens TCA440 IC that incorporates all the elements of a single-conversion receiver. The i-f chosen is about 2 MHz and the values of the input coils are selected for an input frequency of 9 MHz. [Editor's Note: This circuit is provided for tutorial purposes. Further design information on the TCA440 is contained in "Designed Examples of Semiconductor Circuits," Siemens Corp., Issue 1975/76. Copies of the material relevant to the TCA440 are available from Siemens Corp., IC Component Group, 186 Wood Ave. South, Iselin, NJ 08830.]

The 9-MHz signal is taken from the

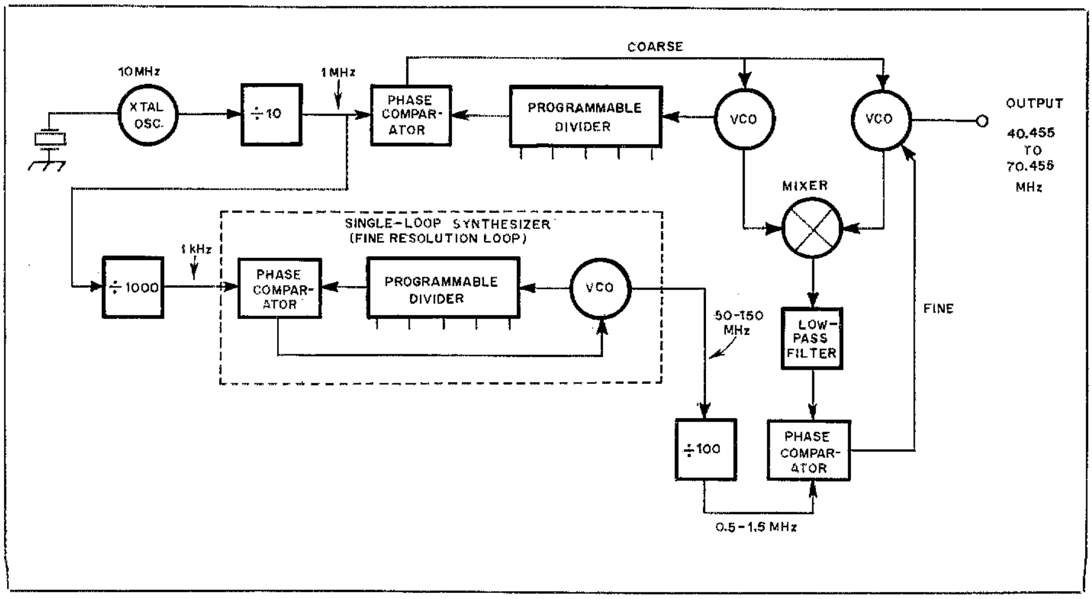

Fig. 5 — The block diagram of a novel frequency synthesizer using the type of VCO shown in Fig. 4.

mixer of the receiver and fed to a CP643 amplifier and a BF246C source follower. The source follower drives a series tuned circuit. The signal is then applied to the TCA440 single-conversion receiver and converted to the 2-MHz i-f. An external germanium diode provides fixed agc voltage to pin 9 of the TCA440. An audio test output is available to monitor the agc action of this receiver section. The 2-MHz i-f output is taken from a BF246 source follower and drives a BC177 with an adjustable-trigger threshold. The 74LS173 IC has the proper rise and decay times to drive the four-diode switching gate via a 2N2219 driver.

It was determined that the intercept point of this arrangement is about 26 dBm and the switching gate has a depth of about 80 dB. This is sufficient to suppress interference since the rf signal-to-noise ratio very rarely exceeds 60 dB. Practical experiments have shown this noise blanker to be superior to other configurations. The famous "woodpecker" completely disappears when it is switched in. The circuit layout should not be too critical. However, some care is required to build the switching gate without leakage. Good balance is required. Slightly better performance can be expected using HP 3081 PIN diodes, but this is achieved at considerably higher expense.

The vulnerability of hf receivers to internally and externally generated noise can be greatly reduced by improving the spectral purity of the LO and adding a noise blanker that introduces a small interference product. This, together with the use of high-level doubly balanced mixers and other low-distortion circuits, will make even tube receivers obsolete with respect to dynamic range.

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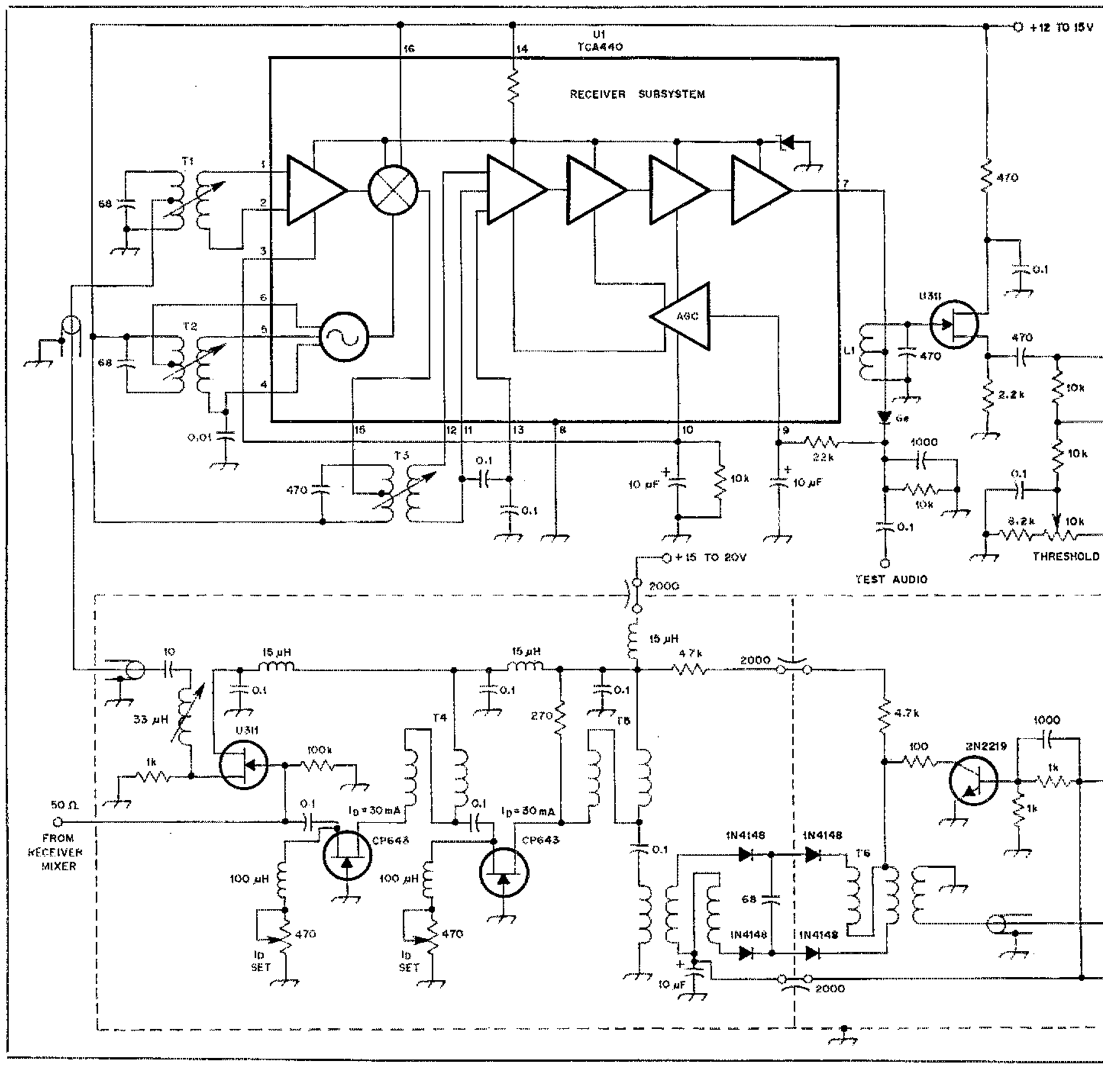

Fig. 6 — A high-performance noise blanker.

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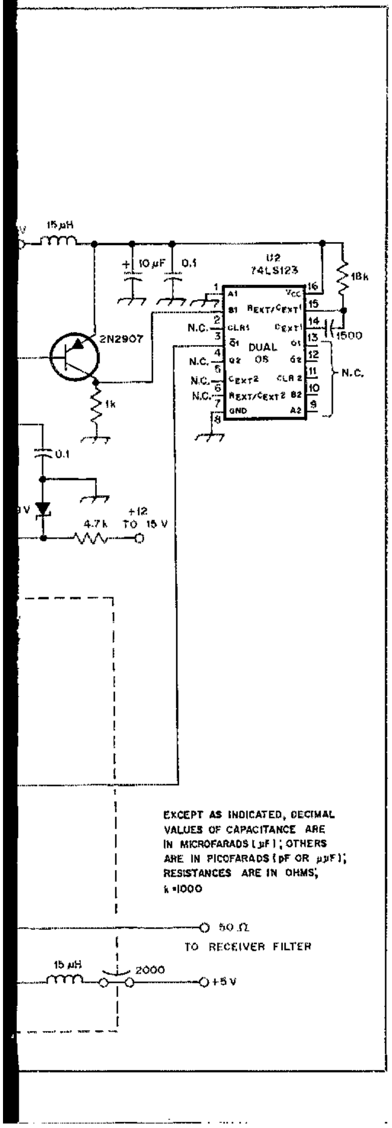


New Books

☐ *Technology — Fire in a Dark World*, by Perry Pascarella. Published by Van Nostrand Reinhold Co., New York, 1979. Hard cover, 6-1/4 × 9-1/2 inches, 172 pages, $12.95.

Hardly a day goes by that we aren't exposed to antitechnology sentiments. Bookburnings, oil spills, and antinuclear rallies capture media attention, but we also hear local grumblings about erroneous bills generated by computers. In his review of *The Zapping of America* (see May 1978 *QST*), Jim Kearman suggested that the antitechnology movement needs study. Perry Pascarella, executive editor of *Industry Week*, has done this job in his new book.

Our thoroughly technical society debates whether technology is good or evil. Pascarella points out the futility of such debate, taking the position that technology is integral to human evolution, and is in fact essential to our continued existence. He systematically refutes the arguments of the zero-growth advocates, drawing support from such eminent futurists and social critics as Toffler, de Chardin, Glasser, Sagan and McLuhan.

The actual problem we face is not how much technology should grow, but in what directions. To analyze this and related questions, Pascarella divides *Technology* into four parts: Toward a Better Life, Misconceptions and Apprehensions, The Worsening Climate for Innovation, and the Democratization of Technology.

"Toward a Better Life" examines the interdependence — the inseparability — of technology and freedom. The author defines what technology is and what it is not. He explores the meanings of innovation, ingenuity and productivity. The "international goodwill" and "advancement of the art" definitions of Amateur Radio fit neatly into this perspective of technology.

In "Misconceptions and Apprehensions," Pascarella looks into society's disillusionment with technology. Misuse of technology and some unexpected side effects have given it a bad name, but much of the criticism of technology should really be directed against our social structure. "If we can put a man on the moon, why can't we eliminate poverty, ignorance and disease?" This is a commonly asked question, and the author's answer is that the lunar problem was well defined and purely technical. Poverty, ignorance and disease are *social* problems, and any solutions must remain social. Nonetheless, technology, when properly applied, can assist in the solutions.

"Haven't we had enough technology?" is another frequently heard question. We can have anything we want, but not everything at once, Pascarella counters. We must select "appropriate" technology to solve our problems.

Jim Fisk answers the often-heard lament that "modern technology is ruining Amateur Radio" in his editorial in the November 1979 issue of *Ham Radio*. He points to exciting new developments and chides those who would return to the "good old days." Fisk is right, of course, but I started out with a 6L6 crystal oscillator on a wooden chassis, and to *me*, radio hasn't been as much fun since. Punching buttons on a microprocessor-controlled 2-meter transceiver doesn't do a thing for me. All the elegant reasoning in the world can't uproot a gut feeling. Apprehensions about change are difficult to overcome. Think about that when you try to justify your new antenna to your neighbor.

Pascarella warns of impending technological stagnation in "The Worsening Climate for Innovation." Today's electronic watches and calculators are the fruition of 15 years of research and development. If we expect anything equally innovative 15 years from now, we will be disappointed, for the labs are empty. Industry has reduced its commitment to basic R&D in the face of stockholders' demands for faster payoffs. Economic and political considerations are forcing an industrial retreat at a time when the solutions to our most pressing problems require long-term effort.

The final section of the book, "The Democratization of Technology," deals with technology's *outward* relationship to society. The author investigates possible options for technological direction from the lay public. The goal is to educate the public so it can make informed decisions. Pascarella believes the technical community is equal to this task. I disagree. After enduring much frustration attempting to teach basic electrical theory to radio amateurs (who are supposedly scientifically oriented), I shudder at the thought of educating the lay public in complex subjects without dangerous oversimplification.

Technology — Fire in a Dark World is a thought-provoking book, and all thoughtful people should read it. Despite exposing some disturbing trends, Pascarella concludes the volume on a hopeful note: "Man will not settle for a future without hope, and hope lies only in change. He must, therefore, make technology his and give it direction. He may tremble as he carries the torch evolution gave him, but he knows the answer to the question 'is it wrong to turn back?' " A comprehensive bibliography documents the work and allows the reader to draw his own conclusions. — *George Woodward, W1RN*

• *Basic Amateur Radio*

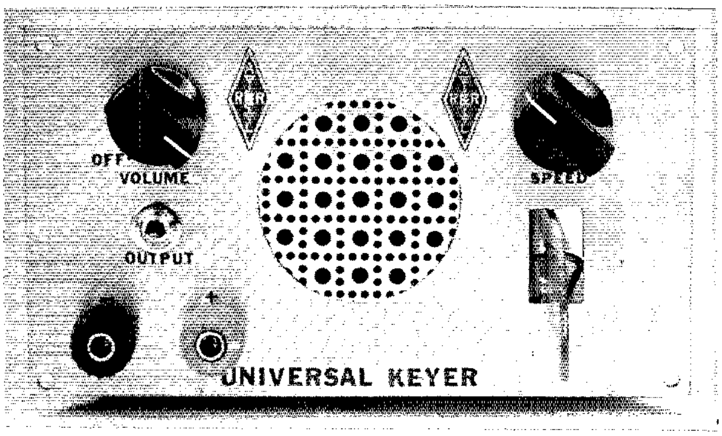
The NOR-Gate Break-In

Break into the world of the mysterious black boxes known as digital ICs. Investigate how these intriguing devices go together. You will come away with a simple, inexpensive keyer and know the basic secrets of the "black box."

By Peter O'Dell,* AE8Q and Robert D. Shriner,** WAØUZO

Have you been sitting on the sidelines listening to conversations in which words like "gate," "inverter" and "flip-flop" were bantered about? Have you dreamed about owning an electronic keyer but shied away because of the high price? If there were a quick, inexpensive and easy way that you could learn the basics of digital ICs and at the same time build a practical keyer, you would want to know about it, wouldn't you? Well, this keyer uses digital ICs and is simple, inexpensive and suitable for use with most rigs. It even has a built-in paddle that *can* be used if you want to avoid the expense of a commercial paddle.

As usual in this series, we're relying on the use of inexpensive materials in our workshop project. Printed circuit-board material is used for the front panel, side brackets, paddle arm and ballast compartment. The Universal Breadboard is employed as the main chassis of the keyer, and we are introducing a Universal IC Breadboard.[1] It will be used in subsequent Basic Radio projects as well as in this one.



Front view of keyer, which features digital ICs and a built-in paddle.

I See an IC

For the newcomer and any veterans who have managed to avoid the last 15 years of technology, an IC is best regarded as a "black box." There is no need (now, at least) to be concerned about what is going on inside the black box; you merely have to be aware of what happens to the output when a change is made to the input.

Basically, we have two general types of ICs — linear and digital. Although it is somewhat of an oversimplification, the beginner can think of the output waveform of the linear IC as being a scale model of the input form. This scale model can be larger, smaller or the same size as the input. Examples are audio amplifiers, rf amplifiers and oscillators.

For the most part, digital ICs are used in logic circuits. They are designed to function as binary (two-state) devices. Any given input or output is either on or off — just as the light switch in your kitchen is either on or off (assuming that you do not have a dimmer connected to it). These two states are usually called "low" and "high," depending on whether the voltage is near zero (or ground potential) or near the supply voltage. Through the use of binary arithmetic, digital ICs can be made to add, subtract, multiply and divide. Digital ICs are used in such things as calculators, clocks, computers, frequency counters and keyers.

ICs are frequently referred to as chips, but don't get the idea that you can eat them while drinking beer or play poker with them! They taste terrible and it is dog-gone near impossible to stack them without ruining the leads. The term "chip" comes from the fact that the ICs are made from numerous transistors

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[1]Notes appear on page 27.

"integrated" onto a tiny "chip" of silicon.

What Good is it If You Can't Eat It?

This month's project is a keyer that automatically produces properly spaced dits and dahs when the appropriate contact is closed. It is designed to mate with the Universal Transmitter that appeared in December 1979 *QST*, and to be powered by the Universal Power supply featured in November 1979 *QST*. It can be used, however, with most other transmitters and the supply voltage is not critical. Although the specifications for the chips that we are using call for a supply voltage between 5 and 15 volts, the unit that we constructed in the lab exhibited some quirks below 7.5 volts.

The "guts" of this month's project is made of eight NOR gates which are found in two CD4001 ICs. Fig. 1 depicts the top view of the CD4001. For each individual NOR gate each input and each output comes to a separate pin. The two remaining pins on the IC package provide power supply connections. Since the CD4001 is a CMOS device, these last two pins are labeled Vss (source voltage) and Vdd (drain voltage).

The schematic diagram of the keyer is given in Fig. 2. Although upon first glance the uninitiated may tend to view it as the scribbling of a demented chimpanzee, it really is a very simple design. There are road maps that will guide those who wish to *wade* through the circuit — the truth tables for the NOR gate and the R-S flip-flops.

The keyer is equipped with a sidetone oscillator. Q1 acts as a switch by turning on Q2, which is wired as a twin-T oscillator. This keyer by itself will work with the Universal Transmitter. If the keyer is to be used with a different transmitter, it is recommended that the circuit in Fig. 3 be added. Chet Opal, K3CU, used this circuit with his Micro-

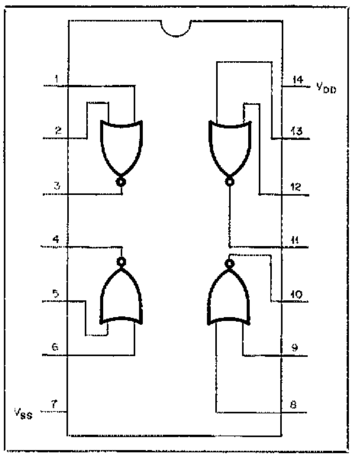


Fig. 1 — The top view of the CD-4001 IC. The indent at the top of the package is used for pin location identification.

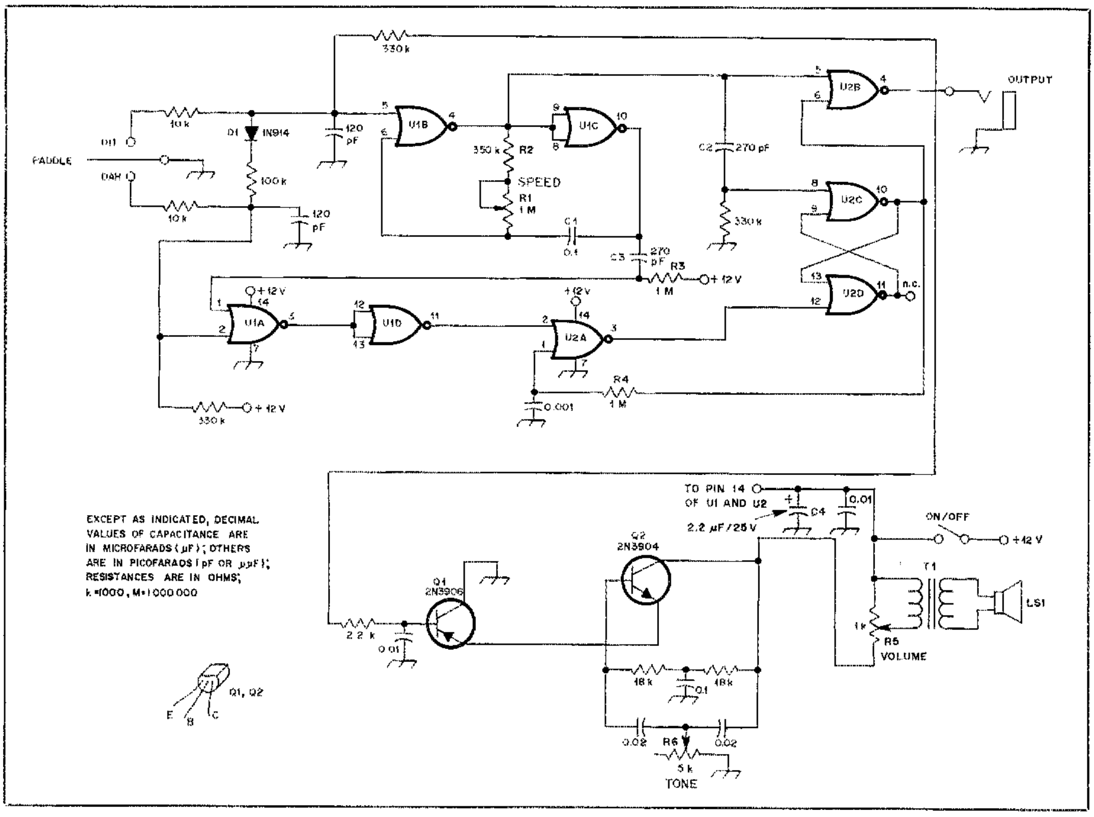


Fig. 2 — Schematic of keyer. All capacitors are disc ceramic, except for those with marked polarity. Fixed-value resistors are carbon-composition, 1/2 watt or less. For ease of understanding the circuit operation prepare the overlay described in the appendix to go over U2C and U2D.

C1, C2, C3, R2, R3, R4 — Numbered for text discussion and parts-placement purposes.
C4 — 22µF, 25 V electrolytic.
D1 — High-frequency switching diode, 1N914 or equiv.
J1 — Miniature phone jack (non-shorting).
J2, J3 — Insulated binding posts, one red (+), one black (−).
LS1 — Small 4- to 8-ohm speaker
Q1 — 2N3906 or equiv. pnp.
Q2 — 2N3904 or equiv. npn.
R1 — 1-MΩ reverse-log-taper.
R5 — 1-kΩ linear-taper, composition control (with spst switch).
R6 — 5-kΩ linear-taper, composition control.
S1 — (Part of R5)
T1 — Audio output transformer, 1-kΩ primary, 8-Ω secondary (Radio Shack 273-1380 or equiv.).

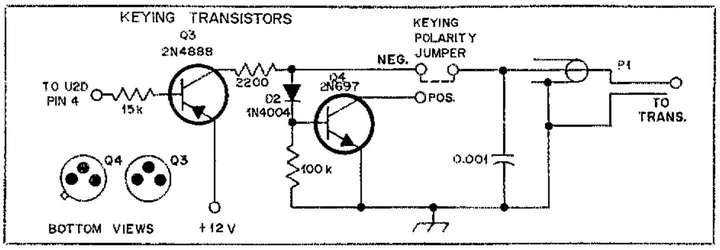


Fig. 3 — Suggested keying circuit to be used when keyer is mated to transmitters other than the one described in this series.
D2 — 1N4004 or equiv.
Q3 — 2N4888 or equiv.
Q4 — 2N697, 2N1711 or equiv.
P1 — (Appropriate plug to mate with transmitter)

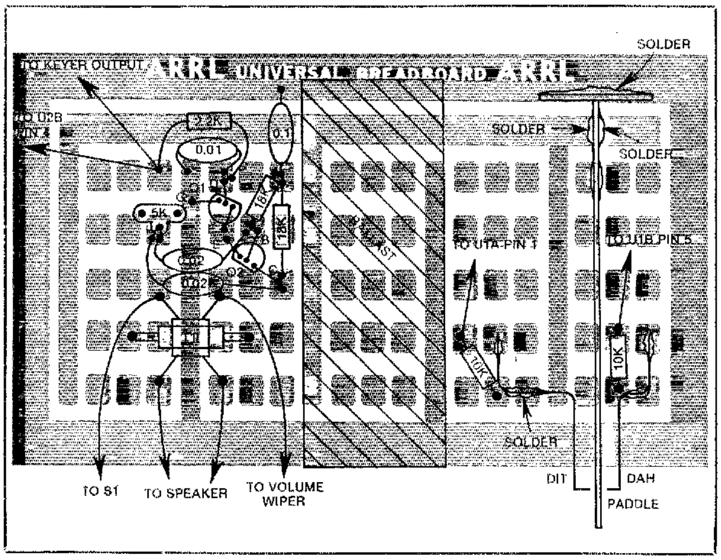


Fig. 4 — Parts-placement guide for part of the keyer. Parts are mounted on the foil side of the board. Resistances are in ohms; k = 1000 and M = 1,000,000. Capacitors are in microfarads. The etching pattern for this board appears on page 47 of September 1979 *QST*.

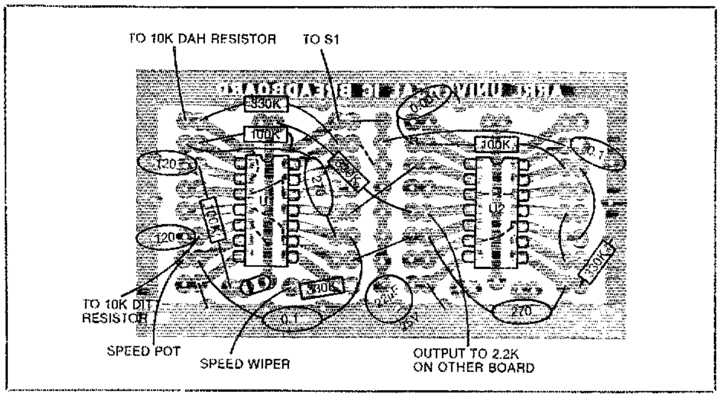


Fig. 5 — Parts-placement guide for IC breadboard of keyer. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. (The etching pattern appears in the "Hints and Kinks" section of this issue.) Resistances are in ohms; k = 1000 and M = 1,000,000. Capacitors with whole-number values are in picofarads except those with polarity shown, which are electrolytic with values in microfarads. Capacitors with decimal-value numbers are in microfarads. Unmarked lines indicate insulated wire jumpers. Broken lines indicate jumpers on foil side of board.

TO Message Keyer, described in February 1978 *QST*.[2] This circuit can be adapted to either positive or negative keying by moving a jumper. Should the builder have more than one transmitter requiring different keying modes, he could substitute a switch for the jumper to facilitate moving the keyer from one rig to the other.

If you like to know what is going on in a circuit, this is covered in the appendix at the end of this article. There you'll find a brief outline of digital devices and a short and very understandable explanation of how the circuit works. For those appliance operators who think that a keyer is the neatest thing since sliced bread, plunge right on into the construction section and ignore the appendix. And you can also forget all the details that we've presented so far, because the quiz scheduled for tomorrow morning has been canceled.

Careful Does It

Construction should be straightforward, with little chance of problems if the builder keeps in mind the quirks of CMOS. Since CMOS can be destroyed by static electricity, it would be advisable to install the two ICs while in an area of low static electricity, e.g., a damp basement. We also recommend that the builder use IC sockets for the two ICs. If not, the builder should use a three-wire, grounded-type soldering iron, or at the very least clip a grounded wire to the tip of the soldering iron.

There is nothing critical about using either of the Universal Breadboards. Other techniques could easily be employed. If the Universal Breadboards are to be used, suitable parts layout is given in Figs. 4 and 5.[3] The keyer should be assembled on the two circuit boards. All leads should be double checked against the schematic. Once the builder is sure that everything is in order, the two ICs can be installed into the sockets. The builder should then apply power and make sure that the keyer is functioning properly. If the keyer is to be housed in a pc board case, as pictured in the photo, the ICs should be pulled after removing power and set aside to avoid damage during the final stages of assembly. Just make sure that you don't confuse these chips with the Pringles.

The Universal IC breadboard serves as one side panel. The dimensions for the front panel and the other side panel were given in an earlier article.[4] The paddle (if desired) is constructed of double-sided pc board material and may be any suitable shape. It is soldered to the Universal Breadboard and to another piece of pc board that is mounted perpendicular to the breadboard and to the key. (See rear-view photo and Fig. 4 for details.) The keyer contacts are made of short lengths of brass welding rod.

The large rectangular object near the center of the breadboard is ballast material. This provides the keyer with enough weight to keep it from "walking" around the operating table while in use. The ballast is made by casting molten lead into a chamber that is constructed of double-sided pc board. If the builder is not steady of hand, it may be wise to cast the ballast before the electronic parts are mounted — *or substitute some less dangerous ballast for the molten lead.* With the ballast mounted first, parts placement will be more difficult.

Now that you have participated in the NOR-Gate Break-In and found the multilegged creatures living there not so bad after all, what are you going to do? Are you going to "stonewall it" and pretend that digital circuits are over your head, or are you going to get involved in this growing facet of ham radio? P.S. Please pass the chips; I'm hungry.

Appendix

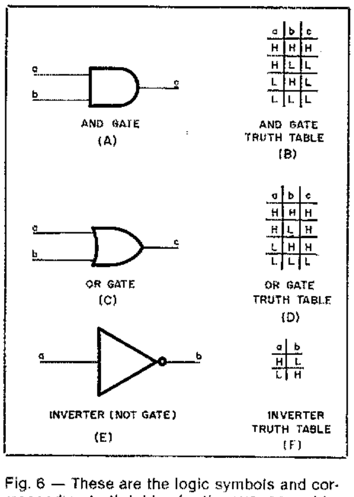
The most basic type of digital IC is the *gate*. It is the electronic equivalent of the gate on your back yard fence (it controls the flow of traffic). In the case of the yard, the gate controls the kids and dogs; in a logic circuit, the signal levels. Even a small dog wouldn't fit through one of these gates.

One type of logic gate is the AND gate. Its output is *high* if and only if both input channels are in their high state. Fig. 6A shows the schematic symbol for an AND gate. A *truth table* for this IC is given at B of Fig. 6. A truth table describes a logic function by listing all possible combinations of input values and indicating for each of the combinations, the true output value.

Next, we have the OR gate. Its output is high when any one or more of the inputs is high. Fig. 6C shows the electrical symbol for the OR gate. Its truth table is shown at D of Fig. 6.

English would become an incredibly difficult language (some of us have enough trouble as it is) without words such as "not," which indicates a *negative* state. Digital logic is facilitated with the use of negative gates called *inverters* or NOT gates. Inverters have one input and one output. When the input is low, the output is high; conversely, when the input is high, the output is low. The symbol for an inverter is given in Fig. 6E; its truth table, Fig. 6F.

The inverter can be combined with the AND gate and the OR gate to produce two additional, highly useful gates. When an inverter is placed on the output of the AND gate, a NAND gate is produced. The output of the NAND gate is the complement of the AND gate output. That is, with equivalent levels at the inputs, the output of the NAND gate will be just the opposite of that of the AND gate. The symbol for the NAND gate is depicted at Fig. 7A. Notice that the only difference between the NAND gate symbol and the AND gate symbol is the small loop on the output of the NAND. An analysis of the truth table of the NAND gate (Fig. 7B) will further establish the relationship between the AND gate and the NAND gate.

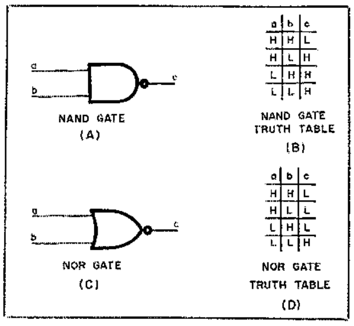


a	b	c
H	H	H
H	L	L
L	H	L
L	L	L

a	b	c
H	H	H
H	L	H
L	H	H
L	L	L

a	b
H	L
L	H

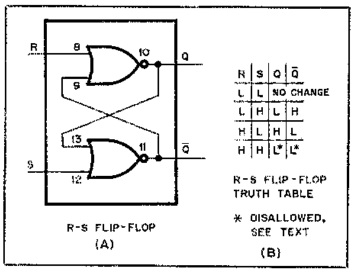
Fig. 6 — These are the logic symbols and corresponding truth tables for the AND, OR and Inverter gates.



a	b	c
H	H	L
H	L	H
L	H	H
L	L	H

a	b	c
H	H	L
H	L	L
L	H	L
L	L	H

Fig. 7 — The symbols and truth tables of the NAND and NOR gates indicate the effect of combining a gate with an inverter.



R	S	Q	Q̄
L	L	NO CHANGE	
L	H	L	H
H	L	H	L
H	H	L*	L*

Fig. 8 — Two NOR gates can be combined to produce an R-S flip-flop. Once wired together in this fashion, the flip-flop can be considered a "black box" itself.

Just as the AND gate can be inverted, so can the OR gate. An OR gate with an inverter on the output becomes a NOR gate. Again, to indicate that the basic function has been inverted, a small loop is placed on the output of the OR gate to indicate that it is a NOR gate (Fig. 7C). The truth table of the NOR gate (Fig. 7D) compared with that of the OR gate indicates the complementary nature of these two gates.

These five basic gates are referred to, in general, as combinational logic. That is, any changes that are introduced are carried out immediately. However, these gates can be combined in such a fashion as to produce circuits that are known as sequential logic. Sequential logic has the ability to store information and hold it for processing during the next (or later) cycle. The simplest form of sequential logic is the R-S flip-flop.

The R-S flip-flop can be constructed from two NAND gates or from two NOR gates. Fig. 8A shows a simple R-S flip-flop using two NOR gates; its truth table is at Fig. 8B. Although this R-S flip-flop is made of two independent NOR gates, it can be thought of as a separate "black box." The S and R are the "set" and "reset" inputs, respectively. The outputs are Q and Q̄ (Q̄ is pronounced "Q-bar" or simply "not-Q"). The outputs are complementary — that is, when Q is high, Q̄ will be low, and vice versa. Typically, only one of the outputs will be used in any given circuit.

If both S and R become low, then there will be no change in the outputs. That is, if Q was low before, it will remain low; if high, it will remain high. The remaining possibility is that both S and R are high — this is said to be disallowed. If both inputs are held high, there is no problem, both outputs are low. But if both inputs are only pulsed high and then go low, the outputs may assume any state. Thus there is no predictability; therefore, it is useless as a storage device. This is a problem only where the inputs are being pulsed simultaneously.

How Did We Get Here?

Digital circuitry came into its own as solid-state technology proliferated. Early in the game it became obvious that speed, power dissipation and noise immunity are the criteria that most affect the usefulness of logic devices. Speed simply refers to how long it takes an output to switch from low to high and back again. One frequently finds reference to the *upper limit* of some family of devices as being some specified number of Megahertz. This gives the user the upper limit of how many cycles from high to low to high again can be expected to occur without errors being introduced.

Power dissipation refers to the heat generated within the IC as it switches states back and forth. Excessive power dissipation can cause problems within a given circuit, e.g., the *clock* (in digital terminology an oscillator is usually referred to as a "clock") may change frequency with a change in temperature, or the device itself may self-destruct. Power consumption is primarily dependent on the number of devices that are connected to the output of a given IC and the speed at which the IC is used.

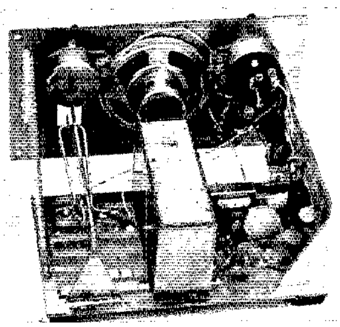
The world that we live in is filled with electrical noise. It would be difficult to design a digital circuit that could be completely isolated from the noise of the outside world. Additionally noise is generated within the digital circuit itself. Much of the noise is in the form of voltage spikes. Even though the duration of these spikes may be very short, they can play havoc with digital circuits. Noise immunity refers to the ability of a device to "ignore" the spikes and respond only to legitimate circuit signals. When a gate responds to a noise spike, it is said to have "falsed."

The first commercially available family of digital ICs was the RTL (*resistor-transistor-logic*). Although its performance was adequate for low level applications, it was soon superseded by DTL (*diode-transistor-logic*). DTL is far less susceptable to noise than is RTL. Some DTL devices are still available, but its use is not now widespread.

DTL was followed by TTL (*transistor-transistor-logic*), which has become one of two main families of logic available to today's hobbyist. The main advantage of TTL over DTL is its superior speed. Each RTL, DTL and TTL chip contains numerous bipolar transistors. Since bipolar transistors operate on the principle of control by current flowing through the base, these ICs require regulated sources of power capable of comparatively large amounts of current. The nominal operating voltage for TTL is 5 volts dc.

Another family of digital ICs is the CMOS (complimentary-metal-oxide-semiconductor). CMOS chips are made up of numerous MOSFETs that have been integrated into one small chip of silicon. Just as TTL has many of the attributes of the bipolar transistor, CMOS has many of the advantages and the disadvantages of FETs. Unlike bipolar transistors, FETs are sensitive to voltage levels. The input impedance to an FET is quite high, resulting in a low level of current flow. The net result is that FETs and CMOS operate at a very low power level. When the signal lines are quiet, the operating current of a typical CMOS chip is measured in *pico-amperes*.

CMOS tolerates a wide range of supply voltages. Where TTL is limited to 5 volts, CMOS will operate on any voltage between 5 and 15. The breakdown voltage for a CMOS gate is on the order of 50 to 90. Once the critical voltage has been exceeded, the gate is destroyed. It does not take much current, either. A person walking across a carpet may develop a static charge in excess of 1000 volts. If this static electricity is discharged through the IC, it will destroy the gate. Care should be exercised when handling a CMOS IC while it is



Rear view of keyer. Note the ballast material near the center of the main board.

out of circuit to avoid damage from static electricity.

CMOS chips may also be damaged if inserted or removed from circuits that have power and signals applied. Power should be turned off and any input should be disconnected before removing CMOS ICs from a circuit. Additionally, if a CMOS chip is to be soldered into a circuit, the soldering iron should be of the three-wire, grounded type. If only a two-wire iron is available, it can be used if it is *made* into a grounded iron. Simply run an alligator clip and a piece of wire from the tip and to a good electrical ground.

Truth in Wading

The heart of the keyer is the oscillator or clock, which is made up of U1B and U1C. The designator "U" comes from "unrepairable assembly." The "1" refers to the first IC, and the "B" and "C" indicate the second and third gate, respectively. Since we are dealing with CMOS, we are concerned with voltage levels and not with current flow. Initially, pin 5 of U1B is high, and as a result pin 4 is low. U1C is wired as a straight inverter. Since pins 8 and 9 are low, pin 10 must be high. This results in C1 being charged high, initially. However, C1 is returned to the output of U1B by the R1 in series with R2. Thus, after the time period determined by the R-C constant of C1 and the resistors, the lower side of the variable resistor, and therefore pin 6 of U1B, will become low. The oscillator will *hold* in this state until it is forced by external means to change.

The external means of change comes in the form of the dit paddle that is connected to pin 5 of U1B. Use the truth table to verify the following. When the dit paddle is grounded (low), the clock begins to oscillate and will continue so long as the paddle is low. Since pin 6 is already low, pin 4 goes high as soon as pin 5 goes low. Pin 10 of U1C goes low. C1 is now charged to the level of U1B pin 4 (high) through the same resistors as before (resulting in the same RC constant). When C1 becomes high, U1B pin 6 also becomes high, which forces pin 4 low, thus starting the cycle over again. The clock will continue oscillating until the dit paddle is released and pin 5 of U1B goes high. At that time, oscillation stops, but the circuit remains poised.

The output of the keyer is pin 4 of U2B. When the clock begins to oscillate, pin 4 of U1B goes high; this forces pin 5 of U2B high, so pin 4 goes low. This provides the keying action. Notice that the output of the keyer (pin 4) is tied back to pin 5 of U1B. If this were not done, the keyer would stop as soon as the dit paddle was released, leading to irregular dits. By depressing the dit paddle, we have made one complete dit.

How does the keyer go about making a dah that is exactly three times as long as the dit that was described? To best understand this process, those interested in wading through the schematic would do well to make an overlay to go over U2C and U2D. Fig. 8A gives the diagram of an R-S flip-flop that is made of two NOR gates. Notice that this is identical to U2C and U2D. Position the overlay over U2C and U2D such that the two NOR gates are replaced with a *box* having R (U2C, pin 8), S (U2D, pin 12) and Q (U2C, pin 10). $\bar{Q}$ is not used. This is another situation where the black box approach simplifies things a bit.

Truth tables for the NOR gate and for the R-S flip-flop will be useful in understanding the circuit operation. Pin 5 of U1B goes low through D1 when the dah paddle is depressed. This starts the oscillator, which causes pin 5 of U2B to go high, resulting in pin 4 going low. Thus far this is the same as depressing the dit paddle. When U1B pin 4 goes high, U1C pin 10 goes low, which forces U1A pin 2 low. Notice that these two gates are connected through C3. Pin 2 of U1A is also connected to +12 V through R3. Thus pin 2 of U1A is only "pulsed" low. The duration of this pulse is determined by the R-C constant of C3 and R3.

Pin 1 of U1A is also low by virtue of being connected to the dah paddle. U1A pin 3 is pulsed high; U1D is wired as an inverter resulting in U1D pin 11 being pulsed low. This places a low pulse on U2A pin 2. Pin 1 of U2A is also low because it is connected to Q of the flip-flop. Pin 3 of U2A goes high placing a high pulse on S.

Pin 4 of U1B is also connected to R through C2. When the clock started and pin 4 of U1B went high this placed a high pulse on R. The duration of this pulse is determined by C2 and the 330K resistor that allows the charge to bleed low. Because this time constant is smaller than that of C3 and R3, the duration of this pulse will be shorter than that of the pulse going through U1A and U1D.

There is a slight delay between the time that a signal appears at the input and when it shows up at the output of each gate. This time period is known as the propagation delay and is on the order of 35 nanoseconds for CMOS gates. Since the signal that comes to S travels through four gates that the signal to R does not, the signal at R reaches the flip-flop about 140 nanoseconds (0.14 μs) before the signal at S.

The sequence of the pulses reaching the flip-flop and their duration are significant. The pulse at R arrives first, which momentarily gives a high on R and a low on S. According to the truth table, this will result in no change since these are the conditions that call for Q being low, which it already is. When the pulse arrives at S, both outputs of the flip-flop become low. The high on R decays before that on S, leaving the situation of S high and R low, which according to the truth table causes Q to go high. Q is also connected to pin 1 of U2A through a delay network consisting of R4 and the 0.001-μF capacitor. After a delay approximately three times as long as the duration of the pulse on S, pin 1 of U2A goes high. At the end of the high pulse on S, S again went low, leaving a condition of both S and R low, which left Q unchanged (high).

As the clock continues, pin 4 of U1B suddenly goes low. This causes pin 5 of U2B to go low, but since Q is high, pin 6 is also high. Therefore, pin 4 of U2B stays low. Since R is already low and since pin 2 of U1A is already high, nothing changes at the flip-flop.

When pin 4 of U1B next goes high, another string of pulses is generated. If the dah paddle is still depressed the pulse proceeds through U1A; if not, it stops at this point. R is pulsed high just as the first time that U1B pin 4 went high. R is high and S is low, which causes Q to go low. Because the delay on U2A pin 1 is about three times longer than the duration of the low pulse reaching pin 2 of U2A, these two pins do not go low at the same time. Therefore, pin 3 of U2A, and consequently S, remain low.

With R, S, Q and pin 6 of U2B low, pin 4 of U2B goes high when pin 5 goes low. This places a high on pin 5 of U1B if neither of the paddles is depressed, which stops the oscillator. If one or the other of the paddles is depressed, the output of the keyer remains high for the duration of one dit, and then the cycle starts again.

If this did not "sink in" the first time, try switching back and forth from this description to the schematic to the truth tables. There is nothing magical or "deep" about this. Once you get used to using truth tables with schematics, you will find it easy to *wade through* just about any digital circuit.

Notes

[1]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.

[2]Opal, "The Micro-TO Message Keyer," *QST*, February 1978, p. 13.

[3]Etching pattern for the Universal Breadboard appeared on page 47 of September 1979 *QST*. The etching pattern for the Universal IC Breadboard appears in "Hints and Kinks," elswhere in this issue. See note 1 for information on ready-made boards, negatives, etc.

[4]Shriner and DeMaw, "A Simple RF Sniffer," *QST*, October 1979, p. 16.

New Books

☐ *Audio IC Op-Amp Applications*, by Walter G. Jung, second edition. Published by Howard W. Sams & Co., 4300 West 62nd St., Indianapolis, IN 46268. Soft cover, 8-1/2 × 5-1/4 inches, 208 pages, $7.95.

Walt Jung, who's authored a number of "cookbooks" (electronic, that is), has a new offering. This one is aimed at those searching for information on how to apply op amps in audio-signal processing.

The introductory chapter discusses those IC types that are dealt with throughout the rest of the book. It points out certain types that are optimum for use in audio applications, methods of compensation, protection and layout considerations necessary for stable operation. After examining various op-amp parameters, the book explores the multitude of configurations in which the ICs may be used. Then, it's a step into practical audio circuits, equalized amplifiers and active filters. The latter should be especially of interest to those involved in designing and building their own audio filters for cw and/or ssb reception.

A variety of special-purpose audio circuits is analyzed in the last chapter. The appendix is a handy reference for names and addresses of manufacturers of the different ICs discussed as well as a data sheet on a single op amp, the 5534. The book is replete with diagrams and required formulas and each chapter contains a list of references that may be used to obtain further detailed information. — *Paul K. Pagel, N1FB*

From Spark to Satellite: A History of Radio Communication, by Stanley Leinwoll. Published by Charles Scribner's Sons. Hardcover, 9-1/4 × 6-1/4 inches, 241 pages, $14.95.

Not another dry treatise of radio, that modern wonder of wonders, you say? No. Mr. Leinwoll has presented here a comprehensive *and interesting* story. History, as the title suggests, is boring. This is the *story* of radio communications from the beginning to present, laced with anecdotes involving notable contributors to the radio art, amusing sidelights, and intimate pieces of understanding. The book begins with a chapter devoted to the Father of Wireless, Guglielmo Marconi. One is immediately taken with the spirit of adventure that must have existed, and with the spirit of competition once others realized the commercial possibilities. The book proceeds chronologically with chapters on the early days; technological developments, Continuous Waves, The Audion; "Early Regulation," "Progress and Problems;" "Broadcasting and ensuing regulation. "The Amateurs Break Through" describes amateur activity following World War I. When vacuum tubes became available, amateurs were among the first to experiment, spelling doom for spark-gap. The amateurs, of course, were relegated to the frequencies under 200 meters where they would remain "out of the way." Everyone knew that radio propagation at these frequencies was ridiculous. (Tell that to a Spratly Island DXpedition today!) Further chapters cover the advent of television, fm, radar, semiconductors and, finally, space and laser communications, with an excellent chapter, "Hams in Space," which outlines the OSCAR program. The book should be of great interest to hams wondering just where Amateur Radio has fit in to the scheme of things in the past 90 years. — *Richard K. Palm, K1CE*

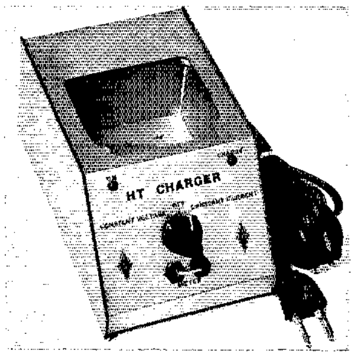
☐ *Handbook of Electronic Formulas, Symbols and Definitions*, by John R. Brand. Published by Van Nostrand Reinhold, 135 W. 50th St., New York, NY 10020. Hardcover, 4-1/4 × 7 inches, 368 pages, $15.95.

This outstanding little book should be invaluable to persons who are engaged in electronics work. Radio amateurs should also be delighted with the contents, as every formula one might encounter in studying for a higher class license or during a workshop design project is contained in the book. Professional persons will no doubt want it as a constant companion which can be carried in the attache case, to and from the office. Electronics students may find this volume their most useful tool for classroom and home-study applications.

This book contains thousands of "instant access" formulas, negating the need for a vast collection of references through which to sift for needed information. An important feature of this publication is the logical order in which the data are presented. That is, each page heading contains a letter of the alphabet under which the appropriate information is found. The alphabet is presented in its normal progression from A to Z. Therefore, if the reader wanted to look up the formulas for decibels, he or she would look under page heading "D." In each example, all of the pertinent variations of the basic equation are given.

The volume also contains such data as the Greek alphabet, phase-angle definitions, transistor math (extensive), op-amp symbols, math and circuits, plus a multitude of other modern data found in no other single reference. In the reviewer's opinion this is a book that will be hard to put down after perusing its contents. The owner may discover that this neat compendium will occupy a place alongside the *Radio Amateur's Handbook*; it will be carried with the *Handbook* almost every place the owner goes! — *Doug DeMaw, W1FB*

A Deluxe NiCad Charger for Hand-Held Transceivers



A useful accessory for the amateur who has a hand-held 2-meter transceiver is this NiCad charger designed by WAØUZO. The enclosure is made from printed circuit-board material. To charge the batteries, the transceiver is placed in the opening. The two pins visible at the bottom of the opening are the charging-voltage contact pins. See text for details.

Keep your NiCad batteries up to charge with this voltage-regulated unit. It's worry free and designed to maintain your transceiver ready for action.

By Robert D. Shriner,* WAØUZO

When it became my good fortune to afford the purchase of a new 2-meter hand-held radio, I found that finances would not stretch far enough to acquire a good desk-type charger as well. Previously, I had experienced poor luck when charging NiCad batteries. Now, with a new transceiver, having a reliable means of keeping the NiCads "up to snuff" seemed more pressing. After all, I wanted to keep these expensive little rascals in good shape for as long as possible.

Traditionally, if an amateur can't afford to buy ready-made gear, the alternative is to build what is needed. Rather than do without a suitable charger, I chose the construction route, opting to design a deluxe unit that would take advantage of components on hand and

*1740 E. 15th St., Pueblo, CO 81001

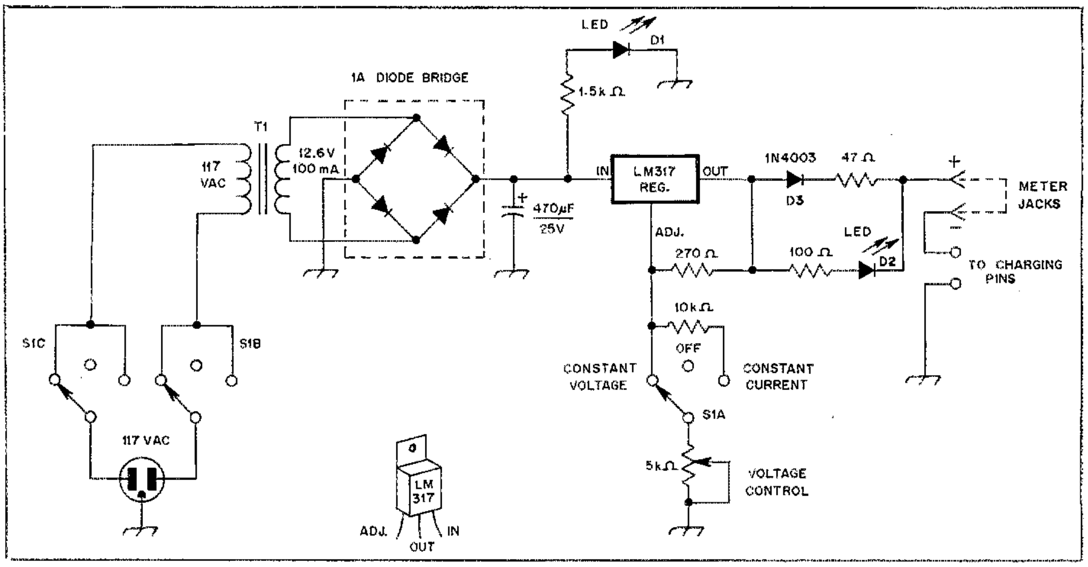


Fig. 1 — The WAØUZO charging circuit for hand-held transceivers. Proper charging of NiCad batteries is provided by this arrangement.

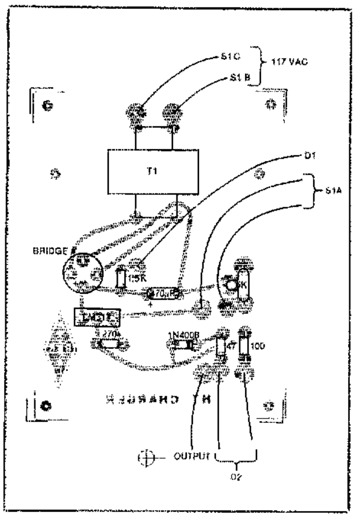


Fig. 2 — The WAØUZO hand-held radio NiCad battery charger may be constructed on perforated board or on an etched circuit board, as indicated here. This view shows the construction from the component side of the board. The shaded area represents an X-ray view of the copper pattern. (The etching pattern appears in the "Hints and Kinks" section of this issue.) Resistances are in ohms; k = 1000.

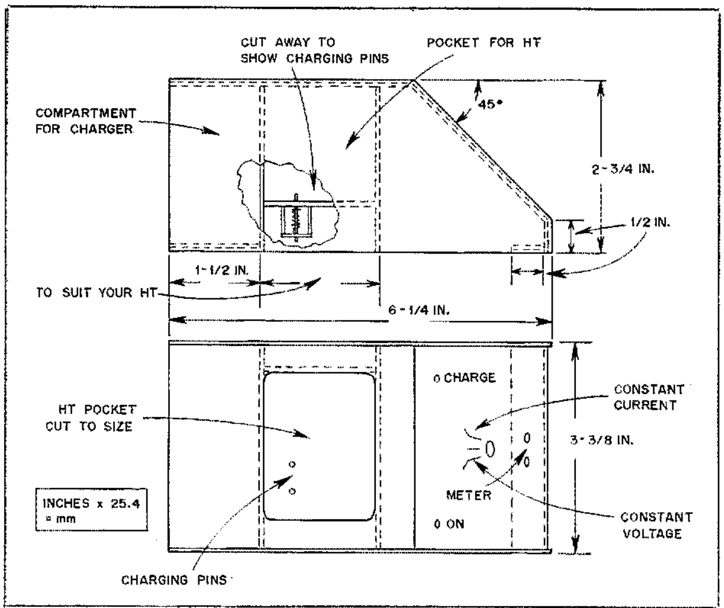


Fig. 3 — An attractive enclosure for the charging circuit can be fabricated with printed circuit-board material. Patterns for making the cabinet are shown above. The cut-away portion shows a spring-loaded pin used for connecting power to the transceiver battery circuit.

minimize the number of parts requiring purchase.

After determining my objective, I next performed some research. An analysis of information related to NiCads and charging methods disclosed that there are three popular methods of charging nickel-cadmium batteries. There is a choice of the *pulse* method, the *constant-current* method or the *constant-voltage* system. Before I go into detail about my design, let us briefly examine all three of the options.

Pulse charging is generally done with a square wave, a very good but expensive method that requires additional circuitry to control the charge. Constant-current charging, a popular way, does involve the danger of ruining a set of batteries if one forgets to shut the charger off or intentionally leaves it on longer than the recommended 16 hours. With that in mind, we arrive at the third choice, the constant-voltage system. This method will never harm your batteries. The disadvantage is that a full charge takes nearly 36 hours.

A design that combined the best features of all three methods seemed feasible. From the drawing board came the circuit shown in Fig. 1. Once the prototype was developed and tested, I found that the charger performed beyond all expectations.

The Circuit

A charging-circuit power transformer must have ample current- and voltage-handling capability for the task. T1 in Fig. 1 is a 12.6-volt unit rated at 100 mA. It has proved adequate for the purpose. Under small loads it produces 15 volts. Add a full-wave bridge to T1 and you can take full advantage of available current.

The 470-μF electrolytic capacitor at the output of the bridge rectifier smoothes out the ripples besides charging up to peak voltage. The formula for peak voltage is rms × 1.4 or 15 × 1.4 = 21 volts. That amount is available for constant-current charging. To ensure the presence of a constant voltage, the circuit contains a voltage regulator.

Pulse charging is obtained by means of the 470-μF capacitor. Under a heavy current charge, which will occur when the batteries are low, this value of capacitance will allow some ripple voltage through the system giving a 120-Hz pulse.

To prevent a reverse charge from getting into the batteries (but without sacrificing the constant current), a 1N4003 diode is in series with the output of the voltage regulator. The 47-ohm resistor serves as a limiter.

At the heart of the charging circuit is the LM-317 regulator IC. This unit of the charger deserves some explanation, particularly concerning the control capability. An LM-317 voltage regulator, rated at 1 A, will run "cool as a cucumber" under the load required for charging the NiCads. The output can be varied from 2 volts to full voltage by means of a 5-kΩ variable resistor. A 10-kΩ resistor is switched in series with the variable resistor, enabling the adjustable leg of the LM-317 to be raised far enough above ground to allow full voltage to pass through for constant current. The LED, D1, is a *power on* indicator. D2 performs as a *charge* indicator.

Construction

The circuit may be assembled on perforated board, or an etched circuit board may be used. (See Fig. 2.) After installing all parts, set S1 for constant current. A 100-mA meter should then be connected in the line to your battery. A reading of 50 mA is normal, but this will vary according to the charge held by the battery.

Next, charge the battery fully and switch to constant voltage. Adjust the

5-kΩ resistor so that a charging current of 3 mA is observed.

Now, just for the fun of it, turn your hand-held radio on. By doing so the charge rate will go up to nearly 5 mA. When a station comes on the air, you will be able to see the voice peaks on the meter as the charger automatically jumps in to replace the small amount of current used on modulation. With these adjustments completed, the charger should perform properly.

Making the Cabinet

Furnishing a suitable enclosure for the charger is next on the agenda. I resorted to the old "home-brew" method after a visit to the local supply house failed to produce a suitable cabinet. Being quite familiar with printed circuit-board material, I decided to use some for my enclosure. The accompanying photographs show the cabinet parts before assembly and the finished product.

Dimensions shown in Fig. 3 will accommodate most hand-held transceivers. The width of the enclosures may have to be increased for some of the larger sets. You can cut the printed circuit-board material to the dimensions shown in the illustration or they may be purchased in precut form.[1] To prepare the cabinet parts, get your hands on a good, sharp single-cut file. In order to clean up the edges of the board material, lay a sheet of wet or dry sandpaper on a flat surface. Stand the board on edge. Rub the edge around in a circular motion on the sandpaper. Keep at it until the edges are smooth. Check for squareness as you proceed. The file is used to round the upper edges for a neat finish.

Take your time, working carefully in order to provide a professional appearance. That appearance will depend only upon the quality of your work. Lay out the hole in the top of the case for your transceiver. Allow 1/16 inch (1.5 mm) clearance for easy "drop in" of the hand-held set. The cutout can be made with a "nibbling" tool or small metal cutting saw.

File the angle on the control panel, top and front pieces. Go slowly at this point for the sake of good workmanship. After you have completed trimming the parts to fit, polish them with fine steel wool.

When preparing to solder the cabinet panels in place, a helping hand will be of much assistance. Having someone hold the panels in position will free your hands to work with the soldering iron.

Lay the front panel down on the top piece of circuit-board material, which will serve as a spacer. Position one side panel in place and have your helper hold it so that you can solder the panel in place. Be careful not to solder your helper. That could result in some knots on your head and the loss of some good help!

Place the other side of the cabinet in position and tack it in place. Next comes the top piece. Again, use the piece of circuit-board material for a spacer with the top piece laid on it. Position the assembly. Check the fit. Tack solder the work as needed and proceed to tack on the short front piece. Continue to work slowly. Use a bit of common sense while assembling these parts. Avoid working yourself into a blind alley!

If all has gone well, then fit in place the two spacers that will form the pocket for the hand-held radio. Tack them with solder. Now position the two sides of the pocket, using the general procedure mentioned above.

At this point, stop to look over your work. If any parts fail to fit properly, a little solder wick will aid in the removal of solder so that the offending piece can be removed and dressed down. Once refitting is accomplished, run a bead of solder along the full length of all seams.

The Final Touches

Most hand-held transceivers are equipped with a pair of contact buttons on the bottom of the cabinet. These are for charging the NiCad batteries with a desk charger. If your set lacks this feature, I suggest that you install a pair. Providing the charging contacts is the most difficult part of the project. A study of your "HT" will show the best place for them. Just make sure that they are recessed a little so that a short will not occur if the transceiver is placed on a metal surface.

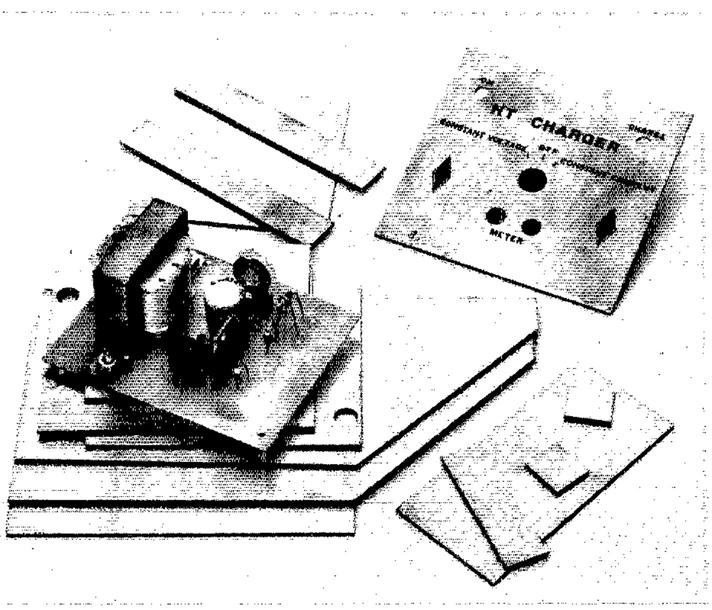
Select the piece of circuit-board material that will form the bottom of the pocket. Mark the location of the charging pins. Fig. 3 illustrates the method I used to make these pins. Cut the copper foil around the positive pin to provide insulation.

Apply your own ingenuity to make these contacts, if you wish. The contacts should be spring loaded and the positive pin must be insulated from ground. After these are made and installed on the board material, position the piece so that the contacts will fit in the transceiver without the possibility of developing a short.

Polish the case with fine steel wool and apply a coat of polyurethane varnish. Most hardware stores have this in easy-to-use spray cans.

Once you assemble the charging unit in your enclosure, your work is done. Note that a set of jacks is provided on the front panel for metering the charging rate. Normally, a shorting bar is placed across these jacks when a meter is not connected to the unit. The LEDs are held in place by a drop of epoxy cement.

If you need a charger or are not satisfied with the one you have, construct this circuit. Several of them have already been made in my local area. Each one performs nicely. I believe it is the best. No doubt you will agree. QST



Components for the WA0UZO NiCad charging unit are shown mounted on a printed circuit board. The precut panels used for making the cabinet are also displayed.

[1]Circuit board, material and parts kits are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.

The Half Sloper — Successful Deployment is an Enigma

That new leaning-wire DX chaser you've installed may be the "in" thing, but VE2CV puts a new slant on the sloper that may change your thinking about it!

By John S. Belrose,* VE2CV

The so-called half-sloper antenna seems to have reached its heyday. Bill Orr, W6SAI, for years has lauded the performance of slopers. George Smith, W4AEO, writing in *73 Magazine,* has discussed both full- and half-sloper antennas. Dana Atchley, W1CF, and Doug DeMaw, W1FB, have recently published their comments in *QST.*[1-6]

An antenna of this configuration consists of approximately 1/4 wavelength of wire that slopes from the top of a tower. An angle of 45 degrees between the wire and ground level is considered appropriate. Termination of the far end of the antenna may be placed from 5 to 15 feet (1.5 to 4.6 meters) above ground. The general practice is to feed the antenna with 50-ohm coaxial cable, the center conductor of which is connected to the antenna and the sheath connected to the tower at a position adjacent to the feed point. Some amateurs tape the cable to the outside of the tower, but others prefer to pass the cable through the center of the tower in an effort to minimize any effect of the radiated field on the transmission line.

Among the many radio amateurs who have slopers, there are those who claim that a perfect match has been attained by employing a sloping wire cut to the traditional length for a 1/4-wave radiator but shortened 5%. Others have found that the wire had to be 8% longer than 1/4 wavelength. Still others have found that with a tower shorter than 1/4 wavelength, the radiator had to be considerably shorter than a 1/4-wave antenna. Bob Lunsford, formerly WB4DPG/5, found that the best match is obtained when the end of the antenna is parallel to the ground and close to the earth for some distance.[2] From all this, one must infer that there does seem to be a problem in regard to resonating and matching the impedance of the antenna.

Concerning performance, some amateurs have reported good results with this type of antenna. Others have been unable to make it work or became discouraged when they failed to make it resonant. The azimuthal and elevation patterns for the antenna are unknown. In some descriptions of the half sloper, the tower is thought to be like a reflector, providing some directionality to the azimuthal pattern. Most amateurs who have used the antenna agree that it should be a good radiator because the current maximum is generally in the clear, being at the top of the radiator rather than appearing near the bottom, as would be the case with a 1/4-wave vertical antenna.

Although the author of this article has not used the half sloper for 80 or 40 meters, he has modeled the antenna at 200 MHz, measured its impedance and graphed polar diagrams on a professional antenna-pattern range which is over a perfectly conducting ground plane. This article discusses these results.

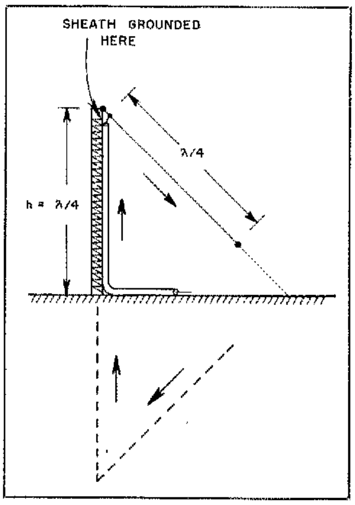


Fig. 1 — A half-sloper antenna showing method of feed and the ground image. The arrows show the instantaneous direction (phase) of current flow on the antenna and its image.

Resemblance to a Delta Loop

A half-sloper antenna and the image on the ground plane are shown diagramatically in Fig. 1. It is clear that if the antenna were fed at the far end, with the sloping wire connected to the top of the tower, the radiator would indeed be a half delta loop (the other half for full-wave resonance is the image of the antenna in the ground plane). The antenna, however, is fed at the top of the tower with the far or lower end open-circuited. It must radiate, therefore, like some form of bent grounded 1/2-wave radiator or perhaps like a top-fed, top-loaded vertical radiator. Previous users of this antenna have considered it to be of the former type.

*3 Tadoussac Dr., Aylmer (Lucerne), Quebec J9J 1G1 Canada

[1]References appear on page 33.

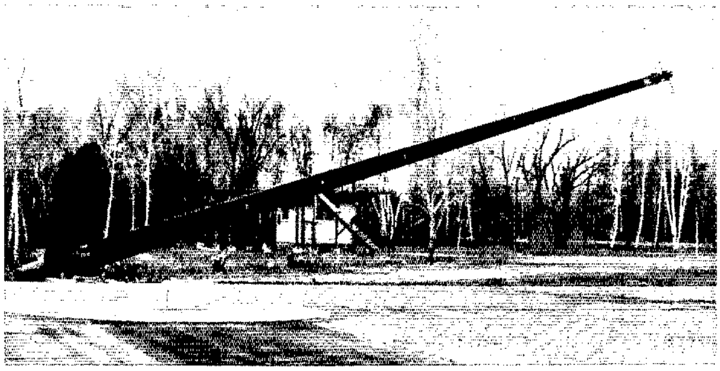


Fig. 2 — Photograph of antenna-pattern range showing boom for measuring vertical pattern, and flush-mounted turntable for measuring the azimuthal pattern.

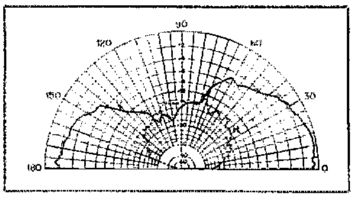


Fig. 3 — The solid line (V) represents the vertical pattern for vertical polarization measured in the plane containing the sloper and the tower. A graphical representation of the vertical pattern for horizontal polarization measured in the plane perpendicular to that containing the sloper and the tower is shown by the dashed line (H).

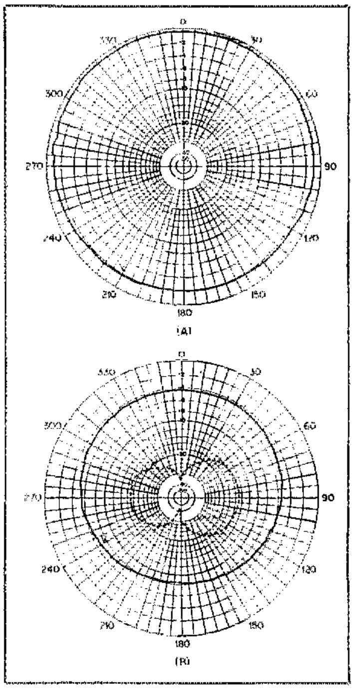


Fig. 4 — Azimuthal patterns for vertical polarization measured at elevation angles of 10° and 45° above the horizon are shown by solid lines in A and B, respectively. A figure-eight azimuthal pattern for horizontal polarization measured at 45° elevation is represented by the dashed line in B.

The sloper the author built was 1/4 wavelength long, calculated by the usual formula for wire antennas in which there was an allowance of 5% for shortening from a free-space quarter wavelength. The tower is physically 1/4 wavelength high. In order to obtain a repetition of the antenna feed-point impedance at the transmitter end of the transmission line, the transmission line was 3/2 waves long.

Tests disclosed that the antenna did not resonate at the design frequency (200 MHz). Measurements indicated the impedance to be 150 + j190 ohms. None of the adjustments of the antenna parameters (height of the tower or length of the sloping wire) resulted in obtaining resonance. Next, the configuration was changed so that the coaxial cable passed upward through the center of the tower. Little difference was found. Obviously, since the antenna would not resonate when driven from a transmission line of random length, the apparent impedance could be anything, depending on the electrical length of the line. This seems to agree with the results of other amateurs.

The Polar Diagrams

Data for the polar diagrams shown in this article were obtained from measurements made on a professional antenna range. This ground-level pattern range is 70 feet wide by 200 feet long (21.4 × 61 m). It is laid out in the form of a wire grid at one end of which is a copper-clad, flush-mounted turntable that is 20 feet (6.1 m) in diameter.

The model antenna was placed at the center of this rotatable part of the test range. A counter-balanced boom at one edge of the range can be swung overhead to measure the vertical pattern for either vertical or horizontal polarization (see Fig. 2). We did not attempt to match the impedance of the sloper. Therefore, the relative gain with reference to a monopole, for example, was not measured.

Our sloper radiated essentially like a grounded-monopole vertical radiator. The radiated field was dominantly vertically polarized and the azimuthal pattern was essentially omnidirectional. The horizontally polarized component, which is maximum in the plane broadside to that containing the sloper, was 10 dB down from the vertically polarized field.

Various measurement patterns are illustrated in Figs. 3 and 4. In Fig. 3, we show the vertical pattern for vertical polarization measured in the plane containing the sloper and the tower; and the vertical pattern for horizontal polarization measured in the plane perpendicular to that containing the radiator and the tower. In Fig. 4, we show the azimuthal pattern for vertical polarization at elevation angles of 10 degrees and 45 degrees above the horizon. The azimuthal pattern for horizontal polarization at 45 degrees elevation (Fig. 4) shows that for horizontal polarization, the field is maximum in this direction. In Fig. 4 the sloper and tower are aligned along the 0- to 180-degree axis.

Discussion

In view of the foregoing, the questions I ask myself are: (1) What does the antenna have going for it? Personally, if I had a single, grounded 1/4-wave tower, I'd employ a full-wave delta loop, apex up, lower corner feed — the best DX-type antenna I've modeled. But that is another story. An alternative is to excite the tower as a folded unipole or as a half delta loop. (2) How were the users of the antenna able to get a good match when the impedance differs so markedly from that of the 50-ohm feed line? Undoubtedly, therein lies the explanation of the difficulty many amateurs experienced when attempting to resonate the antenna. Doug DeMaw's note reveals that indeed the input impedance is probably high. He found that when the feed point became covered with ice the antenna was rendered useless. The SWR reading was full scale under those conditions.

George Smith, W4AEO, suggested grounding the sloping wire to the tower and end feeding the lower end of the sloping wire. He points out that by doing so one could avoid installing cable from the bottom to the top of the tower, an expense- and labor-saving advantage. Indeed, if we visualize this method of feed (refer to Fig. 1), we can see that the anten-

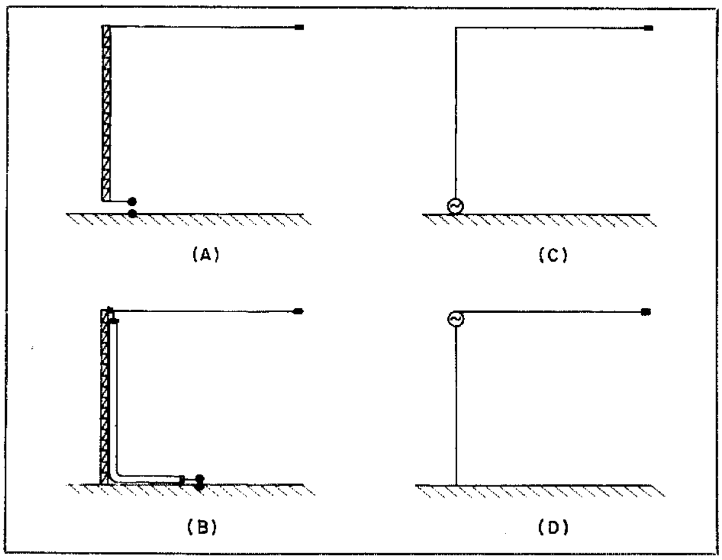


Fig. 5 — Actual and equivalent circuits for base-fed (A and C) and elevated feed (B and D) L-type antennas.

na type is clearly a grounded vertical half-delta loop (the loop is full-wave resonant since the other half of the loop is formed by the image in the ground plane).

What do we conclude about performance? Doug DeMaw has made glowing claims about the performance of his 40-meter sloper; for him, in fact, the antenna does work mighty well. Doug previously used a half-wave (a full-sloper) antenna. I have not used the half-wave sloper but had thought it to be a good one. If it is an effective radiator, then I believe the 1/4-wave sloper cannot be 10 to 20 dB better. So we haven't entirely resolved the enigma of the sloper.

Further experiments with the antenna, after we completed the antenna-pattern measurements, included measurement of the SWR over a very wide frequency range For this purpose, we used a sweep-frequency signal generator, an SWR bridge and an oscilloscope display. Curiously enough, the antenna was found to be resonant at a frequency very much lower than any for which we had previously made impedance measurements. The antenna resonated at 134 MHz and near 283 MHz rather than at 200 MHz. This suggests that the antenna is, in fact, a type of top-loaded vertical monopole. It further indicates that users of this antenna should be aware that the operating frequency is above the self-resonant frequency of the antenna by a factor of about 1.5.

This interpretation is made clear in Fig. 5, where we show actual and equivalent circuits for (A) a conventional insulated-base, base-fed antenna and (B) an antenna, like the half sloper, with elevated feed (fed with coaxial cable at the top of the mast). The equivalent circuits are shown in (C) and (D) respectively; i.e., the feed arrangement shown in (B) is equivalent to inserting the generator between the mast and the top loading. The half sloper is an L-type antenna in which the upper arm is sloping instead of being horizontal. More exactly, it is an umbrella-type radiator in which the "active guys" have been reduced to one.

In conclusion, I do not recommend the use of this antenna. The radiator is nonresonant for frequencies near those expected. The pattern is essentially omnidirectional. This same pattern can be obtained by using a more sensible arrangement of feeding a grounded quarter-wave tower, such as converting it into a folded monopole or a half-delta loop.

Acknowledgements

The author wishes to express his thanks to L. R. Bode of the Communications Research Center, Department of Communications, Ottawa, who built the model antenna and measured the impedance. Appreciation is also extended to J. G. Dunn who measured the antenna pattern on the National Research Council's antenna-pattern range.

References

[1]Orr, "Antennas" *CQ Magazine*, September 1975, pp. 41-44. The author describes an 80-meter sloper antenna built by W6MZ.
[2]Orr, *CQ Magazine*, February 1976, pp. 46-48.
[3]Orr, *CQ Magazine*, February 1976, pp. 44-46.
[4]Smith, "Shortened Antennas for 75 and 80 Meters Which Fit Your QTH — Slopers Exposed," *73 Magazine*, July 1979, pp. 58-64.
[5]Atchley, "Putting the Quarter-Wave Sloper to Work on 160," *QST*, July 1979, pp. 19-20.
[6]DeMaw, "Additional Notes on the Half-Wave Sloper," *QST*, July 1979, pp. 20-21.

Strays

MOVING? UPGRADING?

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ED REDINGTON MEMORIAL SCHOLARSHIP

☐ An Ed Redington Memorial Scholarship has been established in honor of W4ZM. Contributions from his many friends have been coming in to the Washington, DC, Foundation for Amateur Radio. Funds are already available to provide scholarships for at least the next two years.

Ed, one of the best known and best loved of the old-timers, was known coast to coast for his talks about the old days and his demonstrations of an operating spark-gap transmitter. His passion was helping young people get on the air.

To establish a sustaining fund, a substantial amount of money will be needed. Won't you help us reach that goal? Donations in any amount will be most gratefully accepted and acknowledged. Send contributions to: Foundation for Amateur Radio, Ed Redington Scholarship Fund, c/o Mr. Kenneth L. Joseph, W4SIG, 9416 Hermosa Dr., Fairfax, VA 22030. — *J. William Miller, K4MM, Fairfax Station, Virginia*

OPERATORS NEEDED FOR THE ASTEROID-INTERCEPT NET

☐ Precision phone operators, to become part of the new Asteroid Intercept Net, are wanted in the following cities: San Angelo, San Antonio, Austin and Dallas, Texas; Oklahoma City, Oklahoma; Shreveport, Louisiana; Little Rock, Arkansas; Kansas City and St. Louis, Missouri; Huntsville, Alabama; Jacksonville and Tampa, Florida; Atlanta, Georgia; and Washington, DC. Hams in other cities along the path of the upcoming asteroid occulation (eclipse) may also be needed. Contact William R. Shoots, K5BY, 709 Ballentine St., Seabrook, TX 77586. Only queries accompanied by an s.a.s.e. can be answered. — *William R. Shoots, K5BY*

Technical Correspondence

Conducted By
John C. Pelham,* W1JA

CONVERSION OF SURPLUS RELAYS TO OTHER OPERATING VOLTAGES

□ Do you happen to have some old 28-volt relays in your junk box, and at the same time have a need for relays for 12-volt mobile operation? I did, and decided to rewind one of the relays to operate on 12 volts. Here is how a replacement winding can be designed.

The pull of the armature is determined by the magnetic flux produced by the coil current; and this flux is proportional to the number of turns times the current, or NI. To operate the relay at another voltage, we must rewind the coil so that the new voltage will supply the original magnetic flux.

If we use wire of twice the original diameter for the new winding, we would get half the number of turns per layer and half the number of layers — 1/4 the original number of turns and 1/4 the original length of wire. In general, $L \alpha 1/d^2$ and $N \alpha 1/d^2$, where d is the wire diameter, N is the number of turns and L is the total length of wire. (The symbol α means "is proportional to.")

The resistance of the winding is proportional to its length and inversely proportional to the square of the diameter: $R \alpha L/(d^2)$. Since $L \alpha 1/d^2$, it follows that $R \alpha 1/d^4$.

From Ohm's Law, the relay current is equal to E/R where E is the applied voltage. Therefore $I \alpha Ed^4$. Since $N \alpha 1/d^2$, the ampere-turns (NI) of the relay is $NI \alpha (1/d^2)(Ed^4)$, or $NI \alpha Ed^2$. This means that the quantity Ed^2 must be the same for the new winding as for the original winding. Mathematically, $E_1 d_1^2 = E_2 d_2^2$, where the subscript 1 refers to the old winding and the subscript 2 refers to the new winding. This may be rewritten as

$$\frac{d_2}{d_1} = \sqrt{\frac{E_1}{E_2}}$$

This is the equation we need for choosing the wire size for the new winding. There is no need to know the dimensions of the winding space, the number of turns on the original winding, or the length of the wire. Just measure the diameter of the old wire, calculate d_2, look up the nearest corresponding wire size, and fill the winding space with wire of that size!

Since $I \alpha Ed^4$ and since the power dissipated in the coil is $P = EI$, we have $P \alpha E^2 d^4 = (Ed^2)^2$. Since we have kept Ed^2 constant, the power dissipated in the new coil will be the same as the power dissipated in the original coil, so our conversion will not cause overheating.

As a practical example, let's consider the conversion of a 28-volt relay for nominal 12-volt operation. From Eq. 2 we find that d_2/d_1 should be 1.53 for 12-volt operation and 1.42 for 13.8-volt operation. The diameter of the original wire on my relay measured 4.5 mils (0.114 mm). Allowing a little for the enamel, it must have been no. 38 wire (copper diameter of 4.0 mils or 0.102 mm). Thus, I needed to choose

$d_2 = 4.0 \times 1.53 = 6.12$ mils (0.155 mm) for 12 volts or

$d_2 = 4.0 \times 1.42 = 5.68$ mils (0.144 mm) for 13.8 volts.

From the Copper Wire table in the *Handbook*, no. 34 wire has a diameter of 6.3 mils (0.160 mm) and no. 35 wire has a diameter of 5.6 mils (0.142 mm). I happened to have a spool of no. 35 in the junk box. I wound and installed the new coil, and the relay worked perfectly. In fact, it would pull in for voltages less than 12, showing that a good margin of safety had been designed into the original relay and had remained in the converted model. As a check on the design equation and my winding techniques, I modified two other relays with equal success. — *Harvey W. Lance, K7IT, Route 8, Box 314-A, Tucson, AZ 85710*

DON'T BREAK THE SEAL

□ This is a comment on the construction procedure employed in "Tune Up Swiftly, Silently and Safely," in December 1979 *QST*. I gulped when I read that the builder "ground down"

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8 PRINT"'FROM' LOWEST RELECTION COFFICIENT";
10 INPUT U
12 PRINT"'TO' HIGHEST REFLECTION COEFFICIENT";
14 INPUT L
16 PRINT"INCREMENTED BY 'STEP' VALUES OF";
18 INPUT I
20 PRINT
30 PRINT" G3/G1  R.C.  VSWR F3DB/FAP G1,7  G3,5  G2,6  G 4"
40 PRINT" RATIO  (%)   ----  -----     (F)   (F)   (H)  (H)"
50 FOR R = U TO L STEP I
60 V=(1+R/100) / (1-R/100)
70 A=-4.3429 * LOG(1-(R/100)↑2)
80 K=(4.17↑.14286) / (A↑.07143)
90 D=.5*(K+1/K)
100 B=A/17.37
110 X=LOG((EXP(B)+EXP(-B)) / (EXP(B) - EXP(-B)))
120 Y=.5*(EXP(.071429*X)-EXP(-.071429*X))
130 G1=.44504/Y
140 G2=.554956/((Y↑2+.188255)*(.44504/Y))
150 G3=2.24698/((Y↑2+.611261)*G2)
160 G4=3.603876/((Y↑2+.95048)*G3)
180 A$=" #.###  ##.## #.### #.###  .#### #.### #.### #.###"
185 PRINT USING A$;G3/G1,R,V,D,G1,G3,G2,G4
190 NEXT R

10 CLS : PRINT : PRINT : INPUT"FROM";U
20 INPUT"TO";L : INPUT"STEP";I : CLS : PRINT
30 PRINT" G3/G1  R.C.  VSWR F3DB/FAP G1,7  G3,5  G2,6  G 4"
40 PRINT" RATIO  (%)   ----  -----     (F)   (F)   (H)  (H)"
50 FOR R = U TO L STEP I
60 V=(1+R/100) / (1-R/100)
70 A=-4.3429 * LOG(1-(R/100)[2)
80 K=(4.17[.14286) / (A[.07143)
100 D=.5*(K+1/K) : B=A/17.37
110 X=LOG((EXP(B)+EXP(-B)) / (EXP(B) - EXP(-B)))
120 Y=.5*(EXP(.071429*X) -EXP(-.071429*X))
130 G1=.44504/Y
140 G2=.554956/((Y[2+.188255)*(.44504/Y))
150 G3=2.24698/((Y[2+.611261)*G2)
160 G4=3.603876/((Y[2+.95048)*G3)
180 A$=" #.###  ##.## #.### #.###  .#### #.### #.### #.###"
185 PRINT USING A$;G3/G1,R,V,D,G1,G3,G2,G4 : NEXT R
```

Fig. 1 — The upper list is a modified BASIC computer program for calculating design parameters of 7-element Chebyshev low-pass filters. The lower program is tailored for TRS-80 Microsoft BASIC.

*Asst. Technical Editor, *QST*

47-ohm resistors with a grinding wheel or hand file to obtain the needed 50-ohm value.

The only protection that carbon resistive material has against the disastrous effects of moisture is the specially formulated and specially applied hermetic-type covering. With this seal broken, all the production care of the manufacturer has gone down the drain. When accurate or matched-resistance values are needed, this technique may serve as a temporary aid — measured in hours. Beyond that, it would be safer to use run-of-the-mill 20% tolerance resistors. Sealing the body with a dense epoxy may lessen the absorption rate, but one must remember that moisture is devilishly persistent. — *C. Dale Peterson, N8AJV, Lock Box 7, Keursarge, MI 49942*

AN IMPROVED BASIC PROGRAM FOR LOW-PASS FILTER DESIGN

☐ It is pleasing to see *QST* increasingly cognizant of the applications of computers to Amateur Radio. The article by Wetherhold in December 1979 *QST* appeared to be an excellent one. The inclusion of a BASIC-language computer program was in theory very helpful, but in reality almost useless because the BASIC dialect used is extremely rare and specialized. I'd guess that very few readers of *QST* will be able to make the program run because of its highly specialized coding.

I've modified the program so it will run on most computers that support BASIC at the LOG, EXP and PRINT USING level. It is given in Fig. 1A. In Fig. 1B is a "quick and dirty" version specifically tailored to Microsoft BASIC as implemented on the Radio Shack TRS-80.

Keep up these fine articles with more use of the computer as an aid. We've barely scratched the surface. — *Dr. David A. Lien, W6OVP, 8662 Dent Dr., San Diego, CA 92119*

☐ I am grateful to Dr. Lien for taking the time to write, and I will defer to his expertise regarding the BASIC dialect I used — it no doubt is rare. His guess that very few readers of *QST* will be able to make the program run may be true, but he makes the assumption that a reader is not capable of making the minor changes that are necessary to make a program that will run. My intent in providing the program was to document the equations (lines 60 to 160) so the reader could take these equations and apply them to whatever program language he is most familiar with. This is what Dr. Lien did, and I expect that others will do the same. — *Ed Wetherhold, W3NQN, Honeywell, Inc., P. O. Box 391, Annapolis, MD 21404*

MICROCOMPUTER RFI ADDENDUM

☐ In my article, "Microcomputers and Radio Interference," March 1980 *QST*, an erroneous statement occurred on page 18, the second paragraph in column two. Concerning radiation from internal leads, the Radio Shack TRS-80 does only *reasonably* well in this respect. Radio Shack has made several versions of the CPU board, and lead radiation depends on which board one has.

Radio Shack has recently been using a different keyboard assembly on a metal plate, which opens the possibility of much better shielding of the unit. I just recently obtained one of these units, lined the plastic enclosure with heavy-duty refrigerator foil (cutting out the vents), and grounded the keyboard mounting plate to the foil at several points. This makes a good scheme to reduce RFI, but not too many of these units are in the field. Such modification also voids the guarantee!

Macrotronics has introduced the M-800 terminal software, which is much improved over the M-80 mentioned in my article. I worked with this version in its formative stages, and the same ideas apply as far as RFI reduction is concerned. There are at least two new systems about to be introduced by other manufacturers. The newly introduced Atari microcomputers are the first in a new generation of machines which the FCC has forced to be designed for minimum electromagnetic interference. They are at least an order of magnitude better in this respect. — *Paul E. Cooper, N6EY, P. O. Box 324, Carmel Valley, CA 03924*

Q&A CORRECTION

☐ The newly released *Advanced/Extra Q&A Book* should be a helpful study aid for those hoping to upgrade their licenses. However, two questions in the advanced section have an unfortunate combination of typographical and conceptual errors that may confuse some readers. In Question 107, the notion of ac power is misused. Power has meaning only when averaged over at least one complete cycle. For a sinusoidal signal, the power is the product of the rms voltages and currents. Peak power has no real meaning in this context. The word "peak" should be deleted from Q. 107. The power dissipated by the resistor is, of course, 1 watt.

When the amplitude of the wave varies from cycle to cycle, as in a-m, *peak* power is the product of the rms voltage and current in the cycle having the greatest amplitude. While it can be shown that a signal having nonuniform amplitude from cycle to cycle is not a sine wave, the variation is gradual in a-m radio emissions, and the peak power can be computed as if each cycle were sinusoidal.

When analyzing amplitude-modulated waves it is convenient to speak of the *envelope* of the signal as seen when an oscilloscope is adjusted to display *many* cycles of rf. Peak envelope power (PEP) is defined just like peak power in the preceding paragraph. PEP *input* is difficult to measure — a transmitter's meters won't register it, although a scope connected across a sense resistor in the B-minus lead might do the trick. It's easy to measure PEP rf *output* across a known load resistance, though. An oscilloscope will display the peak envelope voltage. Since the modulating frequency is low compared to the carrier frequency, the amplitude difference between one rf cycle and the next is small, so the sine-wave formula, rms $= pk/\sqrt{2}$, can be used. To compute PEP, take the highest visible rms voltage, square it, and divide by the load resistance.

When an ssb envelope is composed of several equal-amplitude tones (the two-tone test is used to establish linearity and power capability), the individual tones can be viewed on a spectrum analyzer. The vertical scale of the analyzer is calibrated in *power*, so the level of each tone can be read out in watts.

Here's how to compute the PEP of a signal composed of several equal-amplitude tones: $PEP = (E_{max(rms)})^2/R$. E_{max} is the sum of the individual tone voltages. The rf envelope voltage reaches this value whenever the peaks of the individual sine waves coincide. For n equal tones, $E_{max} = nE_{(rms)}$, where $E_{(rms)}$ is the voltage of a single tone. The PEP, then, is $(nE_{rms})^2/R$, which is $n^2(E_{rms})^2/R$. Since $(E_{(rms)})^2/R$ is the power in a single tone, we can say $PEP = n^2P$, where P is the power in one tone.

A simple example will illustrate the use of this formula. Suppose we have three tones, each developing 4 volts rms across a 2-ohm load. The power in each tone is $4^2/2 = 8$ watts. The PEP is $3^2(8) = 72$ watts. The average (heating) power of the composite signal is simply the sum of the individual tone powers, which in this case is 24 watts. Mathematically, $P_{average} = nP$. Since $PEP = n^2P = (n)nP$, the peak-to-average ratio is n. From this we see that for a single-tone emission (such as cw) the PEP and rms powers are equal.

In Question 113, the answer should read: The PEP of a multiple-tone (equal amplitude) signal equals the rms power of any single tone times the *square* of the number of tones. Also, +30 dBm is *1 watt*, not 100 watts as printed. Why I committed these errors only Murphy knows, but it wasn't because I didn't know any better.

Some readers may be interested in the more general case, where the tones are *not* equal. Maximum envelope voltage occurs when the peaks of the sine waves coincide. For two tones having rms voltages E1 and E2, $PEP = (E1 + E2)^2/R = (E1^2 + 2E1E2 + E2^2)/R$. $E1^2/R = P1$, so $E1^2 = P1R$, and $E1 = \sqrt{P1R}$. Similarly, $E2 = \sqrt{P2R}$. Substituting these expressions in our power equation, we have $PEP = P1 + P2 + 2\sqrt{P1R}\sqrt{P2R}/R$. The third term can be written as $2\sqrt{P1P2R^2}/R$ or $2R\sqrt{P1P2}/R$, which becomes $2\sqrt{P1P2}$. Expressing all data in power (as does a spectrum analyzer), $PEP = P1 + P2 + 2\sqrt{P1P2}$. For three tones, the formula is $P1 + P2 + P3 + 2\sqrt{P1P2} + 2\sqrt{P1P3} + 2\sqrt{P2P3}$, and this method can be extended to any number of tones.

I hope this discussion will motivate those studying for the higher licenses to try to learn theory by understanding, and not merely rote memorization. — *George Woodward, W1RN*

Feedback

☐ The overload-protection circuit for Field Day generators described in the March "Hints and Kinks" should have shown the coil of K2 connected across the generator side of the 117-V line but still controlled by K1. DS1 consequently should be wired across the K1 contact controlling K2. These corrections will permit K2 to be properly energized and DS1 to indicate when an open circuit exists. By connecting R10 to pin 3 of U1, Q1 can be turned on as intended. Thanks to Ronald Young, W8RJL and Greg McIntire for these recommended changes. Additional protection is offered by a modification that "Ivy" Iverson, WD0BXK offers in the forthcoming July "Hints and Kinks."

☐ An omission occurred in "The WARC Warriors" (March *QST*, page 60). Mr. Gordon R. Elliott, W6CIT, is a contributor of $100 or more to the ARRL Foundation WARC Fund.

Product Review

Conducted By Paul K. Pagel*, N1FB

Kenwood TS-180S Transceiver

"Bells, whistles and features galore." That's the slogan this writer would assign to the TS-180S hf-band transceiver if a catch phrase were necessary. But the rig shouldn't need promotional gimmickry in order for the manufacturer to sell it: The Kenwood name has long been of high repute among buyers of hf-band equipment. The TS-180S appears to reflect the quality that Kenwood owners appreciate.

But what about these bells and whistles? Well, let's examine the features that are offered. First, the unit covers from 1.8 to 29.7 MHz in six bands. WWV is available (receive only), plus auxiliary band positions for operation from 2.0 to 15 MHz (any 500-kHz segment thereof), 18.0 to 18.5 MHz and 25.0 to 25.5 MHz.

This new transceiver is completely solid state in circuit design. It contains 145 bipolar transistors, 21 FETs, 33 ICs and 213 diodes. A substantially greater number of semiconductor devices are contained in the rig if the digital frequency control (DFC) module is included as an accessory. The dc input power to the transmitter section is 200 watts PEP on ssb, 160 watts peak on cw and 100 watts on fsk. The ssb and cw modes are derated to 160 and 140 watts, respectively, for 10-meter operation.

The i-f selectivity is 2.4 kHz at the −6 dB points of the response curve and is 4.2 kHz at the −60 dB points. A cw filter (YK-88C) is available as an option. It has a bandwidth of 500 Hz and 1.5 kHz at the −6 and −60 dB points of the curve. A second ssb-bandwidth i-f filter (YK-88S) can be added as an option at the output end of the i-f amplifier strip. This will greatly reduce the wide-band noise in the receiver while improving the skirt selectivity of the i-f system. The i-f strip is common to the transmitting and receiving modes. Therefore, the use of the second ssb filter enhances the characteristics of the ssb signal when speech compression is used. In other words, the additional filter helps to keep the transmitted signal narrow by virtue of improved skirt selectivity.

There are no tuning controls for the solid-state PA stage. To move from one band to another it is necessary only to adjust the band switch and peak the drive (the drive control serves also for peaking the receiver front end). The PA transistors are each rated at 250 watts. They are SRF1714s, and are made for Kenwood by Motorola. An SWR shut-down circuit is included in the design. It begins to shut off the drive to the final amplifier when a SWR of 3:1 occurs. Additionally, if the case temperature of the PA transistors rises to an unsafe level the drive is reduced automatically.

Notable is the fact that this transceiver is capable of covering the new WARC-79 allocated bands. The TS-180S internal VFO covers more than 50 kHz above and below each band, for MARS and other applications.

The transceiver is a single-conversion type. A PLL type of local oscillator is employed. Only one crystal is used in that system. The net result is a reduction in possible spurious responses,

The Kenwood TS-180S is shown here with its companion power supply. This transceiver is capable of covering the new WARC bands.

plus an improvement in frequency stability over that which is attainable with other types of local oscillators.

The manufacturer rates the frequency stability at ±1 kHz during the first hour of operation, after 1 minute of initial warm-up. Thereafter, the drift is not supposed to exceed 100 Hz during any 30-minute period after warm-up. These claims appear to have been made for the purpose of allowing a wide latitude of possible drift; the review unit was much better than the published specifications

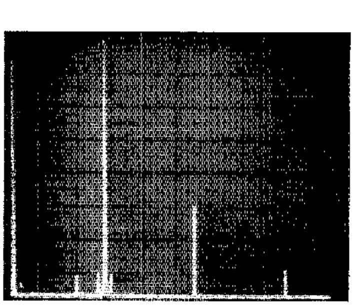


Fig. 1 — Worst-case spectral display of the transceiver at rated dc input power as observed at 28 MHz. Vertical divisions are 10 dB each. Horizontal divisions are 10 MHz each. The spurious products close to the carrier frequency are 70 dB down with respect to the operating frequency. Other spurs are down at least 50 dB.

Kenwood TS-180S HF Transceiver
Claimed Specifications

Frequency coverage: 160 to 10 meters, plus WWV and the three WARC-79 bands (see text).
Modes: Ssb, cw and fsk.
Power (dc input): 100 to 200 watts (see text).
Power requirements: 13.8 V dc (nom.) at 20 A (transmit). Can be obtained from PS-30 ac power supply.
Receiver sensitivity: 0.25 μV S + N/N, 10 dB or greater.
Audio output: Greater than 2 watts with less than 10% distortion — 4-Ω load.
Mic impedance: 500 Ω to 50,000 Ω.
Weight: 25 lbs (11.5 kg).
Size (HWD): 5-1/4 × 12-13/16 × 11-5/16 inches (133 × 325 × 287 mm).
Price class: $1150.
Manufacturer: Trio-Kenwood Corp., 111 West Walnut St., Compton, CA 90220.

*Asst. Technical Editor, *QST*

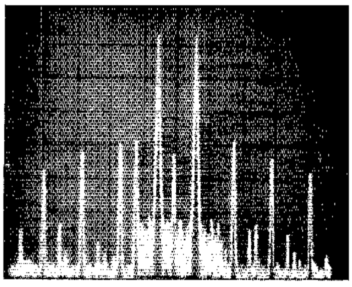


Fig. 2 — Output display of the '180S during a full-power 14-MHz two-tone test. Each vertical division is 10 dB and each horizontal division is 1 kHz. The third-order distortion products are down 38 dB from the PEP level.

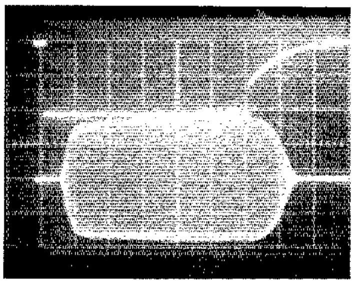


Fig. 3 — The keyed cw waveform of the Kenwood TS-180S. The horizontal divisions are each 5 ms. The upper waveform displays the actual key-down time. Such a smooth waveform should not have any clicks.

suggested. During a period of 1 hour after initial warm-up (1 minute) the maximum frequency change on 20 meters was 40 Hz.

The spectral output of the transmitter is shown in Fig. 1. It complies nicely with the FCC regulations. The 3rd- and 5th-order IMD products from the transmitter are shown in the spectrograph in Fig. 2. The distortion level is low, thereby ensuring a clean signal if the transmitter is operated in accordance with the manufacturer's instructions.

Fig. 3 shows the waveform during cw keying. On-the-air reports indicated that the TS-180S produced a clickless note that was neither "too hard" nor "too soft." Most of the solicited comments came back as, "the rig sounds excellent." Similar reports were received during ssb operation, with and without the speech processor activated. But, as is the case with all processed speech, the so-called "naturalness" of one's voice is degraded noticeably.

The usual testing ground this reviewer uses for receivers was utilized during the practical analysis of the '180S — just two blocks from the W1AW "onslaught" on 80 through 10 meters. The W1AW 10-, 15-, 20- and 40-meter beams are boresighted on the writer's QTH (at the 1-kW power level). No desensitization or cross-modulation effects were noted on any band, except when the W1FB triband Yagi was pointed toward W1AW. It then became necessary to use 20 dB of receiver front-end attenuation to clean up the weaker signals being received. It was noted during these tests (and simulated later by means of two signal generators) that the PIN diode attenuator in the TS-180S actually made the cross-modulation effects on weak signals worse than with no attenuation at all. The two-step PIN diode attenuator used in the '180S is shown schematically in Fig. 4. It is unlikely that this phenomenon would be experienced in normal amateur environments. Laboratory tests of the receiver dynamic range (based on test methods described by Hayward in July 1975 *QST*) revealed that the MDS is −139 dBm, the blocking commences at −114 dB and the IMD is 83 dB on 20 meters. For 80 meter operation the numbers are, respectively, −139 dBm, 112 dB, and 82 dB. These figures result in input intercept figures of −14.5 dBm on 20 meters and −16 dBm on 80 meters. The 500-Hz cw filter was used during these tests.

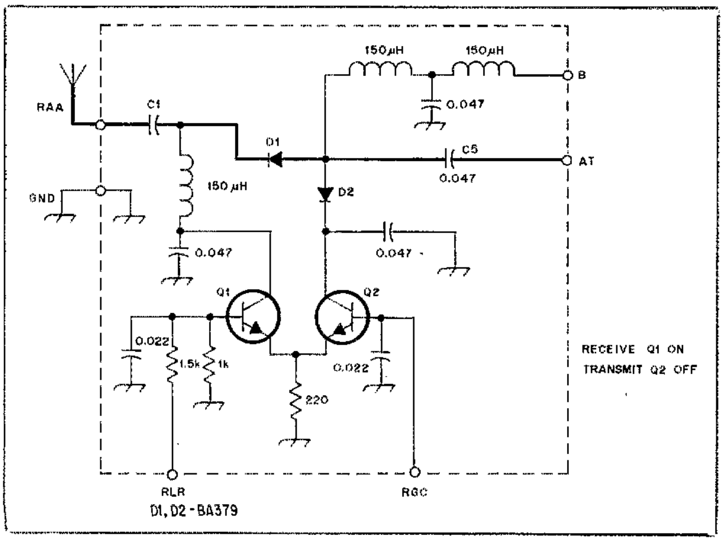


Fig. 4 — Schematic diagram of the PIN-diode rf attenuator (see text).

Other Features

The DFC module mentioned earlier in this report permits digital frequency control with four tunable memories. These memories can be used during the transmit or receive periods. Split-frequency operation can be effected by using the internal VFO and the memories, or by using an outboard VFO (VFO-180) and the memories. Frequencies from the TS-180S VFO, the outboard VFO or the "fixed channel" can be stored in the memories. Also, frequencies can be transferred between the memories. A unique feature is the memory-shift paddle on the front panel. It enables the operator to tune the memories up or down in 20-Hz steps without disturbing the initial frequencies which have been stored in the memories.

Among the access ports on the rear apron of the unit are I-F OUTPUTS 1 and 2. These are used for observing waveforms from within the circuit. There is an XVTR jack for use when attaching transverters. The ACSY (accessory) terminal permits the connection of linear amplifiers and other outboard gear. A jack is available to allow connection of an outboard receiver to the receive-antenna line in the '180S. An RTTY jack is also located on the rear of the transceiver for use during FSK operation.

In addition to the two i-f filters already mentioned as accessories, the operator can obtain the PS-30 ac power supply for fixed-station use. An SP-180 external speaker with selectable audio filters is available also. The VFO-180 and DF-180 units were discussed earlier in this report.

Instruction Manual

The TS-180S instruction manual is nicely written in clear English narrative. Detailed information is given concerning the installation of the transceiver and its accessories. A section of the manual is set aside for an explanation of how the various circuits function. This should be useful during trouble-shooting exercises. A trouble-shooting chart is provided in one section of the manual. There is even a three-page treatment of mobile operation. It provides all of the basic details for installation, antenna mounting and tune-up, plus noise reduction. Kenwood seems to have gotten away from the sometimes nebulous and confusing instruction-book passages of yesteryear. The translation from Japanese to English is excellent in this booklet. — *Doug DeMaw, W1FB*

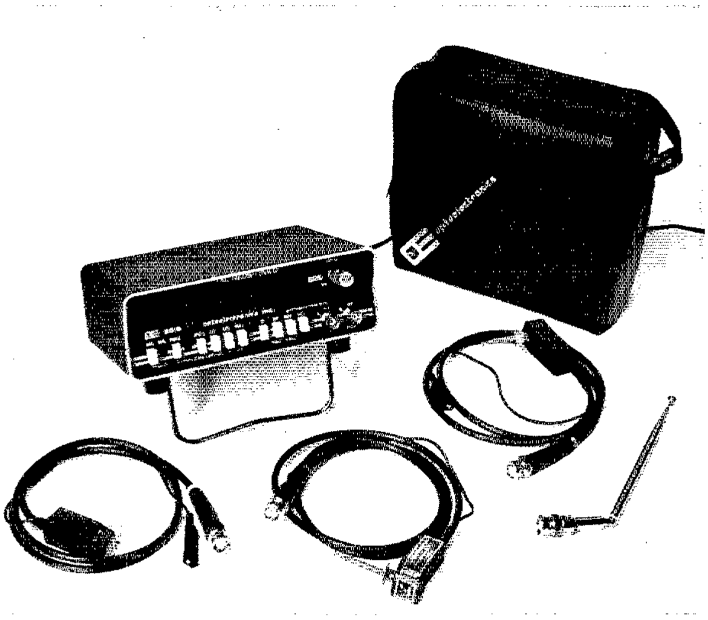
THE OPTOELECTRONICS 8010 FREQUENCY COUNTER

Optoelectronics Inc., Ft. Lauderdale, FL, manufactures a variety of modern digital measurement instruments. A very interesting member of their product line is the model 8010, a 1-GHz frequency counter. The 8010 is available in three versions differing in their maximum frequency range and time-base stability. The basic 8010 is supplied with a 1-ppm, 10-MHz crystal time base, while the model 8010.1 has a precision time base with a stability of 0.1 ppm over the 20° to 40° Celsius temperature range.

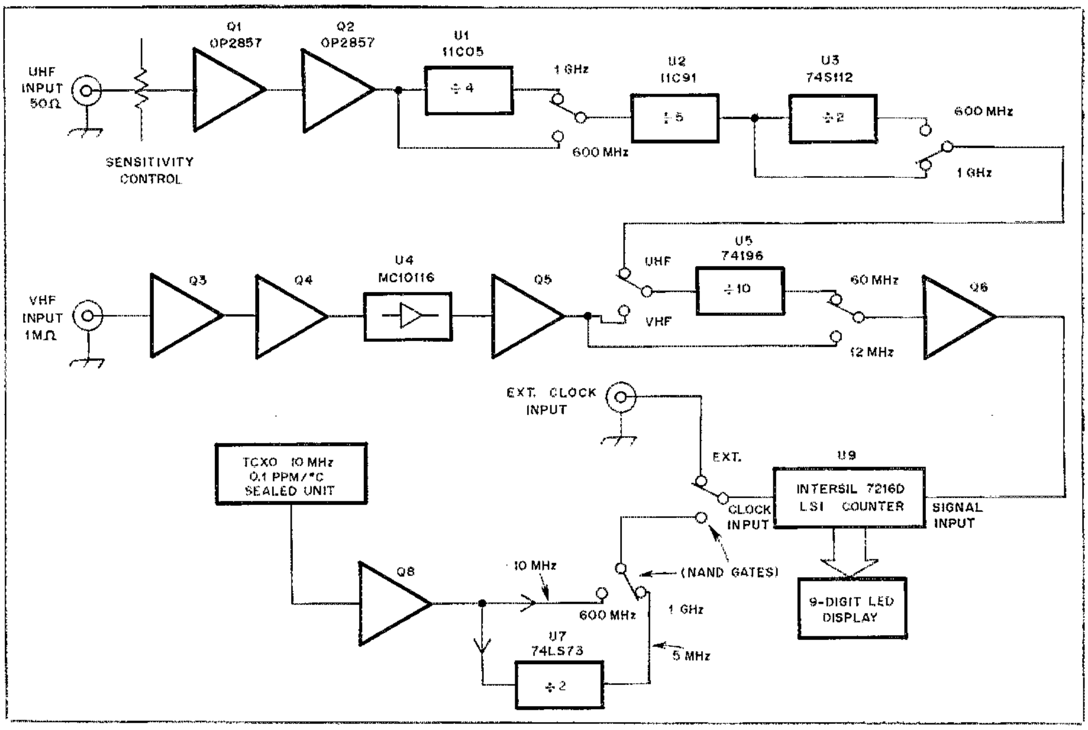
For those who find the 1-GHz maximum frequency a limitation, specially selected and tested model 8010.1 counters are available with a guaranteed upper frequency limit of 1.3 GHz. These are designated as model 8010.1-13. All models are supplied with three test probes, telescopic pick-up antenna, 117-V ac wall-plug transformer and a 17-page owner's manual. Extra-cost options include a NiCad battery pack and charger for mounting inside the 8010 and a vinyl carrying case. The unit supplied for review was a model 8010.1-13 with the vinyl case.

The 8010's black anodized-aluminum case provides an attractive appearance and good rf shielding. When placed close to a general coverage receiver, harmonics of the 10-MHz time-base oscillator could be detected but were at very low levels. Use of a nearby 1-kW transmitter had no effect on the counter operation when shielded test leads were used. The pick-up antenna on the counter allowed measurement of a transceiver output frequency even while operating into a Heath Cantenna dummy load. A flip-up stand holds the counter at an angle suitable for viewing from most working positions. This and the size of the unit allow for very convenient use on the test bench.

Front-panel switches select one of four gate times from 0.1 to 10 seconds and frequency ranges of 12, 60 or 600 MHz, or 1 GHz. When the 1-GHz range is used, the selected gate time is doubled. This is because the time-base frequency is reduced from 10 to 5 MHz, thus maintaining the same 10-Hz maximum resolution on both the 600-MHz and 1-GHz ranges. Using the 12-MHz range and a gate time of 10



The Optoelectronics 8010 frequency counter and accessories. The probes, antenna and carrying case are optional. A wall transformer is supplied with the counter for ac operation.



Block diagram of the 8010.13 frequency counter. The switching shown is simplified to make the general signal flow more apparent. A complete diagram is provided in the owner's manual.

seconds yields the greatest resolution, 0.1 Hz. Two more front-panel push buttons allow selection of an external time-base signal and a "display hold" function. The hold function inhibits the display update for easier reading of a fluctuating count or retains the most-recent reading after removing the input signal. Two BNC connectors serve as signal inputs to the separate vhf and uhf front ends. Input A, a 50-ohm input, is used with the 600-MHz and 1-GHz ranges. When the 12- or 60-MHz ranges are used, the high-impedance B input must be used. This does not force you to use the HI Z input for all measurements below 60 MHz, as both the 600-MHz and 1-GHz ranges have a specified minimum frequency of 25 MHz. During lab tests, the 600-MHz range was found to function well to below 10 MHz. The only remaining front-panel control is the combination power switch and sensitivity control. The sensitivity control affects only the 50-ohm B input. It was noted that this input is sensitive to input signal level. Using the variable sensitivity control allows a wide range of signal levels to be measured. No variable control is needed with the HI Z A input, as it handles a wide range of signal levels without need for adjustment. On the front panel are nine 7-segment LED displays and two LED indicator lights. One LED indicates that an external time-base signal has been selected and the other shows when the counting period is completed.

The external clock input, a BNC connector, also serves as a clock output making available the internal 10-MHz time-base signal. This connector, along with the power connector is located on the rear panel. Also provided on the rear of the case are the display test and battery charge/operate switches. Access to the TCXO frequency trimmer is made through a small hole in the rear panel.

Examination of printed circuit board reveals that considerable attention has been paid the input stages; this is necessary to insure good sensitivity over the wide frequency range of the counter. The low-frequency B input has a JFET first stage, two bipolar stages and an ECL triple line driver, Q3 through Q5 and U4 of Fig. 1, to provide amplification and waveform shaping. To maintain the input to the 7216D LSI counter below its maximum frequency, an additional divide-by-10 operation is performed by U5 on the 60-MHz range. The high-frequency input A has a two-stage bipolar amplifier using two SOE (stripline-opposed emitter) packaged transistors. As shown in Fig. 1, these are followed by the frequency prescaler composed of U1 through U3, providing division by 10 on the 600-MHz range and by 20 on the 1-GHz range. The actual counting, latching and display multiplexing functions are performed by a single 28-pin IC, the Intersil 7216D. Use of LSI circuits such as this results in great reductions in size, power consumption and cost over that possible using random logic.

Sensitivity checks made using a calibrated 500-MHz signal generator showed that the 8010 was within specifications on all frequency ranges. No sensitivity tests were made above 500 MHz because there was no suitable signal generator, but the output frequency of a 1296-MHz transceiver with a nominal 1-watt output was easily measured after a 40-dB attenuator was placed in the line.

After having used the 8010 both at home and at work in the ARRL lab for several weeks, I found it to be a very accurate, reliable and easy-to-use instrument. The three supplied test probes, offering high-impedance, low-pass and direct coupling were useful, and the pick-up antenna is convenient for checking transmitter frequency calibration. The vinyl carrying case is large enough to hold only the frequency counter; no room is provided for the test probes or wall transformer. The owner's manual provides complete specifications and operating instructions. A minor error was noted in the table of specifications in the manual. The high-impedance input is referred to as input A while the front-panel marking show it as input B. Also included in the manual are seven pages of information on correct frequency counting techniques, a bibliography of articles relating to frequency counting and a certificate of calibration. For anyone needing to make accurate, high-resolution frequency measurements at uhf, the Model 8010.1-13 should fill the bill very nicely. Price class: Model 8010.1-13, $495; CC-80 carrying case, $10; TA-100 telescoping antenna, $10; P100 1X-50 probe, $14; P101 low-pass probe, $17; P102 high-impedance probe, $17. — *George Collins, AD0W*

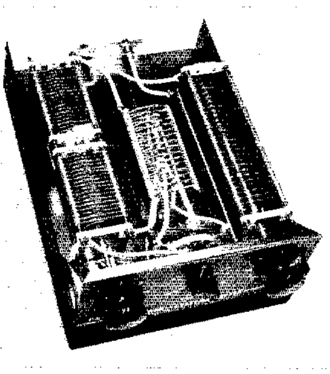
THE APOLLO TRANS-SYSTEMS TUNER 2000X-2

The circuit used in the Apollo Products 2000X-2 tuner is an adaptation of the original McCoy Ultimate Transmatch that appeared in *QST* some years ago.[1] A tapped coil has been substituted for the roller inductor as was done in a follow-up article.[2] Although the front panel doesn't show it, there actually is a 160-meter switch position at 6 o'clock where the lettering "band switch" appears. The tuner is designed primarily for use with coax-fed antennas. No feed-through insulator is provided for single-wire feed, nor is a balun or SWR meter included.

The "works" are housed in a black, clamshell cabinet with a contrasting wood-grain front panel. The enclosure is spacious and there is no crowding of components. This cabinet is also available separately for those wishing to use their own components in constructing an antenna-matching network.[3]

Since the review item was already wired, one could only "guesstimate" how long it would take to bring the '2000 from shipping carton to finished product. At most, three hours should be required. Should a factory-wired unit be purchased, some of the coil-tap positions may have to be altered to fit the individual antenna systems in use at your particular location. During use, it was found that the coil taps on the review model had not been well soldered and it was necessary to remake each connection.

Although it is not mentioned in the construction manual, indenting every other turn along the tapped quadrant of the coil when making the coil-tap connections, will make the job easier. The advertisement mentions the coil for the kit model has indented turns, but the factory-wired unit had no such provision; the indented turns of the coil in the unit shown in the photograph were made when resoldering the coil taps. When selecting the coil-tap positions, use those which provide the lowest SWR readings consistent with the use of the largest amount of capacitance for the two tuning capacitors. These settings will afford the greatest amount of harmonic attenuation. (Remember to turn the transmitter off when changing taps!)



The Apollo Products 2000X-2 Trans-Systems Tuner. Interconnecting wiring is made with glass cloth-covered braid. The bracket at the rear of the unit supports the input and output coaxial connectors.

It was felt that it would be easier to set the taps for the higher frequency bands (15 and 10 meters) if a coil with a lower pitch were used for that part of the matching unit inductor. At the higher frequencies, lead lengths come into play and become a substantial part of the network. The manner in which the coil is physically mounted also means the higher-frequency coil taps are the farthest from the band switch and they require the longest lead lengths. When making the coil connections, attempt to keep the tap leads as near the center of the coil as possible to prevent any possible arcing from the tap lead to another part of the coil.

Without a ground connection on the '2000, hand capacitance affected the SWR meter readings and adjustments made to the unit. Once the unit was grounded, no difficulties were encountered. (Good practice would dictate having all station equipment connected to a good, common ground in any case.)

The stand-off insulators for the coil and capacitors are made of PVC. While PVC may not always exhibit good dielectric qualities in certain applications, no problems were encountered with the test unit at the 1-kW dc and 2-kW PEP input levels. Measured insertion of the tuner while using a commercial 50-ohm load was less than 0.5 dB.

The impedance-matching range of the tuner will be somewhat limited by the initial setting of the coil taps; different antenna systems may require different coil-tap positions be used. Additionally, the setting of the band switch is not sacrosanct. Under certain circumstances one may find a tuner band-switch setting of, say, 40 meters would provide the required match on the 80-meter band when using fixed-tap positions.

The Trans-Systems Tuner 2000X-2 is available from Apollo Products, P. O. Box 245, Vaughnsville, OH 45893. Price class: $125 kit form, $145 wired and tested. — *Paul K. Pagel, N1FB*

[1] McCoy, "The Ultimate Transmatch," *QST*, July 1970.
[2] Myers, "The Rollerless Ultimate," *QST*, November 1973.
[3] The cabinet model is TM-5.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

FT-101ZD FINAL-AMPLIFIER CURRENT MONITORING

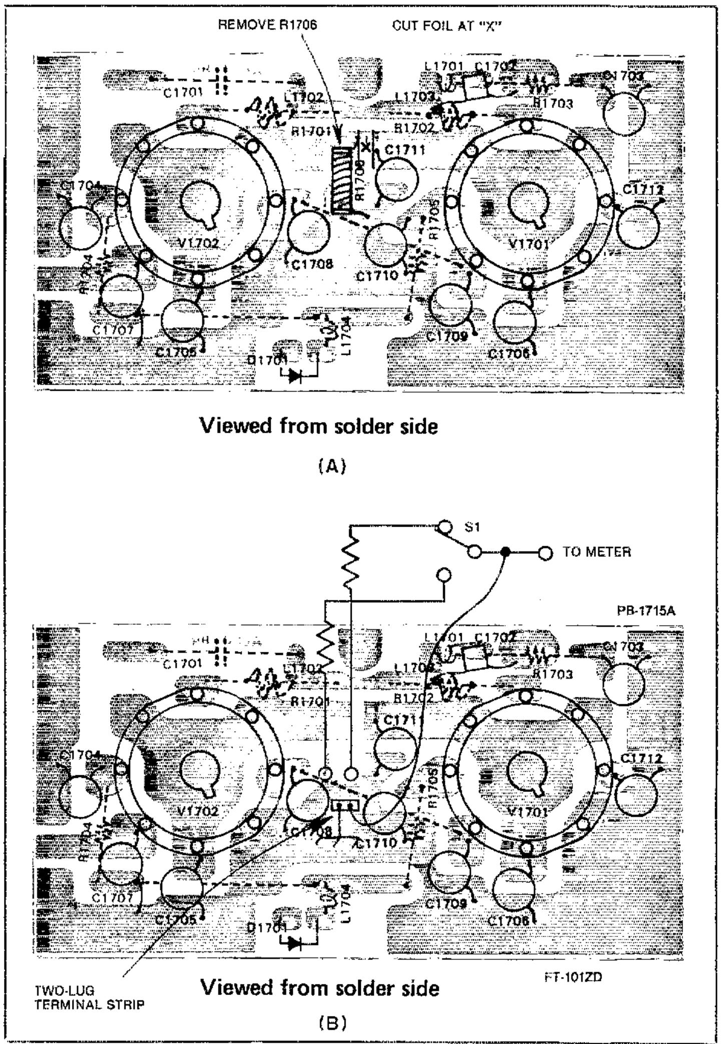
When using parallel-tube final amplifiers, the "bottles" being used should be closely matched. If they are not, one or more (depending upon the number of tubes involved) may "hog" the current being drawn, resulting in poor performance and eventual troubles. The unsuspecting operator using a single meter to monitor the combined tube currents would discover all too late wherein his problems lie. In every rig the writer has owned in the recent past, a modification has been made to enable observation of the current drawn by the individual tubes in the final amplifier. The FT-101ZD is no exception.

The modification, shown at the right, is simplicity of the first order. An added spdt toggle switch and a couple of meter shunts coupled with an easily repairable cut in a circuit-board foil are all that is needed.

Not wishing to deface the front panel of the new transceiver, I drilled the mounting hole for the switch on the rear panel between the ground lug and the driver output phono jack, J11. The existing meter shunt, R1706, is removed and the meter lead unsoldered from the foil pad. The foil which connects the cathodes of the 6146Bs is cut with a sharp knife. Application of a bit of heat from a soldering iron will aid in lifting the unwanted foil from the board. See the diagram. For the sake of convenience, a two-lug terminal strip (one ground, one insulated) was soldered to the board (ground lug to ground foil). The previously removed meter lead is attached to the insulated lug and a wire connected between this lug and the center terminal of the toggle switch, S1. The meter shunts were each made of five, 10-ohm, 1/4-watt carbon resistors in parallel. The shunts should have a value of 2 ohms each and be as closely matched as possible; this will ensure accuracy. One end of each shunt is connected to a side of the switch. The opposite ends of the shunts are soldered to the amplifier tube cathode connections of the pc foil. The installation process may be easily reversed by simply bridging the foil break with a piece of wire and a "dummy" machine screw may be used to fill the hole vacated by the removed toggle switch.

The meter deflection for each of the tube currents will make it appear as though nothing has been altered. Because only half the current is being measured, the shunt resistance has been doubled. The resulting meter indication is about the same as before the modification. (If the meter shows a particular tube current to be 250 mA, the actual current is 125 mA.) This has the advantage of providing a current indication that is easier to read as well as providing a "psychological salve" by showing the more familiar meter deflection, rather than one lower on the scale. Switching between the two tube currents should show them to be tracking within plus or minus 10 percent of one another if they are closely matched. If not, you've got one "worker" and one "goldbricker." With matched tubes, the meter switch may be left in either position and bias and loading adjustments performed as is normally done. — *Paul K. Pagel, N1FB, Asst. Technical Editor,* QST

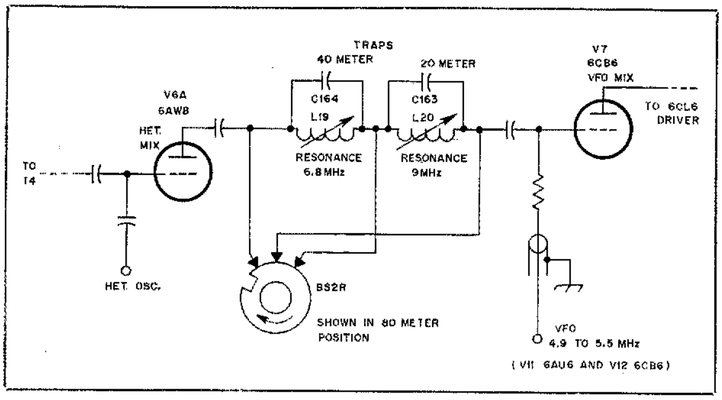
*Assistant Technical Editor, *QST*



The foil side of the final-amplifier board (PB-1715A) is shown at A prior to modification. At B, the foil cut and added wiring are shown. See text for resistance values.

FT-101ZD RF FEEDBACK

When the Yaesu FT-101ZD was reviewed in December 1979 *QST*, it was mentioned that rf feedback into the mic amplifier had been a problem. The factory suggestion of bypassing the mic and PTT leads with 0.01-µF disc-ceramic capacitors was followed and the problem was eliminated. It was also reported that Yaesu would be installing these capacitors in all current production models. Further communication with the factory reveals that 'ZDs with lot numbers of 12 or higher have these capacitors installed. If your '101ZD has a lower lot number, you may have to install these capacitors. An even more extensive approach to curing the problem was discussed by Cliff White (WB5DYA) in the November/December 1979 issue of the *Fox-Tango Newsletter.* — *Paul K. Pagel, N1FB, Asst. Technical Editor, QST*



Correct adjustment of the HX-10 traps, shown in the drawing, is essential in order to avoid spurious emissions. Mason provides an explanation in the accompanying text.

SPURIOUS EMISSIONS FROM HX-10 TRANSMITTER TRACED TO MISALIGNED SWITCHABLE TRAPS

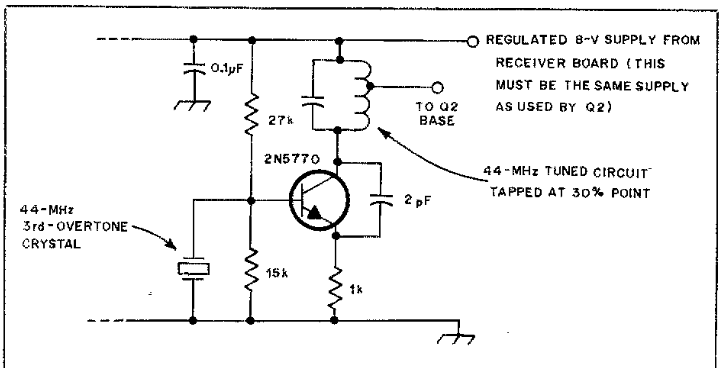
I traced the source of spurious emissions from my HX-10 Marauder, noticed near 6800 kHz, to the two switchable traps in the mixer plate circuit. These traps, intended for harmonic suppression, are switched, one at a time, on both 20 and 40 meters. The 40-meter trap should attenuate the second harmonic of the heterodyne oscillator 3.4-MHz output. Apparently this signal can sneak through the final amplifier and be radiated. In my HX-10, I measured this signal at 6797.5 kHz.

The remedy was to set the HX-10 on the 40-meter band, adjust the VFO to 7 MHz, set the function switch to standby and, while listening to the receiver purposely tuned to 6800 kHz, I adjusted the final-amplifier grid drive for maximum S-meter indication. The rf gain control on the receiver was then adjusted to provide a 40 dB above S9 meter level. Next, I tuned the 40-meter trap for minimum S-meter indication. This procedure dropped the signal level to S5. The trap had been a long country mile out of adjustment.

On-the-air checks with WA8SUW, Grand Rapids, Michigan, and W8PPY in Mt. Clemens, Michigan, revealed no evidence of spurious emission. I proceeded to observe the performance of the 20-meter trap. This too was out of adjustment. It is intended to attenuate the 9-MHz signal that can sneak through the heterodyne mixer and combine with the VFO output, producing spurious signals from 13.9 to 14.5 MHz. The tuning related to these signals is backward to that for those signals normally produced by mixing the 9-MHz signal with the 10.4-MHz crystal output and the 14.5-MHz signal with that on 13.9 MHz. The HX-10 performed in shipshape condition once these corrections were made. — *R. M. Mason, W8NN, Lima, Ohio*

CONVERSION OF SINGLE-CHANNEL RECEIVER TO MULTI-CHANNEL OPERATION

Since my article "A Single-Channel VHF Monitor Receiver" was published in the December 1979 *QST*, I have had a number of letters from people who want to use it as a multi-channel vhf monitor receiver. The method mentioned in the article uses expensive crystals and I have developed an inexpensive solution using low-cost 44-MHz crystals which provides a satisfactory arrangement for this conversion. This solution uses Q2 as a tripler by omitting C12, R5 and R6, increasing the value of C13 to 0.01 μF and driving the base of Q2 from the overtone oscillator shown in the accompanying illustration.



G4CLF uses this modification to convert his single-channel vhf monitor receiver to multi-channel use. See December 1979 *QST*, p. 24. Resistances are in ohms.

The performance of this modification is as good as that of the original. Standard 2-meter receiver crystals, such as are used in the TR2200 and similar equipment, may be used. I have not developed a separate printed circuit board for the application. — *James M. Bryant, G4CLF, Swindon, Great Britain*

A METHOD OF CALIBRATING THE SPEED CONTROL OF AN ELECTRONIC KEYER

This procedure involves the modification of a pocket calculator. The normal functioning of the calculator will not be impaired and the inventive ham will find many uses for the resultant "digital counter." Only calculators that add and display a running total by punching the equals key will work in this application. Most of the inexpensive models do perform in this manner. To test your calculator, punch 1 + 1 =. The display should read 2. Now push the equals button again. If the display reads 3, you have the right type of calculator for the modification.

Open the case. Locate the two conductors leading to the equals switch on the keyboard pad. Carefully solder a piece of hookup wire to each of the conductors. Install a small two-conductor jack in the calculator case. Solder the remaining ends of the two pieces of hookup wire to this jack. Use an appropriate plug to mate the jack and from it connect leads to the output of the keyer. If the keyer has a relay-type output, everything should be ready to go. Should the keyer have a transistor switch in the output, you may have to reverse the polarity of the leads before the keyer will actuate the equals switch.

To determine the keying rate at some given setting of the speed control of the keyer, punch in 1 + 1. Use a clock to monitor the time. Send a string of dits for exactly one minute. According to Downs (see March 1979 *QST*, p. 11), a word may be represented by a string of 25 dits. Dividing the amount shown on the display by 25 should then give you the keying speed in words per minute. It is assumed that the keyer follows the standard 1:3 dit-to-dah duration ratio. — *Jim Pitts, K4EY, Louisville, Kentucky*

MORE ON IMPROVING THE SB-104A/644A

☐ Laurence David, W4YEJ, one of several amateurs who wrote to *QST* regarding the modification article about improving the SB-104A/644A presented in the August 1979 *QST*, points to a need for an update on the article because of a manufacturer's production change. That change, confirmed by Heath's Technical consultant, Ed Mosher, means that amateurs with recent versions of the SB-104A should follow the procedure outlined by W4YEJ. David writes:

"I completed building my SB-104A in May of last year. It was great, therefore, to see the modifications by Harlan Bercovici in the August issue of *QST* with additional notations in the September 'Feedback.'

"I uncovered a wiring problem after the specified leads were removed from the audio board (F-19) according to the instructions. Subsequently, I learned that this problem applies to any SB-104A that was wired from assembly instructions with serial numbers starting with 03 or 04 and later. The 13.8-V source lead from the power plug goes directly to F-19. From there, it is connected to G-2, then to B-2 and the collectors of Q1 and Q2. This line is then connected to pilot lamp 1, pin 1. An extension of the lead goes to F-19, RY-11 and finally K-3.

"Therefore, I suggest removing all the wires on F-19, tying them together at an added terminal strip and connecting a new wire from F-19 to RY-3. This will keep 13.8 V on K-3, RY-11, G-2, B-2, the collectors of Q1 and Q2 and the pilot lamp. Doing so also enables one to key 13.8 V to F-19 as wanted."

Ed Mosher of Heath makes these additional suggestions. "For better protection change the 560-ohm resistor, mentioned in the tenth step of the August article, to 1000 ohms. Owners of sets with serial numbers beginning 03 and before should change R578 to 1.8 kilohms and R581 to 1.8 megohms. If necessary, both of these resistors are found on the 'F' circuit boards."

II Harlan Bercovici, WØMYN, author of the SB-104A/SB-644A article, has provided supplemental information concerning the modification for removing talk-back. He states that one of the changes is to remove the 13.8 volts from pin F-19 (the receiver i-f/audio board) during ssb transmission. While this change does eliminate the talk-back problem, it introduces another, namely that of erroneous frequency readings while the TUNE button is depressed. This is a display error only. The actual frequency is shown on receive. The reason for this condition is that before modification, the counter preset inputs had separate switches for usb, lsb and cw. But there was no switch or input for TUNE. (Reference is made to pins 2, 4 and 6 of switches S3A, S3B and S3C.) When the TUNE button is depressed, the counter preset would use whichever of the other three buttons was also depressed. Actually, the TUNE function automatically selects the same carrier frequency as for cw. While there would be a slight error in the frequency reading under these circumstances (use of TUNE and either usb or lsb), the difference would only be a few hundred Hz. The reading, nevertheless, would be correct the moment the TUNE button was released.

After the ten-step modification to remove the 13.8 V from pin F-19 is completed, the counter preset for the cw mode is obtained from pin 3 of switch S3C. This is the 11-volt section of the cw switch. The switch logic is so implemented that this line goes to 11 volts whenever either the cw switch is depressed or whenever the TUNE switch is pushed. The preset signal at pin A-24 will be present whenever either the CW or TUNE button is activated. Now, if either the USB or LSB button is depressed and you push the TUNE button, you will actually present two presets to the counter at the same time. That results in an incorrect frequency reading.

If your transceiver happens to be in the cw mode and you push the TUNE button, the frequency reading will be *correct*. If it is in the USB position and you pushed the TUNE button, the reading will increase by 4.1 kHz. Use of the lsb mode in conjunction with the TUNE position results in a reading change of 3.2 kHz. The important point to remember, Harlan states, is that these incorrect readings are present *only* when the TUNE button and either the LSB or USB are activated together. As soon as the TUNE button is released, the reading again becomes correct. Logic was investigated as a means of eliminating this problem, but Harlan reports that after consideration he determined such a solution was not worthwhile.

Simply remember this. Set the SB-104A frequency *before* you push the TUNE button. If the TUNE button is depressed first (except when associated with the cw mode), the frequency display is wrong. By referring to the circuit diagram, you can derive a more meaningful impression of why this is so.

By way of conclusion, Bercovici recommends that the following correction be made for step 2 on page 31 of August 1979 *QST*. The directions should be changed to read, "Disconnect the jumper from lug 3 of the TUNE switch to lug 2 of the cw switch." Delete the words "and reconnect it." Ed Mosher points out, however, that as long as the operator realizes that he is seeing a *display error* only, and *not* a *frequency shift, there is no need to perform this last step.*

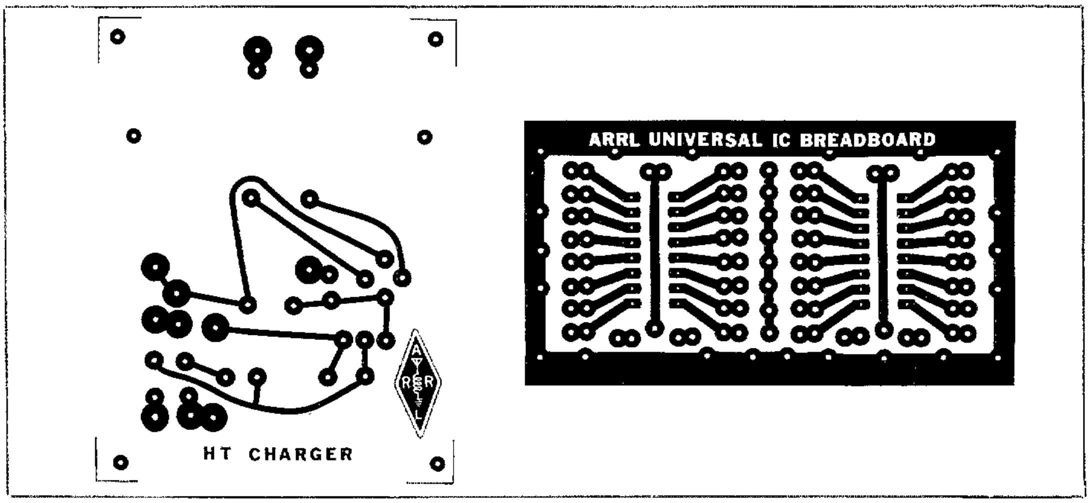
OLD TIMER'S NOTEBOOK: FIXTURE FOR CENTERING HOLES IN SHAFTS OR SCREWS

Many times I have tried to drill a hole in the end of a screw or a volume-control shaft, but I always have had difficulty centering the hole. I finally devised a fixture which permits the drilling of an accurately placed centering or starting hole.

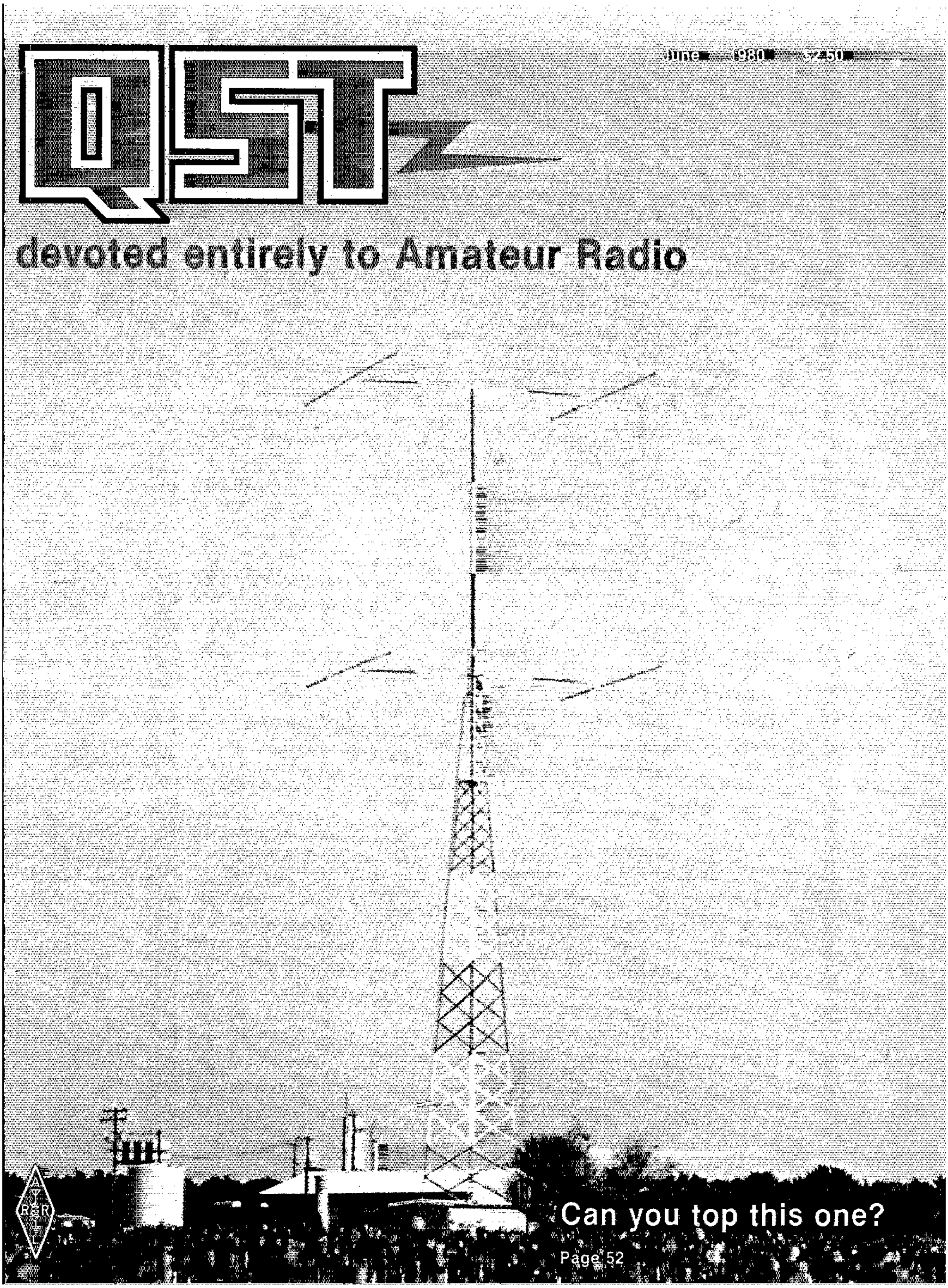
The fixture, shown in the drawing, consists of a piece of soft iron or brass, about one by three inches and one-half inch thick. I first drilled three holes clear through the block using a no. 40 drill. One of the holes, A, was then redrilled halfway with a no. 35 drill and tapped for 6-32; B was redrilled halfway with a no. 29 drill and tapped for 8-32 thread. The third hole, C, was redrilled halfway with a 1/4-inch drill to accept the standard-sized shafts of variable controls.

The small holes serve as guides for a small drill which will make a centering or guide hole in the end of the screw or shaft. — *Felix W. Mullings*, Hints and Kinks for the Radio Amateur (1949) QST

A fixture for use in drilling a centering hole in the end of a screw or shaft.



Circuit-board etching patterns for projects appearing in this issue of *QST*. The patterns are shown at actual size from the foil side of the board, with black representing copper. Each board has copper on one side only. At the left is the pattern for the NiCad battery charger (Fig. 2, p. 29), and at the right is the Universal IC Breadboard used for the keyer in "The NOR-Gate Break-In," Fig. 5, p. 24.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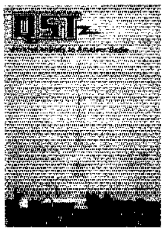
THE COVER



Another in the series of state-of-the-art antennas has risen above the orchards at W6KPC. The 20-meter array will be computer controlled for the optimum combination of bays. (See page 52. *(photo courtesy Fahey Photography)*

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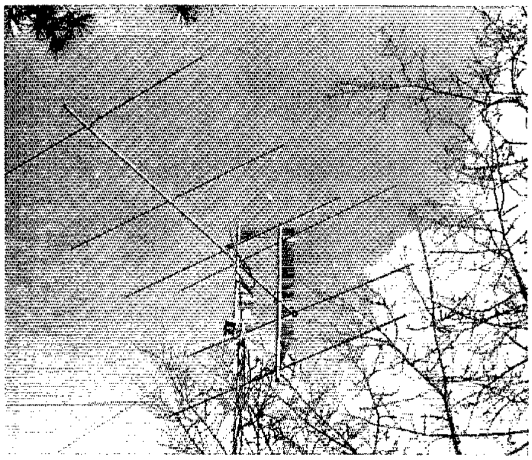
A Tri-Yagi for 50 MHz



For long-boom performance with short-boom safety, start from scratch or convert your old standard Yagi. It's cheap, easy to make and it works!

By Vincent A. Quaresima,* K2NE

One of the most important factors to keep in mind when designing any beam antenna is that there is usually an optimum design compromise between boom length, number of elements and wind loading. Referencing this to the question of 6-meter Yagi designs, an ideal boom length would seem to be 12 feet, particularly because of the ready availability of aluminum tubing stock in precut 12-foot lengths. Several manufacturers clearly have taken advantage of this fact, as evidenced by the number of 6-meter antennas on the market featuring boom lengths of 12 feet.

It would seem that the ideal number of elements for a 12-foot boom length at 50 MHz would be four. With optimized spacing along the boom, a Yagi configuration of this type should yield approximately 9-dBd gain. While this may be adequate for most routine users, the serious vhf DXer or contest operator might want some improvement in performance over that provided by the traditional 4-element Yagi. Although many people immediately recommend one of the commercially available long-boom, wide-spaced Yagis as the best way of increasing forward gain, there is an often-overlooked possibility of accomplishing this without encountering the severe wind-loading problems attendant in the long-boom Yagi.

A Compromise for Stacking Yagis

Stacking Yagis at 50 MHz presents several physical problems, both from the construction aspect and from the standpoint of wind loading. However, the advantages of obtaining additional gain by H-plane pattern[1] compression are too great to be summarily dismissed. An ideal compromise would be to compress the H-plane pattern of the antenna system without having to worry about stacking frameworks, manifold-feed systems and whether or not the darn thing will stay up once installed on the tower!

*Department of Mathematics, John K. Ossi Vo-Tech High School, Medford, NJ 08055

[1] E-plane pattern refers to the electric field. H-plane pattern refers to the magnetic field. See Kraus, *Antennas*, 1st edition, McGraw-Hill Book Co., 1950.

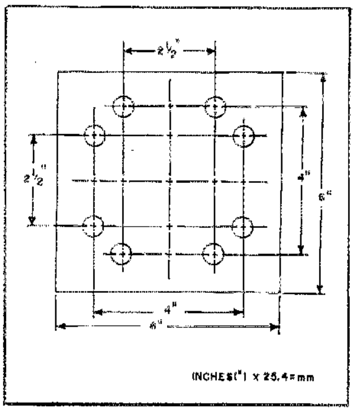


Fig. 1 — Template for the boom-to-boom bracket. The plate is constructed from 1/4-inch (6.4-mm) steel. All holes are 17/32-inch (13.5-mm) dia to accommodate 2-inch (51-mm) U clamps.

Test Measurements

For the purpose of gain measurement, test transmissions were made over an 8-mile path from K2NE to KA2BOP. Observations of the signal level with the Yagi were made first and then compared with the signal-level observations made next with the dipole. The procedure was to increase the power level transmitted through the dipole until the monitored signal had the same strength as obtained via the Yagi. The results given in the article were obtained by using the figures for the original power output (through the trigonal Yagi) and the figures for the adjusted power output (through the dipole). These were applied to the formula, gain (dB) = 10 log (p/p_T), where p = power to the dipole and p_T = power to the test antenna.

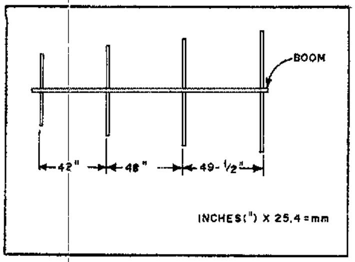


Fig. 2 — Planar element configuration of the K2NE 6-meter antenna. Element lengths are as supplied by manufacturer. *Do not use the shortest director.* Element lengths are not drawn to scale.

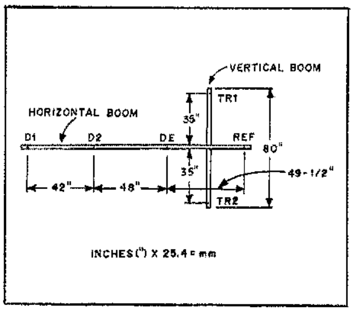


Fig. 3 — A side elevation of the beam with trigonal configuration.

Fortunately, there is such a compromise. On the average, replacing the standard Yagi reflector with a corner-type reflecting screen will improve the forward gain of the antenna by about 4 dB. At 50 MHz, however, a corner-reflector screen would dangerously increase the wind-loading of the antenna, particularly in icing conditions, as well as being impractically large for most users.

While not as efficient as a full screen-reflector, a trigonal reflector configuration still represents a way of improving gain of a Yagi over the "stock" Yagi configuration. In the case of the Cushcraft 5-element Yagi, this conversion is easy to do and inexpensive, and results in an antenna that will perform favorably when compared against the 6-element "standard" Yagis on booms of length varying between 21 and 26 feet. Note again that we are talking about 6-element, "wide-spaced" performance on *half* the boom-length and with significantly less wind loading.

The Conversion

To make the conversion, you will have to acquire aluminum tubing (two 12-foot or 3.66-m lengths) having 3/8-inch (10-mm) outer diameter, and an 8-foot (2.44-m) length of 2-inch (51-mm) OD tubing. You will also need six 2-inch (51-mm) U clamps. A diagram of one possible bracket for securing the trigonal support mast to the main boom is given in Fig. 1. Construct two elements, each identical to the reflector that is supplied by the manufacturer, being sure to drill holes in each element for the U clamp which is used to attach them to the reflector support mast.

Simply reposition the four remaining "planar" elements in accordance with the spacing information that is outlined in Fig. 2. Then mount the trigonal assembly as indicated in Fig. 3. Feeding and matching the antenna is done according to the manufacturer's instructions. It is not a bad idea to aim the antenna straight up while matching adjustments are made. This will minimize the interference caused by immediate obstructions and make the job of matching the beam quicker, easier and more accurate.

Simplicity of Matching the Antenna

In practice, matching the antenna to the feed system is a simple matter accomplished by varying the position of the shorting bar along the gamma match until the point of the lowest SWR is located. An SWR of less than 1.2:1 is quite easily attained. The antenna is fed with RG-8/U coaxial cable, although any low-loss 50-ohm unbalanced feed line would work. The end result, shown in the accompanying photograph, is mounted with an Alliance U-100 rotator atop a 30-foot (9.1-m) collapsible mast. The wind-load factor for this antenna is significantly less than that of a wide-spaced 6-element antenna on a boom in excess of 20 feet (6.1 m). Forward gain is in the neighborhood of 11 dBd, according to tests run with another amateur located 8 miles away. The comparison antenna for the gain test was a half-wave center-fed dipole mounted on the same mast, prior to the actual mounting of the "Tri-Yagi." The 11-dBd gain is obtained by H-plane pattern compression. Thus the normally wide, half-power beamwidth of the 4-element Yagi is not compromised in the E plane at all. This is important to consider when using the antenna for weak-signal work. It won't help much in reducing interference off the front of the beam during a contest, but the improvement is impressive!

Scatter Experiment

An interesting experiment would be to try establishing ionospheric scatter circuits. Mounting this antenna at 35 to 40 feet above ground and tilting the boom axis upward on an angle from 35 to 40 degrees might produce significant improvement in scatter results.

I wish to thank James Esposito for the original drafting and James Cramer and Paul Clark for the photography.

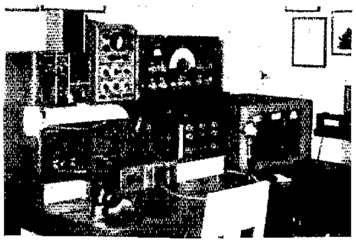
Strays

THE FRONT PANELS DON'T MATCH, BUT . . .

☐ "You don't have to be continually buying and investing in ham gear to fully enjoy the hobby," says Tom Fielder, W4EPL, of Columbia, South Carolina. Tom has come to believe in homemade and surplus gear — and his station shows it.

The top shelf of his uncommon station setup includes af and rf test oscillators, modified scope for monitoring and the ssb exciter from June 1958 *QST*. The bottom shelf holds a modified BC-348 (with product detector from February 1966 *QST*), converters for 10, 15 and 20 meters (February 1956 *QST*) and a 1-kW linear amplifier that contains 4CX250Bs. The control panel includes a phone patch, sidetone monitor and the Monimatch SWR indicator from February 1957 *QST*.

Tom wrote the receiver modification article that appeared in February 1966 *QST*. He sums things up by saying, "While the station may be antiquated in today's environment, the net result is a clean signal, good audio and a receiving capability that is not often surpassed." If anyone thinks that older gear is ugly looking, it may be worth quoting noted *QST* author W7ZOI: "Ugly-looking gear does not denote inferior performance!" — *Doug DeMaw, W1FB*



W4EPL says that this station, featuring homemade and surplus gear, has been in operation for 18 years, essentially unchanged.

QST Congratulates . . .

☐ Richard I. Vaughn, N5AA, who has been named FCC Regional Director, San Francisco.

ATTENTION AFFILIATED CLUBS

☐ Have you mailed in *your* annual report forms yet? We would like to keep your club on our mailing list, but cannot if we don't hear from you. — *Sally O'Dell, AE8P, Club and Training Department*

A Telephone-Line Repeater-Control Device

Each repeater licensee must control his repeater. A handful of parts will net a circuit to fill that need.

By John Nery,* WA1ESO

A method for direct on/off repeater control is extremely desirable, both to assure compliance with FCC regulations and for the licensee's peace of mind. The project described here has unique advantages: It is easy to build and very simple to use. The repeater can be "dumped" with just a telephone call — dial the repeater, let it ring *only once* and hang up. The repeater will shut down after eight seconds. Since no special control equipment is needed, any member of a repeater group may be assigned control-operator duty. All that is required is a telephone line to the repeater site.

Even this expense can be spared if a

*3 Springer Ave., Tiverton, RI 02878

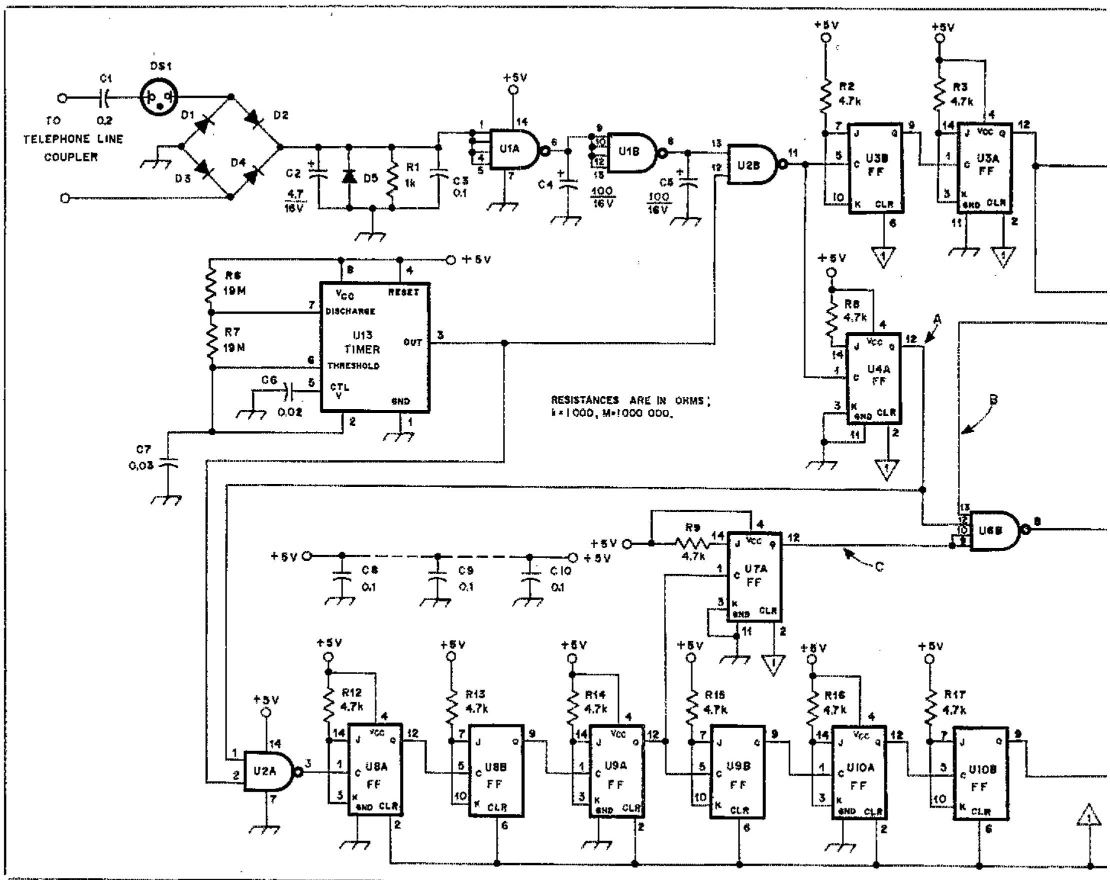
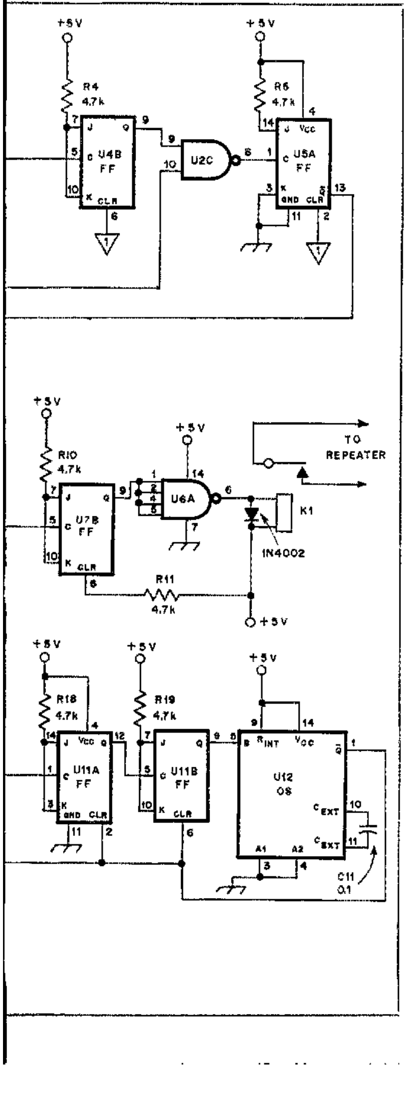


Fig. 1 — The WA1ESO repeater-control circuit. Resistors are 1/4 watt; k = 1000, M = 1,000,000. Capacitors are in µF and are disc ceramic except those with polarity indicated, which are electrolytic.

D1-D4 incl., D6 — Silicon rectifier diode, 1N4002 or equiv.
D5 — Zener, 6-V, 1-watt.
DS1 — Neon lamp, NE-3.
K1 — Reed relay, see text.
U1 — TTL dual 4-input NAND Schmitt trigger IC, 7413.
U2 — TTL quad 2-input NAND gate IC, 7400.
U3, U4, U5, U7, U8, U9, U10, U11 — TTL dual J-K flip-flop IC, 7473.
U6 — TTL dual 4-input NAND buffer IC, 7440.
U12 — TTL one shot IC, 74121.
U13 — IC timer, 555.

repeater club member has a telephone that receives few or no incoming calls. A radio or hard-wire link can be set up between the member's phone and the repeater. This idea is also useful if the repeater is in too remote a location to have a telephone line installed at the site. Of course the repeater should be monitored at that phone and manual control used when the phone is in use. [If the repeater already has a telephone line for an autopatch, this line cannot also be used as the sole control line. When the autopatch is in use, the control operator will get a busy signal! — Ed.]

The circuit is designed to toggle the repeater off or on when it receives one "ring" pulse from the telephone line. More than one ring will have no effect. Thus if the control line receives a "wrong number," the repeater will not be shut down, because the caller would normally let the phone ring several times. The control circuit is unresponsive for about two minutes after it receives a valid command. Then the repeater can be toggled back on with one ring in the same manner.



Circuit Details

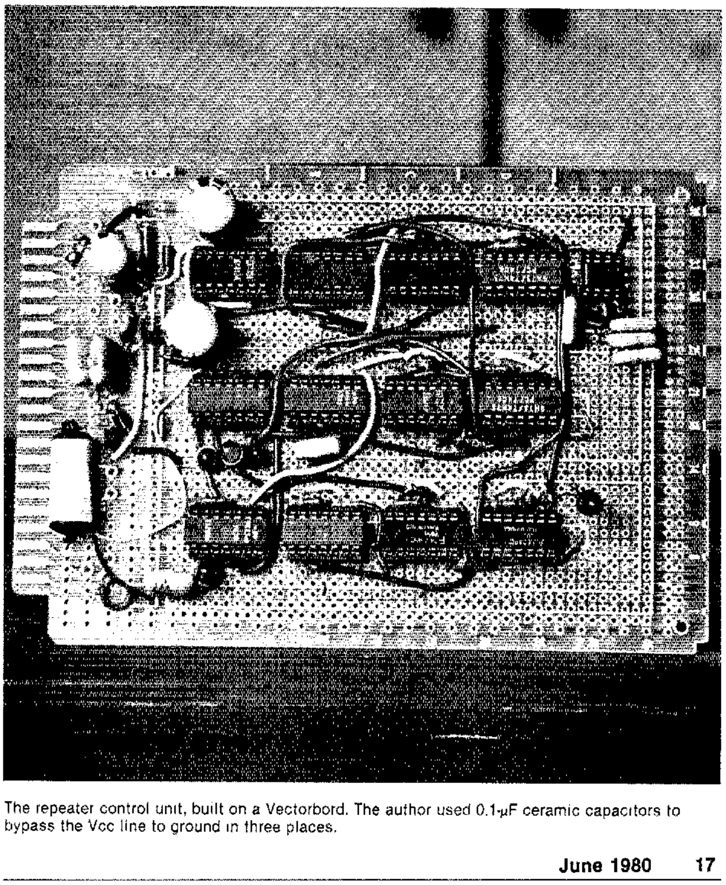
The circuit, shown in Fig. 1, consists entirely of 7400-series TTL integrated circuits. When the circuit has reset itself, two minutes after a command, points A and C are in the "low" state while point B is "high." Each ring is detected by diodes D1 through D4, limited by D5 and filtered by U1A, U1B, C4 and C5. When one ring is detected, J-K flip-flop U4A will toggle, causing point A to go high. The high at A enables U2A, passing pulses from the 2-Hz oscillator, U13, to the binary counter consisting of U8A and B, U9A and U7A. After about eight seconds, point C goes high. This, together with the high at A and B, enables U6B which toggles flip-flop U7B, causing the reed relay to change state.

When several rings occur rather than one ring, U2C is enabled by the binary counter consisting of flip-flops U3B, U3A and U4B. Gate U2C toggles flip-flop U5A, *disabling* U6B. Thus flip-flop U7B cannot be toggled.

The two-minute reset pulse is generated by U12, which is triggered by U11B, the last flip-flop in the counter chain. U12 holds all flip-flop clear inputs (except U7B) low long enough to ensure that all are reset.

The repeater control circuit is built on a Vector Plugboard, no. 3677-2[1] (see photo). Any reed relay that draws less than 40 mA at 5 volts can be used. To power the circuit, a 5-volt supply is needed. The current requirement of the circuit is about 200 mA. It is good practice to install 0.1-μF capacitors from Vcc to ground at several points on the board to prevent noise problems. Since the board will be used in a strong rf field, it should be built in a shielded box with all external wiring bypassed to ground. The circuit works well connected directly to the phone line, but an FCC-registered coupler should be used.

[1]Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, CA 91342.



The repeater control unit, built on a Vectorbord. The author used 0.1-μF ceramic capacitors to bypass the Vcc line to ground in three places.

The Electronic Voice-Saver

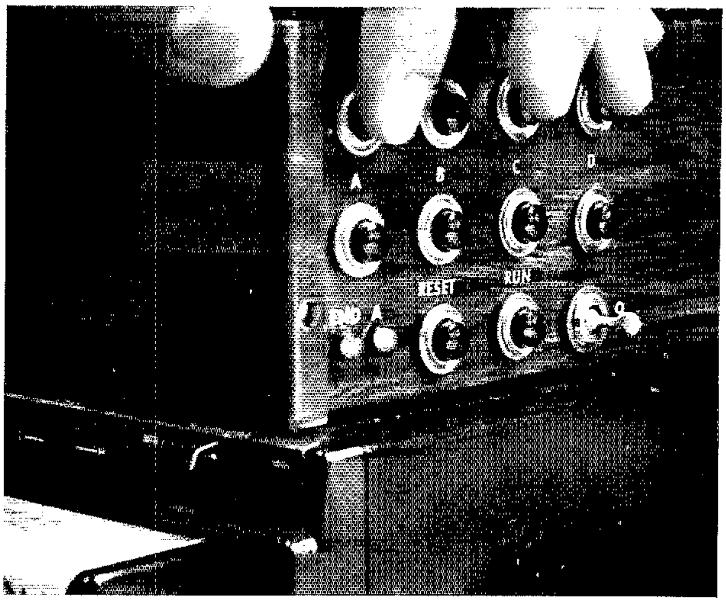
Ever operate a 24-hour contest with a 6-hour voice? Here's the perfect prescription for that one-too-many-contacts throat.

By A. Douglas Brede,* W3AS

Six hours into the contest and I was tiring from the shouting battle. "I've waited long enough," I thought, sliding my "secret weapon" across the operating table. The push of a button sent the wattmeter needle dancing as my voice poured from the monitoring headphones: "CQ contest, CQ contest . . ." Muttering the call of the W9 who answered the call, I pushed another button and he received, "you're 5 by 9 in western Pennsylvania." Scribbling down his exchange, with a push of a third button, "73 and QRZ" was the reply. All this time I was sitting back, a throat lozenge slowly dissolving in my mouth.

Ever dream of a contest machine that would do for the phone operator what the memory keyer did for the cw contester? The Electronic Voice-Saver features a push-button-controlled digital logic circuit that selects any one of eight prerecorded messages from a standard 8-track tape player to provide the phone equivalent of a memory keyer. What's more, with one additional 20-cent IC, it can double as a cw memory keyer.[1] The Electronic Voice-Saver uses all the existing hardware in the player. Metallic sensing tape (Radio Shack 44-1155) is used to "doctor" the playback tape to provide three 10-second segments.

All of the ICs used in the circuit (including the two voltage regulators) cost approximately four dollars. The 2N3055s are available at Radio Shack (276-1634) and are priced at two dollars for a package of six. Practically any general-purpose npn transistor can be substituted for the 2N2222s used here.



The Electronic Voice-Saver is shown perched atop the modified 8-track tape player. The cabinet is covered with adhesive-backed, wood-grain, vinyl paper. Side-mounted push buttons permit squeezing the buttons instead of pushing them because a 1-second depression is required to complete mechanical track changing.

Theory of Operation

The circuit diagram is shown in Fig. 1. When any one of the eight push buttons is depressed, the tape player drive motor is activated through U6, U7 and U8. The motor remains running until the tape-sensor contacts (ordinarily used for track changing) close. U7 and U8 also decode the button selection and switch a relay (via Q3) from one stereo channel to another.

*16E Graduate Circle, University Park, PA 16802

[1] Kilpatrick, "Keying a Transmitter With a Tape Recorder," Hints and Kinks, *QST*, January 1974.

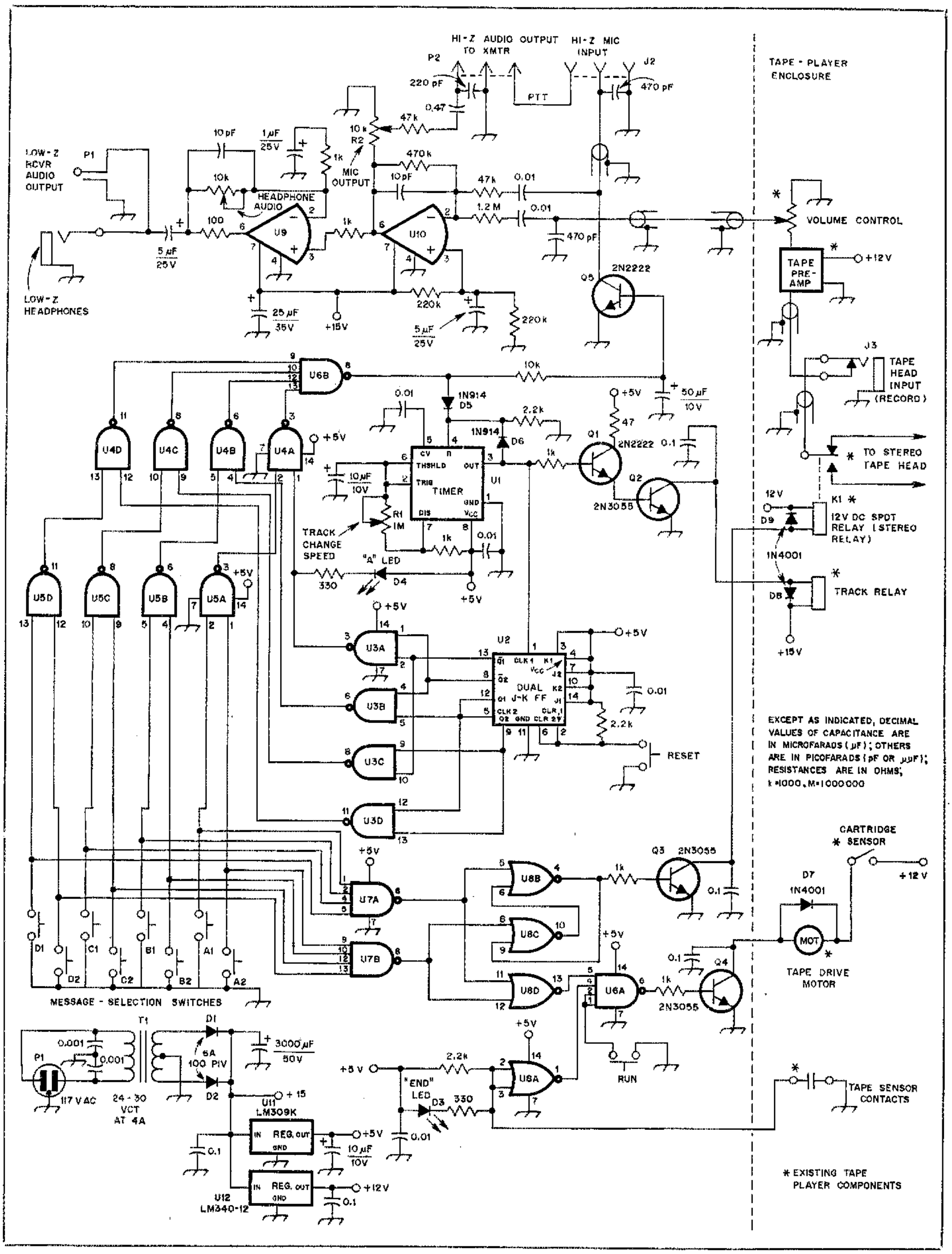
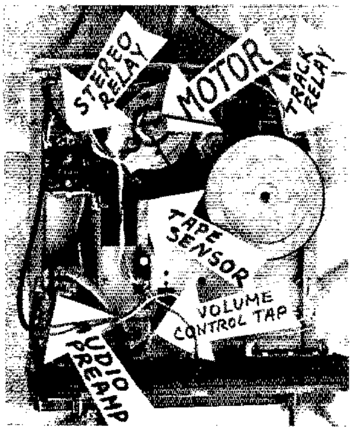


Fig. 1 — The diagram of the Electronic Voice-Saver. With the exception of the diodes, relay and J3, the components to the right of the dashed line are indigenous to the 8-track tape player. The message-selection switches (A1 through D2) are normally open push-button types.

U1 — 555 timer.
U2 — 7473 dual J-K flip-flop.
U3-U5, incl. — 7400 quad NAND gate.
U6, U7 — 7420 dual NAND gate.
U8 — 7402 quad NOR gate.
U9, U10 — 741 op amp.



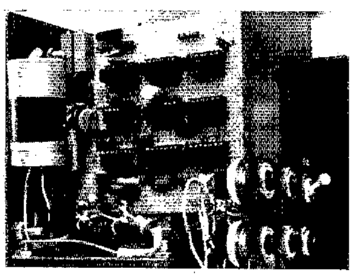
Any standard 12-V dc (negative ground) 8-track tape player can be adapted. Important components are identified in this unit, which was purchased for two dollars. The tape-sensor contacts are not visible in the photograph, but are near the indicating arrow and the more readily visible cartridge-sensing contacts.

Tightly wound tape will bind and overly loose tape may catch on the splices. Minimal tape tension is important and easy to obtain. The tape loop winds in a clockwise direction.

Since most inexpensive tape players have no track indicators, a dual flip-flop (U2) "remembers" the track to which the mechanical selector is set. U4 compares the push button selected with the information stored in memory. If it is different, U6 gates the timer (U1) to advance the track relay and memory until the correct track is located. While the relay is being energized, the microphone input is muted to prevent the noise from tripping the transmitter VOX. U10 mixes the mic and tape player audio for delivery to the transmitter audio stages. U9 provides sufficient gain to drive a low-impedance headset which may be used for monitoring.

Construction and Adjustment

Flea markets and audio repair/dealers abound with used 8-track tape players with "blown finals." These players are perfectly suited for adaptation since only one channel of the preamp is required; audio is derived from the arm of the volume control.



The electronics are assembled on perf board using point-to-point wiring. Though compact, there is no crowding of components.

After identifying the existing components in the tape player (see the accompanying photo), test the leads of the drive motor to see if either one is shorted to the chassis. My unit had such a ground and required the installation of small nylon washers and screws. The 1N4001 diodes shown in Fig. 1 should be mounted at the relay and motor terminals.

Adjustment of R1 should produce a 3-Hz pulse rate or the maximum speed at which your track changer can reliably operate. I substituted a 68-kΩ resistor for R1. The mic output potentiometer (R2) should be adjusted for unity gain. Audio from the tape player preamp is balanced with the mic using the player volume control. Headphone audio should be set at a low level so that tape noise does not interfere with reception of weak received signals after the recorded message has ended. Even at high volume levels, acoustical feedback has not been a problem.

Preparing the Tape

The 8-track tape cartridge can be opened at the center seam with a knife. Remove all of the tape, saving a 115-inch (3-m) piece for recording. This tape length will provide three 10-second segments; if you desire longer or shorter messages, adjust the length proportionally. Using three messages per loop allows you to vary your recording style to prevent your transmissions from sounding recorded. Before winding the tape, erase it; an ordinary permanent magnet run along its length a few times will do the job. Next, place a 1-inch (25-mm) piece of metallic sensing tape on the front side of the tape at the 37- and 75-inch (940- and 1900-mm) locations. (The front side of the tape is less glossy than the back side.) Wind the tape on the cartridge spool, rotating clockwise, using no tension. Trim off any excess tape at an angle and splice the tape with a 1-inch (25-mm) piece of sensing tape. Rotate the spool in the cartridge to check for correct tape tension, as shown in the photograph.

Recordings can be made with any tape recorder if an 8-track recorder is unavailable. I installed a jack (J3) on the rear panel of my player to enable a shielded-cable connection to be made to the tape head of a cassette recorder. This places both tape-deck heads in parallel. Simply record the tape as if you were recording on the cassette after pressing the desired track button on the Electronic Voice-Saver.

When recording, allow a brief pause (less than a second) at the beginning of each message to allow for a track-change interval. Since VOX operation usually truncates the first syllable, begin the recording with an unimportant word, e.g., "You're 5/9," as opposed to simply "5/9." I chose to record a CQ in A1, contest exchange in B1, QRZ? in C1, and my call in D1. A longer version of each (for heavy QRM conditions) is selected by the second row of buttons. The "call sign" track, since it is brief, can double as an "oops! I pushed when I didn't mean to" button. The memory-reset feature permits shifting the position of the messages.

Operating Tips

For important contests, keep a duplicate tape handy. With correct tape tension, a single tape will flawlessly outlast many a 48-hour extravaganza.

As with a memory keyer, there is always the tendency to rely too heavily on the machine and not on operating skill. During high activity periods, abandon the taped messages entirely since exchanges are short.

The Electronic Voice-Saver puts fun back into the radio marathon. After all, isn't that what contests are all about? QST

The Electronic Voice-Saver in action. Field testing at the North Hills (Pennsylvania) ARC Field Day outing raised more eyebrows than the home-built cw memory keyer sitting atop the rig.

A Computer-Operated Rotator-Control Interface

Are you still operating the rotator while your computer is just calculating the beam heading? Here's how to make the computer do *all* the work.

By George Blakeslee,* N1GB

While marking time as I rotated the beam antenna for the umpteenth time during a recent IARU Radiosport contest, it occurred to me that there had to be a better way. The TRS-80 was doing an admirable job of logging and dupe checking, but I was acting as the interface between computer-calculated beam directions[1] and rotator control-box switches. This was a task the *computer* should be performing while I was establishing the next QSO. A trip to a local electronics store produced two excellent books on the subject of microcomputer interfacing[2,3] that supported my project motivation with useful know-how. The motivation and information resulted in the circuit described here. Next contest, the computer is going to do *all* the work!

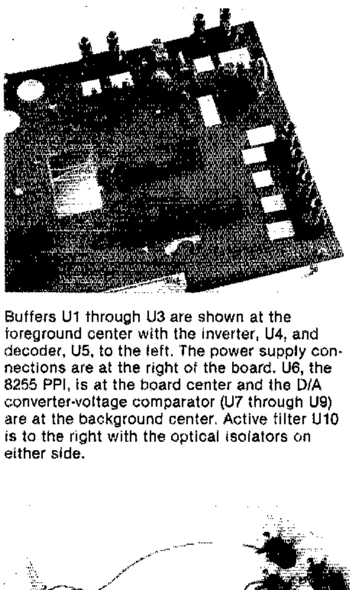
Circuit Description

The computer-to-beam rotator interface consists of three I/O ports, a D/A converter, a voltage comparator and a set of control relays. The I/O ports establish communication between the microcomputer and the interface. The D/A converter and voltage comparator combine to determine the beam heading, and the relays are used to control the rotator brake and motor.

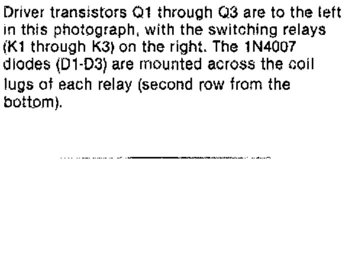
Setting up the programmable peripheral interface (PPI) is the first task for TRS-80 owners and anyone else whose microcomputer does not already have available ports. As shown in Fig. 1, I used a 3-port 8255 PPI IC. I found it necessary to use tri-state buffers (U1-U3) on the data bus. Prior to buffering, stray signals on the bus

*P. O. Box 15, Sudbury, MA 01776

[1]References appear on page 24.



Buffers U1 through U3 are shown at the foreground center with the inverter, U4, and decoder, U5, to the left. The power supply connections are at the right of the board. U6, the 8255 PPI, is at the board center and the D/A converter-voltage comparator (U7 through U9) are at the background center. Active filter U10 is to the right with the optical isolators on either side.



Driver transistors Q1 through Q3 are to the left in this photograph, with the switching relays (K1 through K3) on the right. The 1N4007 diodes (D1-D3) are mounted across the coil lugs of each relay (second row from the bottom).

were causing the CPU to get "lost" during initial power up. Inverter U4 is needed to provide compatible RESET signals for the 8255. Decoder U5 is optional; it was included to provide for later expansion. Enabling the 8255 is accomplished by providing pin 6 with a signal from the address bus. This is done by using a 3-to-8 decoder on bus lines A2-A7, but any of the address lines would work if connected directly. The two address lines connected to pins 8 and 9 are used to determine which of the four 8255 locations is being addressed. If the circuit is wired as presented in Fig. 1, U6 will be selected whenever the address lines AØ to A7 contain the program values 8ØH to 83H.

Enabling the 8255 is not sufficient to initiate operation. An additional signal is required to determine whether U6 is to READ data onto the data bus from an I/O port or WRITE data off the bus into one of the internal buffers. TRS-80 owners have two options: U6 may be addressed as three I/O ports with U6 READ and WRITE pins connected to TRS-80 IN and OUT pins respectively, or the ports may be addressed as memory locations and U6 READ and WRITE pins connected to the TRS-80 READ and WRITE pins respectively. If the latter method is chosen, be sure to choose address locations that are not currently assigned to existing memory.

Once the I/O ports are set up, it becomes possible to monitor and control the rotation of an antenna. It is required that the computer be able to determine the beam heading from the control-box indicator voltage and be able to activate switches that control the antenna rotation. Determining the current heading of the beam involves the use of a D/A converter and a voltage comparator. I/O port A is used to pass a digital value between 0 and 255 to the MC1408L8 D/A converter which generates a corresponding current. U8 converts this current into a voltage. Voltage comparator U9 determines whether the voltage is larger than the analog voltage coming from the rotator. Comparator output is passed back to the computer via I/O port C. The computer decides whether rotation is required and if so, in which direction. Active filter U10 is necessary to eliminate 60-Hz interference from the analog indicator signal.

The digital values passed to the D/A converter are created by a process known as "successive approximation." Basically, the computer "guesses" that the 8-bit value which corresponds to the analog value is 1000 0000 in Binary, or 128. The comparator value is then examined to see if the digital value is larger than the analog. If so, the most significant bit is reset and the next significant bit is set (i.e., 0100 0000); if not, the MSB is left and the next bit is set (i.e., 1100 0000). In this manner, the computer finds the matching digital value for the analog value in 8 "guesses." As there are 256 different possible values, the 8-trial successive approximation method is quite fast and makes possible accurate monitoring of a rotator that is either stationary or in motion.

The computer makes its decisions based on the value of the determined analog voltage and initiates rotation via I/O port B, using three of the eight output pins to operate switching relays. One of the relays is used to control the rotator brake and the others are used to control clockwise and counter clockwise rotation of the antenna. The outputs of I/O port B are latched and while the rotator is *in motion*, the rotator analog voltage is monitored and compared to the desired beam heading value. When the values are equal, the port B outputs are turned off, stopping the rotator and reapplying the brake. The port B control circuitry is protected from the ac voltage that is being controlled by 4N27 opto-isolators (U11-U13). Diodes placed across the relay coils

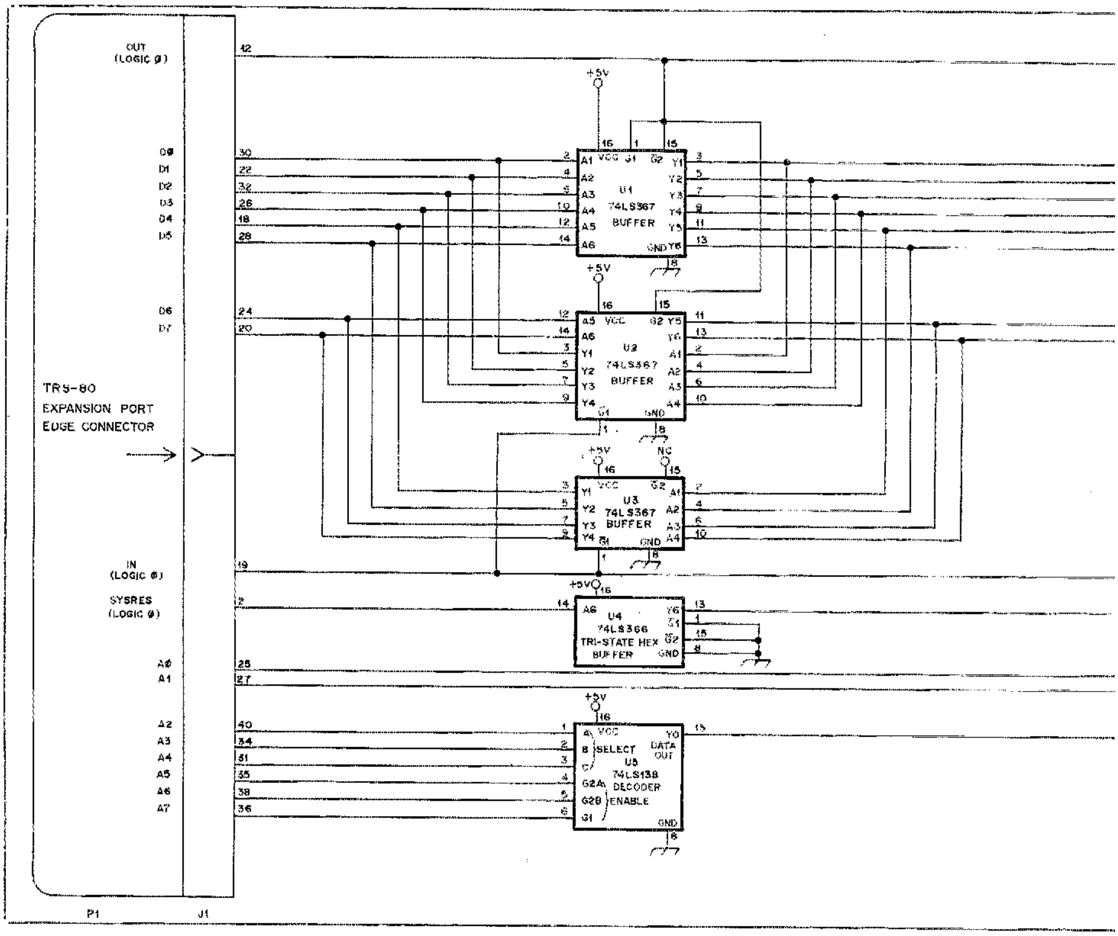


Fig. 1 — The computer-rotator interface diagram. All resistors shown are 1/4-watt. The TRS-80 expansion-port edge connector will mate with an Amphenol 88103-1 edge card connector, or a surplus connector may be used (see text). The components listed below may be obtained from the following sources: Active Electronics, 12 Mercer Rd., Natick MA (U1 through U10 inclusive); You-Do-It Electronics, 40 Franklin St., Needham, MA (remaining components).

D1-D3, incl. — 1N4007 silicon diodes.
J1 — Amphenol 88103-1 edge card connector or other (see text).
J2 — Part of CDE control box.
K1-K3, incl. — CDE No. 302 D-10 relays, spst NO 10-A contacts, 12-V dc/110-ohm coil.
P1 — TRS-80 expansion-port edge connector
Q1-Q3, incl. — 2N3904 npn silicon transistors or equiv.

prevent damage to the driver transistors Q1-Q3. In this application, the relay contacts are wired in parallel with the CDE Ham II control box switches where they are used to control the 120- and 30-V ac brake and motor leads.

Construction

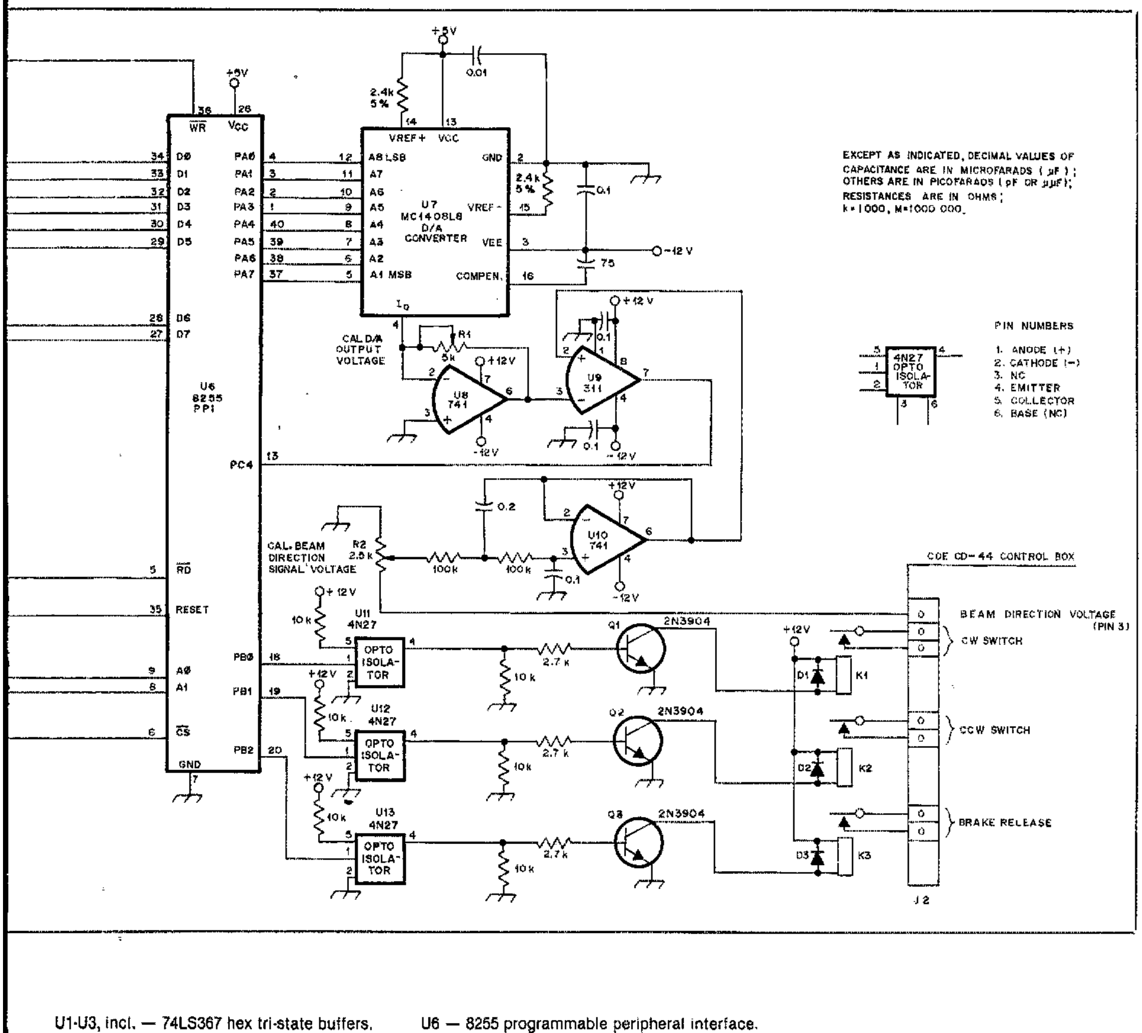
As shown in the photographs, the interface is assembled on two pieces of perf board. One board contains the active filter and opto-isolator circuitry. The other board holds the switching relays and associated components; it is housed in a protective chassis-box. Wire-wrap construction was used throughout the project. Component layout is not critical except that the data bus lines from U6 to the computer should be as short and direct as possible. Ribbon cable with 40 conductors was used to interconnect the interface to the computer. I found that a cable length of 18 in. (460 mm) was the most the computer would tolerate without problems developing. Edge connectors for the TRS-80 expansion port can be hard to locate. I had to use a 60-pin surplus connector that had the correct contact spacing and cut it to size.

Connections to the rotator control box are simply made; the CDE box has plenty of room inside. To get to the switch contact lugs, the bottom portion of the housing must be removed. I used 6-conductor cable to make the connections, routing the cable through a 3/8-in. (10-mm) hole in the chassis rear lip. The relay box and interface board may be interconnected by any convenient means. I used 10 ft (3 m) of 6-conductor cable for flexibility in physical interface placement.

Calibration

To calibrate the interface, +5 V and ± 12 V dc are applied to the proper points and the digital output value 255 supplied to port A. Adjust R1 for the desired maximum D/A converter voltage. This will be in the range of 0 to 10 volts. The books I consulted recommend setting the voltage to 2.55 volts.[2,3] As the D/A range is 0 to 255, this setting results in a 0.01-V resolution.

Manually rotate the antenna to the



U1-U3, incl. — 74LS367 hex tri-state buffers.
U4 — 74LS366 hex inverters.
U5 — 74LS138 3-to-8 line decoder.
U6 — 8255 programmable peripheral interface.
U7 — MC1408L8 digital-to-analog converter.
U8, U10 — 741 op amp.
U9 — 311 voltage comparator.
U11-U13, incl. — 4N27 opto-isolators.

Table 1
TRS-80 Computer-to-Rotator Interface Program

```
                 01000 ;COMPUTER CONTROLLED ROTATOR PROGRAM
                 01100 ;Z-80 MNEUMONICS
                 01200 ;SPECIFICALLY WRITTEN FOR TRS-80 USE
                 01300 ;
                 01400 ;WRITTEN  3 AUG 1979
                 01410 ;LATEST REVISION -  5 NOV 1979
                 01500 ;BY GEORGE BLAKESLEE, N1GB
                 01600 ;
                 01700 ;PROGRAM ORIGIN AND DESIRED BEAM
                 01800 ;HEADING INSSTRUCTIONS
                 01900 ;
FF50             02000               ORG.    ØFF50H
FF60 CD7FØA      02100 BEAMON  CALL    ØA7FH     ;WANT DIR.TO.HL
                 02200 ;
                 02300 ;INSTRUCTIONS TO SET I/O
                 02400 ;PORTS A & B FOR OUTPUT
                 02500 ;AND C FOR INPUT
                 02600 ;
FF63 3E88        02700               LD      A,88H     ;CMD WORD
FF65 D383        02800               OUT     (83H),A   ;CMD WORD TO PPI
                 02900 ;
                 03000 ;DETERMINE CURRENT BEAM HEADING
                 03100 ;AND DECIDE ON TURNING
                 03200 ;
FF67 CDBCFF      03300               CALL    DAC       ;NOW = A
FF6A BD          03400               CP      L         ;NOW-WANT = C FLAG
FF6B CAF4FF      03500               JP      Z,GOBAS   ;NOW = WANT
FF6E D289FF      03600               JP      NC,CCWON  ;WANT < NOW GO CCW
                 03700 ;
                 03800 ;TURN CLOCKWISE
                 03900 ;
FF71 CDA1FF      04000 CWON    CALL    BKREL     ;BRAKE OFF
FF74 3E05        04100               LD      A,Ø5H     ;5 = CW
FF76 D381        04200               OUT     (81H),A   ;ON VALUE
FF78 CDBCFF      04300 TRNCW   CALL    DAC       ;MONITOR
FF7B 95          04400               SUB     L         ; CW
FF7C C278FF      04500               JP      NZ,TRNCW  ; TURN
FF7F CDA1FF      04600               CALL    BKREL     ;CW OFF
FF82 3EØØ        04700               LD      A,ØØH     ;Ø = BRAKE
FF84 D381        04800               OUT     (8ØH),A   ;ON VALUE
FF86 C3F4FF      04900               JP      GOBAS     ;NOW = WANT
                 05000 ;
                 05100 ;TURN COUNTER-CLOCKWISE
                 05200 ;
FF89 CDA1FF      05300 CCWON   CALL    BKREL     ;BRAKE OFF
FF8C 3EØ6        05400               LD      A,Ø6H     ;6 = CCW
FF8E D381        05500               OUT     (8ØH),A   ;ON VALUE
FF90 CDBCFF      05600 TRNCCW  CALL    DAC
FF93 95          05700               SUB     L         ; CCW
FF94 C290FF      05800               JP      NZ,TRNCCW ; TURNING
FF97 CDA1FF      05900               CALL    BKREL     ;CCW OFF
FF9A 3E00        06000               LD      A,00H     ;Ø = BRAKE
FF9C D381        06100               OUT     (81H),A   ;ON VALUE
FF9E C3F4FF      06200               JP      GOBAS     ;NOW = WANT
                 06300 ;
                 06400 ;BRAKE RELEASE / DELAY SUBROUTINE
                 06500 ;
FFA1 D9          06600 BKREL   EXX                 ;SAVE HL
FFA2 3EØ4        06700               LD      A,Ø4H     ;4 = BRAKE
FFA4 D381        06800               OUT     (81H),A   ; OFF VALUE
FFA6 [illegible] 06900               LD      [illegible],ØØH ;COUNT OUT
FFA8 [illegible] 07000               LD      L,Ø5H     ;DELAY LOOP
FFAA Ø1FFFF      07100 HOLD    LD      BC,ØFFFFH ;DELAY COUNT
FFAD ØB          07200 DELAY   DEC     BC
FFAE 78          07300               LD      A,B
FFAF C2ADFF      07400               JP      NZ,DELAY
FFB2 79          07500               CP      C
FFB3 C2ADFF      07600               JP      NZ,DELAY
FFB6 2D          07700               DEC     L
FFB7 C2AAFF      07800               JP      NZ,HOLD
FFBA D9          07900               EXX                 ;RESTORE HL
FFBB C9          08000               RET
                 08100 ;
                 08200 ;    D/A SUBROUTINE
                 08300 ;
FFBC Ø6Ø8        08400 DAC     LD      B,Ø8H     ;LOOP COUNT
FFBE 1EØ8        08500               LD      E,Ø8H     ;BIT SUB VALUE
FFC0 3EFF        08600               LD      A,ØFFH    ;SET TEST
FFC2 [illegible] 08700               LD      (SET + 1),A; BIT VALUE
FFC5 3E8F        08800               LD      A,ØBFH    ;SET RESET TES
FFC7 32F1FF      08900               LD      (RES + 1),A; BIT VALUE
FFCA AF          09000               XOR     A         ;CLEAR A
FFCB CDE2FF      09100 SAPROX  CALL    SAOUT     ;TEST SA VALUE
FFCE 3AE4FF      09200               LD      A,(SET + 1); TEST
FFD1 93          09300               SUB     E         ; NEXT
FFD2 32E4FF      09400               LD      (SET + 1),A;  BIT
FFD5 3AF1FF      09500               LD      A,(RES + 1); NEXT
FFD8 93          09600               SUB     E         ; RESET
FFD9 [illegible] 09700               LD      (RES + 1),A  BIT
FFDC Ø8          09800               EX      AF,AF'    ;RESTORE SA VALUE
FFDD 1ØEC        09900               DJNZ    SAPROX    ;TEST NEXT BIT
FFDF [illegible] 10000               OUT     (80H),A   ;OUT SA VALUE
FFE1 C9          10100               RET
FFE2 ØØ          10200 SAOUT   NOP
FFE3 CBFF        10300 SET     SET     7,A       ;SET SA BIT
FFE5 [illegible] 10400               OUT     (80H),A   ;OUT TEST SA
FFE7 Ø8          10500               EX      AF,AF'    ;SAVE SA VALUE
FFE8 DB82        10600               IN      A,(82H)   ;CK CMPR LOGIC
FFEA [illegible] 10700               CP      ØØH       ;CK LOGIC LO
FFEC [illegible] 10800               JP      NZ,SETBIT; BIT STAYS
FFEF Ø8          10900               EX      AF,AF'    ;RESTORE SA VALUE
FFF0 CBBF        11000 RES     RES     7,A       ;TEST BIT OFF
FFF2 Ø8          11100               EX      AF,AF'    ;SAVE SA VALUE
FFF3 C9          11200 SETBIT  RET
                 11300 ;
                 11400 ; RETURN TO BASIC PROGRAM
                 11500 ;
FFF4 C3[illegible]  11600 GOBAS   JP      Ø19AH
0000             11700               END
00000 TOTAL ERRORS

BEAMON  FF50 02100
BKREL   FFA1 06600    04000 04600 05300 05900
CCWON   FF89 05300    03600
CWON    FF71 04000
DAC     FFBC 08400    03300 04300 05600
DELAY   FFAD 07200    07400 07600
GOBAS   FFF4 11600    03500 04900 06200
HOLD    FFAA 07100    07800
RES     FFF0 11000    08900 09500 09700
SAOUT   FFE2 10200    09100
SAPROX  FFCB 09100    09900
SET     FFE3 10300    08700 09200 09400
SETBIT  FFF3 11200    10800
TRNCCW  FF90 05600    05800
TRNCW   FF78 04300    04500
```

position that produces the largest analog indicator voltage. For the CDE Ham II/CD-44, this position is clockwise south and produces +13 V at pin 3 of the connector strip. Apply this voltage to the active filter U10 and adjust R2 to produce the same voltage value chosen for the D/A converter.

Operation

The interface is now ready to function as a rotator control. The program given in Table 1 will control the interface and make all switching decisions. Written specifically for the TRS-80, the program is intended to be called from a beam-direction BASIC program. The program expects to find the desired beam heading in the L register as a value between 0 and 255. This value is used in program decision making with control remaining in the program until the desired and actual headings are the same. When the two values are equal, control is passed back to the BASIC program.

If you arrive at the given program by a different method, it will be necessary to modify line 2100 to obtain a desired value in the L register. Line 11300 must be modified if you do not desire to return to a BASIC program. The machine language program of Table 1 will work as given with any Z80-based microcomputer.

Finally, if you haven't already programmed your computer to determine beam antenna headings, consider it. Hall's article in *QST* will give you the necessary formulas from which a program can be assembled.[4] Then all you have to do is put together this interface and the computer will do the rest of the work itself.

References

[1] Hall, "Bearing and Distance Calculations by Sleight of Hand," *QST*, August 1973.

[2] Carr, *Digital Interfacing with an Analog World*, No. 1070, 1978, Tab Books, Blue Ridge Summit, PA 17214.

[3] Jung, *IC Converter Cookbook*, No. 21527, 1978, Howard W. Sams and Co., Indianapolis, IN 46268.

[4] [Editor's Note: See Ref. 1. In that article, instructions are included for converting L (difference in longitudes) to a value falling between ± 180°. This was done to aid in manually resolving an ambiguity regarding whether the resultant bearing angle is in an easterly or westerly direction from north. Those steps can be eliminated in a computer program for the procedure, and the ambiguity can be resolved by taking the sine of the value for the difference, directly. If the sine of the value is positive, the bearing is the result obtained from the equation; if the sine value is negative, the true bearing is 360° minus the value derived from the equation.]

• *Basic Amateur Radio*

A Beginner's Look at Op Amps

Part 2: What goes on inside the black box; or a journey from fantasyland to the real world.†

By George H. Woodward,* W1RN

The introduction to closed-loop amplifier theory in Part 1 was intended to dispel any latent fear and loathing you may harbor for those convex triangular symbols. But just as a quick briefing on the facts of life doesn't prepare a person for marriage, our first peek at op amps won't allow us to use them in circuits without some awkward fumbling. This concluding part gives you information on some real circuits.

A "Quasi-Real" Operational Amplifier

You could build the circuit in Fig. 7 to demonstrate the principles I discussed in Part 1. If you're a bit uncertain about Kirchhoff's laws, voltage nodes and black boxes, analyzing Fig. 7 at the component level may help clear the haze. Look first at the input stage, composed of Q1, Q2 and Q3. This arrangement is known as a differential amplifier. Our colorful British friends call it a "long-tailed pair." Old-timers may feel more comfortable thinking of the input circuit as a cathode follower driving a grounded-grid stage, and if you ground one base and excite the other, that's the vacuum tube equivalent of what we have. Q3 is a *constant current source.* The voltage at its base (with respect to the negative power bus or rail) is fixed at 1.2 volts by means of D1 and D2. Since the base-emitter junction of Q3 has one diode drop, the voltage developed across R3 is 0.6 volt. Ohm's law tells us that the current through R3 is 2 mA. The beta (current gain) of the transistor is very high, so its collector current is also 2 mA, provided the collector to emitter potential is at least a couple of volts. Constant current (independent of voltage) means infinite resistance. A constant-current source provides the tightest possible coupling between the emitters of Q1 and Q2 while ensuring the proper bias current.

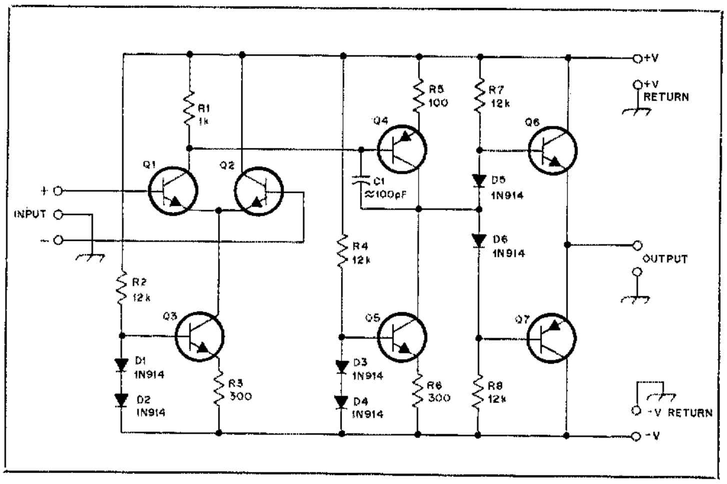


Fig. 7 — An operational amplifier assembled from discrete components. Npn transistors are 2N3904 or similar, and pnp transistors are 2N3906 or similar. Supply voltages from ±6 V to ±20 V may be used.

If we ground both inputs of our op amp, Q1 and Q2 will each conduct 1 mA. An op amp isn't too useful with both inputs grounded, so let's tie the noninverting terminal (the one marked +, remember?) to ground and apply a positive voltage to the inverting terminal. Notice that Q2 has no collector load resistor, so it behaves as an emitter follower. The Q2 emitter follows its base voltage, but since the base of Q1 is grounded and its emitter is connected to that of Q2, Q1 starts to turn off. As Q1 draws less current, its collector voltage rises toward the positive power bus. Q4 is a pnp transistor, and its base is connected to the collector of Q1, so it tends to turn off with Q1.

The circuitry around Q5 looks

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†Part 1 of this article appeared in April 1980 *QST.*

suspiciously like that of Q3, and if you call it a current source, you're right. Q5 forms the load resistance for the collector of Q4. The voltage gain of a bipolar transistor circuit is approximately the ratio of the collector load resistance to the emitter resistance. Since our constant-current load has "infinite" resistance, the stage gain is substantial.

Q6 and Q7 form an output stage called a *complementary-symmetry* circuit. Emitter followers of opposite polarity allow active pull-up (away from ground) for both positive- and negative-going signals.

Would anybody really build an op amp from discrete components? The answer is yes — take a look at the diagram for your high-fidelity music amplifier. It likely bears a striking resemblance to Fig. 7.

We still haven't talked about every component. And do we really *need* all those parts? First things first. The diodes between the bases of the output transistors hold each base one diode drop above its respective emitter. This gives the transistors a slight forward bias, causing them to conduct a small current under static (no signal) conditions. We could eliminate D5, D6, R7 and R8, and simply connect the bases of Q6 and Q7 to the collector of Q4. However, doing this would create a 1.2-volt "dead zone" around our zero-signal output level. The result would be crossover distortion of the output waveform. We'll deal with C1 a little later.

Fig. 8 illustrates the simplest possible operational-amplifier circuit. The constant-current sources have been replaced by high-value resistors, and the output is taken directly from the Q3 collector. In the early '60s (when a 709 op amp cost $75), such circuits abounded in electronic instruments. They work fine in dedicated applications, but their flexibility is limited.

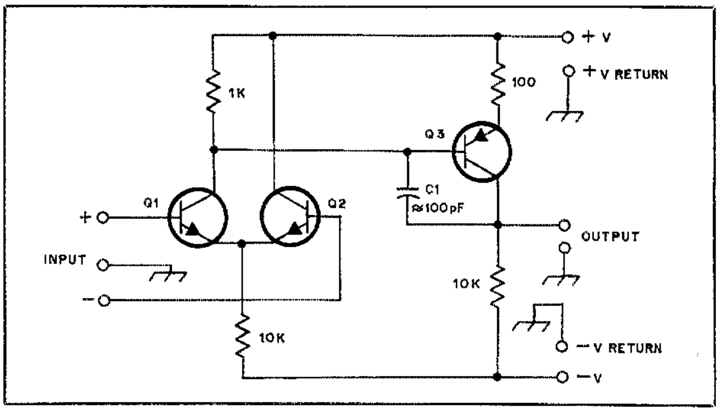


Fig. 8 — Simplified discrete op amp. This circuit was in common use before the advent of inexpensive IC technology.

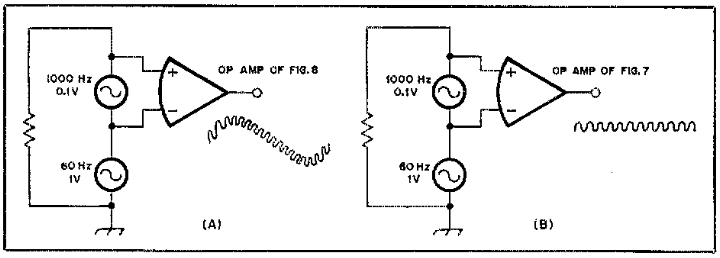


Fig. 9 — Illustration of common-mode noise. The unsophisticated circuitry of the op amp in A is unable to reject a signal common to both inputs. In B, the more elaborate op-amp circuit suppresses the undesired 60-Hz noise. Noise from the power supply is rejected by the same mechanism. See text for an explanation of this phenomenon.

Common-Mode Rejection

The circuit in Fig. 9 shows an op amp sensing a signal that is riding on another signal. An audio amplifier in a direct-conversion receiver is an example of this situation. The 60-Hz generator represents hum picked up by the receiver wiring, and the 1000-Hz generator represents the desired signal. If we assume the 1000-Hz signal source to have zero internal resistance, the hum will appear with equal (common) amplitude and phase on both amplifier input terminals. With only a resistor feeding the emitters of the input transistors, as in Fig. 8, the transistors will respond equally to the common-mode 60-Hz signal. This signal will be developed across the Q1 load resistor, and its amplitude depends on the balance between Q1 and Q2 and the value of the emitter resistor. Increasing the emitter resistance will improve the common-mode rejection at the expense of noise figure and/or dynamic range. If the amplifier of Fig. 7 is used, no signal will appear at the collector of Q1 because of the infinite emitter resistance presented by the constant-current source. The total current in the differential pair can't vary with the input signal. Only the *ratio* of currents in Q1 and Q2 varies, and since the inputs are essentially shorted for the 60-Hz signal, the ratio is unity. When a constant-current source biases the differential pair, the only factor that can degrade the common-mode rejection is unbalance between the input transistors. A constant-current source also greatly enhances the op amp's rejection of power-supply noise.

Offset

Another parameter that depends on the transistor balance is voltage offset. Ideally, shorting the input terminals together would produce zero output voltage. In reality it doesn't happen. A small differential voltage must be applied to the inputs to zero the output. This voltage is called *offset*. IC manufacturers specify this offset with respect to the *input*. To determine the effect of offset voltage on the *output*, simply multiply the input offset by the circuit gain. Most inexpensive general-purpose op amps have offsets of a few millivolts. Some of the newer high-performance units feature offsets of only microvolts. Terminals for trimming the offset voltage to zero are available on many ICs. If the circuit resistances are low, the offset voltage can be measured directly by means of a digital multimeter connected across the input terminals.

A small current flows in the input terminals of real op amps, usually on the order of nanoamperes or picoamperes. If this current flows through a large resistance, a voltage will be developed. To nullify this error voltage, we can make the resistance to ground the same for both inputs. The error voltage will then be the same on both inputs, and the op amp will reject it as a common-mode signal. Fig. 10 illustrates this technique. Offset voltage can be ignored in most amateur applications, but it's a good thing to understand.

Loop Gain

The voltage gain of the circuit in Fig. 10 is simply R_f/R_i. We derived this formula in Part 1 of this article, but it's based on the assumption that the amplifying device has infinite gain. We can't have infinite

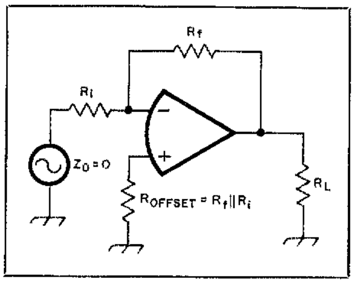


Fig. 10 — Equalizing the resistance to ground in each input leg cancels offset voltage caused by input current.

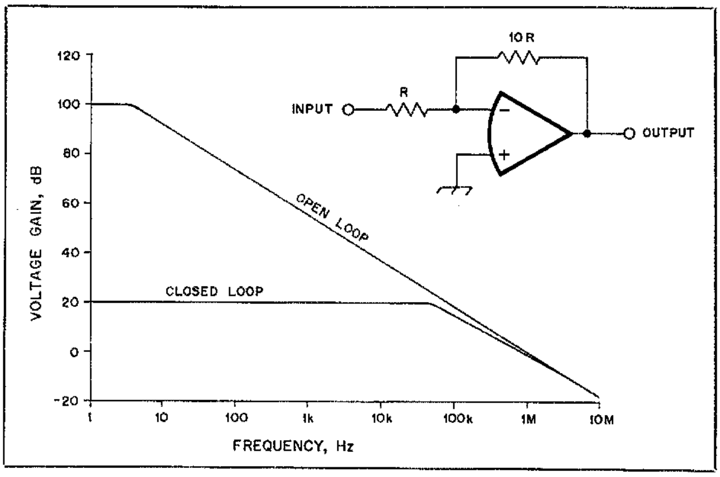


Fig. 11 — Open-loop gain and closed-loop gain as a function of frequency. The vertical distance between the curves is the feedback or gain margin.

gain with real components, but our formula will be reasonably accurate if the amplifying device has at least 10 times the gain we expect from our circuit. The gain of the amplifying device alone is called the open-loop gain. With the feedback network connected, the circuit gain is called, appropriately enough, the closed-loop gain. The numerical open-loop gain divided by the numerical closed-loop gain is known as the *loop gain*. If all quantities are expressed in decibels, loop gain is the difference between the open-loop gain and the closed-loop gain. When expressed this way, loop gain is sometimes called *gain margin*, and is a measurement of the amount of feedback in the circuit. Loop gain is an important parameter in op-amp circuits because it profoundly influences such characteristics as accuracy, distortion and stability.

Phase Shift and Stability

Drawn in Fig. 11 is an inverting amplifier circuit, along with a plot of its frequency response. The closed-loop gain is 10, or 20 dB, as set by the input and feedback resistors, up to about 50 kHz, where the op amp runs out of gas. If we set the closed-loop gain to 100, we could only go out to about 5 kHz before the frequency response drops off. Connecting the op amp as a voltage follower would allow us to approach 1 MHz of bandwidth. The open-loop gain of the device rolls off at 6 dB per octave (20 dB per decade), and the 3 dB corner frequency is about 3 Hz. Three hertz?! But semiconductors are faster than that, aren't they? Yes, they are — much faster. The sloping response comes about as a result of C1 in Figs. 7 and 8. If we omitted C1, the amplifier's frequency response would be determined by the time constants of the semiconductor junction capacitances and resistances. Each parasitic R-C product introduces an attenuation of 6 dB per octave above a corner frequency dictated by

$$\frac{1}{2\pi RC}.$$

As each successive corner frequency is reached, the attenuation slope increases by 6 dB per octave, becoming 12 dB per octave, then 18 dB, and so on. The problem with allowing the parasitic R-C networks to determine the op amp's open-loop frequency response is that each such network introduces some phase shift. At the corner frequency, an R-C network exhibits 45 degrees of phase shift, and this value increases beyond the corner frequency. After passing through three parasitic R-C networks, an input signal above the highest corner frequency has been shifted at least 135 degrees.

In other words, above a certain frequency, an inverting amplifier circuit doesn't invert at all! In fact, if the device still has gain above the third corner frequency, connecting a resistor from the output to the inverting input terminal will cause the circuit to oscillate, because the feedback is really positive. To prevent oscillation, we ensure that the gain drops to unity before the phase shift reaches 135 degrees. A capacitor between collector and base of the main voltage gain transistor is the easiest way to accomplish this. The capacitor doesn't need to be very large because its capacitance is multiplied by the *Miller effect*. Basically, the Miller effect works this way: As the base voltage of the transistor goes positive, the collector voltage goes negative. The voltage across the capacitor, then, is the sum of the base and collector voltages, with the result that the base current must be larger to charge this collector-to-base capacitor than to charge a like-value component connected to ground.

Tailoring an op amp's response to prevent oscillation is called phase compensation or frequency compensation. In some devices, the compensation is internal. The curve in Fig. 11 is for a 741 — a popular internally compensated op amp. In some other op amps, such as the 709 and 301, the frequency compensation must be connected externally. The 6-dB-per-octave compensation is the most stable, but it severely limits the bandwidth over which a large closed-loop gain can be realized. Application notes published for externally compensated types of amplifiers show specialized types of compensating circuits such as two-pole and feed-forward networks. These have the advantages of wider bandwidth and improved transient response, but at the expense of increased load sensitivity. Op amps particularly dislike capacitive loads.

Bandwidth

The small-signal bandwidth of an operational amplifier depends mostly on the phase-compensation scheme. As shown in Fig. 11, lower closed-loop gain (greater feedback) allows wider bandwidth. For large signals (output swing approaching the supply voltage) the bandwidth is smaller, being limited by the amplifier's *slew rate*. Slew rate is a measurement of the amount of voltage change a device can produce in a given time. Energy stored in junction capacitances is the major factor limiting the speed with which transistors can respond to changes. Typical slew rates range from about 0.8 volt per microsecond for the 741 to about 13 volts per microsecond for the high-performance LF356. Devices having small-signal bandwidths of 10 MHz or better typically have power bandwidths on the order of 200 kHz.

Input and Output Considerations

Real op amps have input impedances ranging from megohms to gigohms. Ordinary general-purpose devices having bipolar input transistors usually fall into the megohm category. In order for these op amps to approach "ideal" performance, the input source impedance should be kept below 10 kilohms. Low source impedances generally promote low noise and low offset and drift errors. FET input op amps can sometimes be operated successfully from source impedances greater than 1 megohm.

Although the internal circuit configurations combined with heavy external feedback encourage low dynamic output impedances, most IC op amps aren't happy with load impedances lower than about 2 kilohms. The reason for this is that the chips have built-in current limiting which helps protect them from damage caused by pin-to-pin short circuits. Beyond 10 or 20 milliamperes of load current (source or sink) the output goes into a constant current (meaning high impedance, remember?) mode. For high output currents or low impedance loads, we can add a discrete emitter follower within the feedback loop. As mentioned in the discussion of stability, most op amps tend to oscillate when subjected to capacitive loads. Often a small resistor in series with the output will remedy this condition.

The Norton Amplifier

An unusual type of op amp I didn't discuss in Part 1 is the *Norton*, named for for the network theorem on which its operation is based. Fig. 12A shows a simplified diagram of the input stage of a Norton amplifier. The noninverting input makes use of D1 and Q1 in a *current mirror* configuration. When input current is applied to Q1, it steals base drive from Q2, the inverting input. Obviously, this amplifier must have input current to operate, hence it is *not* a high-impedance device. In the inverting-amplifier configuration the numerical voltage gain is R_f/R_i, but the noninverting input terminal must be returned to the *positive supply* through a resistance of $2R_f$ to equalize the input currents. Any attempt to use this type of IC as a voltage follower is doomed to failure — the input stage will be destroyed by excessive current. The chief usefulness of Norton amplifiers is in single-supply applications where the dc level of the signal is very near ground. The ssb chapter of the *Handbook* features a VOX circuit using the LM3900 Norton op amp.

Some Op-Amp Applications

We haven't learned *everything* about operational amplifiers yet, but with the information presented so far, you should be able to put together a few op amp circuits without getting into too much trouble. April 1980 *QST* featured a microphone amplifier. As well as being a handy gadget and an excellent "first project," that unit is useful for demonstrating basic op amp principles. Other applications for op amps

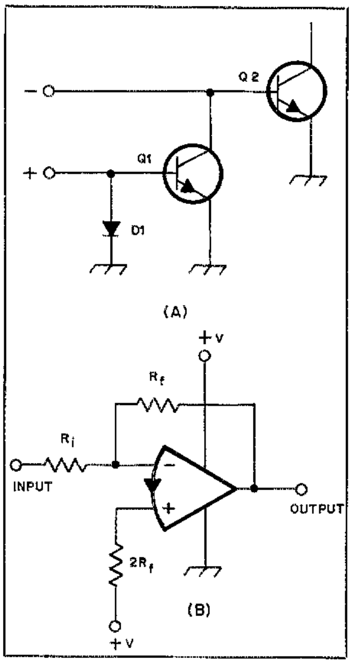


Fig. 12 — (A) Input circuit of a Norton operational amplifier. (B) Norton op amp connected as an inverting amplifier. Note the special symbol used to denote a Norton IC.

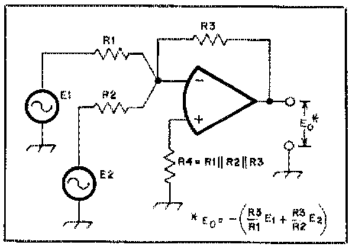


Fig. 13 — A summing amplifier and its transfer function. E1, E2 and E_o are *instantaneous* voltages. Don't forget to assign the proper polarities to the input voltages. Any number of signals can be summed this way.

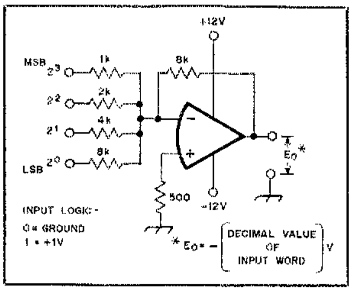


Fig. 14 — Digital-to-analog converter. One application might be an analog (meter) readout for a frequency counter. The circuit is also useful as a coarse steering-voltage generator for a VCO in a frequency synthesizer.

in either inverting or noninverting circuits include receiver audio sections, alc, agc and S-meter amplifiers, and even 50-kHz i-f stages.

All of the circuits we've looked at so far have had only one signal source. An inverting op-amp circuit has the ability to amplify signals from two sources without mutual interference. See Fig. 13. The current in the feedback resistor, R3, is equal to the *algebraic sum* of the currents in the input resistors, R1 and R2. Now you can see why the common connection of R1, R2, R3 and the inverting input terminal was called the *summing junction* in Part 1. Since the summing junction is a virtual ground, the two generators have no mutual current, so they are completely isolated. When audio engineers work with summing amplifiers, they call them *audio mixers*. In most communications work, a mixer is a nonlinear device that generates the sum and difference and other products of two input frequencies. A summing amplifier used as an audio mixer is linear, and only the input frequencies appear at the output. You should be aware of this distinction when speaking of mixers. *Combiner* is a better word than mixer for an audio summing amplifier.

If your interest in electronics is mostly digital, you are about to be rewarded. To interface from bits and bytes to the land between one and zero, we need a D/A (digital to analog) converter. A summing amplifier can serve this purpose. A four-bit D/A converter is drawn in Fig. 14. For simplicity, assume the digital word generator has zero output impedance for both logic levels. If the data input is 0000, the op amp's output is zero, because all of the inputs are grounded. Incrementing the word generator to 0001 applies a positive 1-volt level to the least significant bit (LSB) of the converter. The gain for this input is 8k/8k or unity, so our output is negative 1 volt. An input of 1001 is BCD (binary-coded decimal) nine. One volt applied to the most significant bit (MSB) will cause an output of negative 8 volts, because that input channel has a gain of eight. The LSB input resistor also has a current, and the current in the feedback resistor is the sum of the two input currents. The LSB input caused an output of negative one volt, so the op amp's output will be negative 9 volts. The gain of the MSB channel is eight times that of the LSB channel because the MSB has eight times the numerical weight of the LSB. If the input word were 1111 (hexadecimal F or decimal 15) you'd get an output of negative 15 volts, right? Wrong! Look at the diagram again — the negative power supply is only 12 volts. Most op amps can't generate output voltages closer than about 2 volts from either supply, so we'll have to be content with a BCD converter. Naturally, if we want the output to go *positive* with increasing input numbers, we'd use an inverting op amp after the

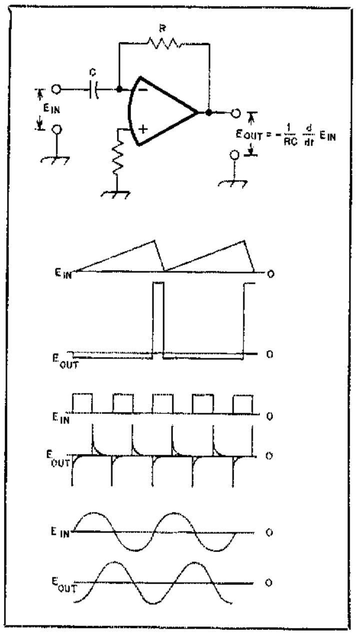


Fig. 15 — A differentiator circuit with its transfer equation. The d/dt notation is from the calculus, where the derivative of a function can be expressed as the ratio of two differentials (increments, or small changes). Typical input and output waveforms are also given. Transposing the resistor and capacitor transforms the circuit into an integrator (see text).

converter.

Early in Part 1 I promised to talk about differentiators and integrators. Differentiation and integration are the fundamental operations of the calculus. When a voltage varies with time, we say that the voltage is a *function* of time. How fast the voltage changes with time is called the *slope* or *rate of change* of the function. When we discussed slew rate, we were really talking about the slope of the output function. An expression defining the instantaneous slope of a function for any given point is called a *derivative*. The process of finding a derivative is called *differentiation*. An electrical differentiator, then, is a circuit whose output voltage is proportional to the instantaneous rate of change of the input voltage.

If the input resistor of an inverting amplifier is replaced by a capacitor, as in Fig. 15, a differentiator results. Several input and output waveforms are sketched in the figure. The first input signal is a linear ramp. As the name implies, the voltage increases with time at a constant rate. While the input voltage is rising, the output voltage is constant. When the input voltage peaks and starts to decline, the output voltage reverses polarity and assumes a constant voltage proportional to the new (steeper) slope.

A square-wave input produces an output that looks very different. The rising edges of the input signal have a near-infinite slope, so the op amp puts out its largest possible voltage. The flat portion of the square wave does not vary with time; its slope is zero. During this period the differentiator's output decays quickly to zero.

When the input signal is a sine wave, the output is also a sine wave, but displaced in phase (time). The derivative of the sine function is the cosine. Since our differentiator is an inverting circuit, the output function is minus cosine, which is the same as a sine wave advanced 270 degrees or retarded 90 degrees. Without a mathematical derivation, you can rationalize the transfer function by analyzing the curves at a few critical points. The input slope is steepest where the curve crosses zero, and it is at this point that the output curve has the greatest amplitude. When the input sine wave peaks and begins to decline, its slope is zero, as dutifully indicated by the differentiated output.

A differentiator has one other characteristic — it's a high-pass filter. It's easy to see why this is so. As the input frequency increases, the reactance (ac resistance) of the capacitor decreases. If you think of the capacitor as the input resistor of an inverting amplifier, you can see that the circuit gain will double every time the input frequency doubles. For this reason, differentiators are sometimes jokingly called "wide-band noise generators."

Analog computers use differentiators to solve mathematical and physical problems involving the calculus. In most electronic applications, the op-amp differentiator serves simply as an edge detector for the generation of timing, triggering and synchronizing pulses.

The inverse of differentiation is *integration*. If we interchange R and C in Fig. 15, our circuit becomes an integrator. The output is the *antiderivative* of the input. If the input signal is a derivative, the integrator tells us what function the input is a derivative *of*. The mathematical expression for the integrator's transfer function is

$$E_{out} = \frac{-1}{RC}\int_{t_1}^{t_2} E_{in}\, dt.$$

In words, we say the output voltage is proportional to the definite integral of the input voltage as a function of time, evaluated over the time interval t_1 to t_2, divided by the RC product. To see how the input and output waveforms are related, just swap the input and output labels on the waveforms in Fig. 15.

As you might suspect, an integrator is a first-order low-pass filter, having an attenuation slope of 6 dB per octave. Aside from its obvious mathematical application, the integrator finds use in ramp generators, frequency-to-voltage converters, duty-cycle detectors, and so forth. Although integrators and differentiators are active filters, other op-amp circuits can provide much more impressive attenuation slopes. Active filters will be treated in a future *QST* article.

Nonlinear Feedback

Our op-amp circuits thus far have had only linear elements (resistors and capacitors) in the feedback loop. A wide variety of transfer functions is possible if we insert nonlinear devices in the feedback path. What's a nonlinear device? One that doesn't strictly obey Ohm's law. The most common nonlinear device is the junction diode. Junction diodes are useful as rectifiers, but at low signal levels the conduction threshold causes severe distortion and loss. We can "linearize" a diode by inserting it in the feedback path of an op amp. The "perfect rectifier" circuit shown in Fig. 16A is an example of this technique. When the input voltage is zero, the output voltage is also zero, give or take some offset. If the input signal goes slightly negative, the output will swing sharply positive. The op amp runs open loop until the IC output voltage reaches the conduction threshold of D2 (about 0.6 volt). From this point on, the circuit's output voltage (at the D2 cathode) is a linear function of the input voltage. The closed-loop condition forces the current in D2 and R_f to equal that in R_i. Since the output voltage is taken between R_f and ground (equivalent to the voltage *across* R_f), the output waveform will be a faithful reproduction of half the input cycle. Of course the current in D2 is still a nonlinear function of the voltage across it (and its temperature), and this characteristic can be seen at the IC output terminal. Positive excursions of the input voltage cause the op amp to output a negative voltage, which biases D2 out of conduction. D1 conducts when the input is positive, closing the feedback loop. A closed loop keeps the summing junction at virtual ground, providing a constant load for the input signal.

Several circuits exist to produce linear full-wave rectification. These are sometimes called *absolute value generators*. The absolute value of a number is the difference between that number and zero. For example, the absolute value of two is two, and the absolute value of negative two is also two. The simplest absolute value generator I've seen is illustrated in Fig. 16B. It isn't "perfect" because the output can go slightly negative. That condition could be rectified (no pun intented) by means of a small bias voltage on the diode's anode —

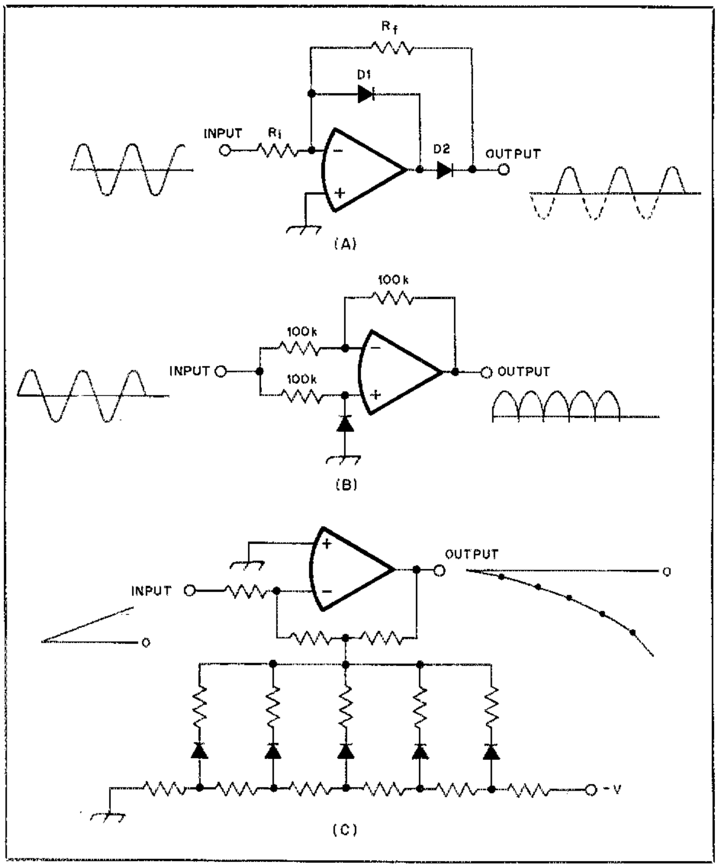


Fig. 16 — (A) Op amp used as a half-wave rectifier or "perfect diode." (B) Simple electronic full-wave rectifier or absolute-value generator. (C) Piece-wise linear approximation of a nonlinear function by means of a shaping network. The break points are set by the voltage divider taps, and the slope between break points is determined by the resistor values in series with the diodes.

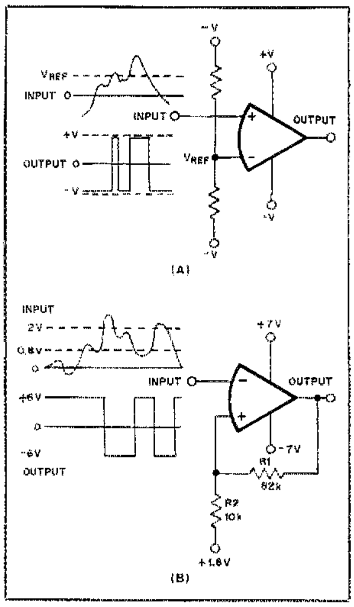


Fig. 17 — (A) Differential voltage comparator. Either inverting or noninverting circuits may be used. (B) Schmitt trigger. The constants shown here are suitable for connecting +5-V TTL to ±7-V CMOS logic.

it's the old trade-off between simplicity and performance. I leave the exact analysis of this circuit as an exercise for the reader.

Fig. 16C shows a method for synthesizing a nonlinear output function from a linear ramp. The feedback resistance is split into two parts. Notice that the anodes of the diodes are tapped along a voltage divider string. The resistance of the divider should be low compared to the feedback resistors. A positive input ramp causes the op amp's output to go negative. As soon as the output voltage forward biases one of the diodes, part of the feedback current gets shunted to ground. In order to satisfy Kirchhoff's current law (equal currents in and out of the summing junction), the output voltage must increase. This means the gain, and therefore the slope, of the output function must increase. If we continue to increase the input voltage, more diodes will be forward biased, raising the gain still higher. Shaping a curve this way is known as *piece-wise linear approximation*. One application for this circuit is in a microwave sweep generator using a varactor-tuned oscillator. As you tune such an oscillator higher in frequency, it takes more and more voltage to obtain a constant frequency increase. A shaping network like that of Fig. 16C allows the oscillator frequency to be calibrated on a linear scale. There are more examples of nonlinear feedback circuits, but it's time to move on.

Op Amps as Switches

Op amps aren't always used with negative feedback. An open-loop implementation is given in Fig. 17A. This circuit is a *comparator*. One input terminal is connected to a fixed reference voltage. When the signal applied to the other terminal crosses the reference voltage, the op amp output swings very quickly to its maximum value, usually near the power supply voltages. The circuit in Fig. 17A is a noninverting configuration. If the signal voltage is more positive than the reference voltage, the output voltage will rest near the positive supply. If the signal becomes negative with respect to the reference, the output will hover near the negative supply. Grounding the reference terminal transforms the circuit into a zero-crossing detector. The existence of essentially two output states immediately suggests digital applications. An array of comparators having different thresholds combined with appropriate logic can form one type of A/D (analog-to-digital) converter. I should point out that digital logic systems can be implemented with standard negative-feedback op-amp circuits, but there is usually little point in doing this.

Introducing *positive* feedback to a comparator helps to speed up the output transition from one state to another, giving the circuit real "snap" action. The circuit of Fig. 17B is a useful application of this principle. To understand its operation, assume the inverting input is driven to zero volts. This is clearly below the threshold voltage, so the op amp output voltage rests near the positive rail — let's say the output is 6 volts. Since the op amp input impedance is very high compared to R1 and R2, we can compute the voltage at the noninverting terminal from the divide ratio. With the 6-volt output potential at one end of the R1-R2 divider and the 1.6-volt reference at the other, the junction potential is just about 2 volts. This means the input signal must exceed 2 volts to flip the output to the low state. Once the output is low, say minus 6 volts, the noninverting input terminal will see about 0.8 volt. *Pulling the input level down to the previous 2-volt threshold won't make the op amp revert to the high state* — we have to provide an input more negative than 0.8 volt to cause a transition.

This inertia effect is called *hysteresis.* You may encounter that term when you study electromagnetism — the meaning is similar. A comparator with hysteresis is a *Schmitt trigger.* The noise immunity provided by a Schmitt trigger gives it great utility as a *line receiver* — a circuit used to restore digital pulses which have been degraded by a long transmission line. The 0.8- and 2-volt trigger levels in our example provide maximum noise immunity for TTL (transistor-transistor logic) inputs. These voltages are the maximum low and minimum high output levels guaranteed for TTL gates. The output states in our example are ideal for driving CMOS (complementary-symmetry metal-oxide semiconductor) logic systems using plus and minus 7-volt power supplies. It is a simple matter to clamp the output voltages to any desired levels by means of diodes.

Wrapping Up

There's much more to the op-amp story than we have space for in this article. Semiconductor technology is advancing rapidly, and new applications will emerge as improved devices become available. In this article I haven't surveyed the op amps on today's market. Each semiconductor manufacturer publishes a "selector guide" in his catalog of linear integrated circuits, and every serious builder or experimenter should make the effort to obtain these books.

Once you understand the principles outlined in this article, you will probably invent your own applications for op amps. When you determine your device requirements, choose an op amp from what's available at your local hobby electronics store or from mail order firms. Operational amplifiers can't replace discrete transistors (or tubes!) in *every* application, but in many cases the "black box" approach with its "cookbook" methods for gain selection and impedance matching can make your electronics hobby simpler, less frustrating and more fun.

Strays

HAM HOOKUP — TEXAS TO NICARAGUA

☐ Living in Bonanza, Nicaragua, a small mining town in the northeastern part of the country, and being licensed as YN4KLB, I thought that Amateur Radio was a wonderful way to talk to my daughter. We have no telephone service in Bonanza and mail from the U.S. takes about two weeks. I was delighted to get in touch with a willing ham, Glen Hallmark, W5AUT, in College Station, Texas, where my daughter, Kathryn, was attending a university. Certainly neither Glen nor I could have imagined that our weekly contacts would become daily contacts, and that they would be our only means of communication for over three months.

Because of our isolation, we felt quite safe from the disturbances that were taking place elsewhere in Nicaragua. We scoffed at rumors that guerrillas were camped in the jungle nearby. Surely they would not bother our insignificant little village. All that changed last spring! Our little village was attacked by Sandinista guerrillas and a battle raged right at our doorsteps. The *Comandancia* (headquarters for the Guardia Nacional) was burned and the Guardia took to the hills. That night the Sandinistas buried their dead and left. The next day a contingent of Guardia was flown in and the red and black flag of the Sandinistas was taken down and the Nicaraguan flag went up again. In the days that followed, those flags went up and down so many times that we lost count. One day we would be under Sandinista control, the next day the Guardia would be back. As foreigners working for an American company, we tried to maintain a neutral position. We cooperated with whoever was in control — or, you might say, with whoever had the guns.

After the raid here and the one in the neighboring town of Rosita made international news, our first concern was to let the families of the foreign staff know that we were alright. Our first thought was of W5AUT. After we contacted him, he notified our families in the U.S. and Canada, and offered to keep in daily contact with us for anything we might need. As it turned out, our need became acute. During one of the guerrilla raids the radiotelegraph facilities at the local airport were destroyed and regular mail and supply flights were stopped. This left the ham radio arrangement with W5AUT as our only means of communication. We had no food and no way of getting any. A few ordinary circumstances became important — a pregnant woman needed a cesarean section and a diabetic needed insulin. We unloaded all our problems on W5AUT. Soon our families realized that there was no other way to learn news of us, and they began keeping in touch with Glen by phone from various places in the U.S. and Canada. He gave news and reassurance and was able to tell them that he was in daily contact with us. Meanwhile in Nicarauga, we were having a series of very tense situations and emergencies. It got to the point that the highlight of each day was the radio contact between YN4KLB and W5AUT. This usually brought news of our families and a few words of hope and encouragement for us. Through W5AUT we were able to get medical supplies for our expectant mother, insulin for the diabetic, and a sick woman was able to get out by private plane. Each of the situations that Glen handled for us is a story in itself.

The war is over — the Sandinistas are in control — both flags are flying these days. The reconstruction period is difficult, but the danger is past. We have rather erratic mail service but still have no radiotelegraph facilities or air service, and the future is uncertain.

We certainly hope that our friend, W5AUT, hasn't developed an ulcer from all the problems that we have dumped on him. He assures us that it's "all in a day's work" and that he has done no more than would be done by another ham under similar circumstances.

Once again, I am back to a weekly chat with my daughter, but now with a renewed respect for the dedicated men and women who devote so much of their time to helping others. My thanks to all of you, and please keep up the good work. — *Kathryn L. Byrd, YN4KLB*

A Two-Band Half-Sloper Antenna

When an off-the-wall empirical design like this works well, suspicion and skepticism are warranted. Maybe you'll agree that this sloper idea is an exception!

By Gary E. Myers,* K9CZB

The popularity of the half-sloper antenna seems to be increasing, as evidenced by recent articles in *QST*.[1,2,3] This type of antenna has some worthwhile advantages, particularly for the lower frequency operator — low-angle radiation for antennas of modest height, compactness and simplicity of construction. On the minus side, narrow bandwidths and difficulties in resonating the system have been reported.[3]

The antenna system to be described here evolved from a simple-minded attempt to design a two-band half sloper for 80- and 40-meter operation. A trap-type of antenna was selected as the design basis because of previous experience with trap antennas and because the inductive loading of the trap on the lower-frequency band allows a somewhat shorter overall length. The same inductive loading, however, was also expected to increase the antenna Q and thereby further decrease the bandwidth. For this reason I was prepared to experiment.

It is well that I was so prepared because the final form of the antenna bears little resemblance to the initial concept. But most interesting — and exciting — is the impressive bandwidth on 80 meters.

The Design

A diagram of the two-band half-sloper antenna system is shown in Fig. 1. It can be seen that there is no obvious quarter-wave dimension in the entire system. In fact, the radiator itself is a nonresonant device.

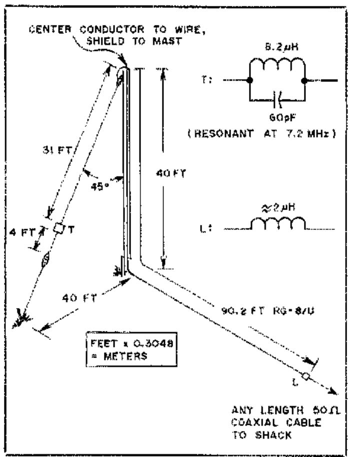


Fig. 1 — The two-band half sloper. To shield the transmission line from the antenna field, the line is routed up the inside of the support mast, which is grounded. Inductor L is needed to resonate the system.

Initial attempts to prune the wires to resonance resulted only in a mound of wire clippings and one frustrated amateur. After many hours of cut-and-try experimentation, accompanied by a growing, gut-level appreciation for what apparently was happening, the magic combination of wire lengths and trap component values was found. Impedances of 40 − j80 ohms at 7.2 MHz and 60 − j40 ohms at 3.6 MHz were measured with a noise bridge. It was then a simple matter to cancel out these capacitive reactances with an inductor.

For convenience, the inductor was placed in the transmission line, rather than at the feed point — final "tweaking" of the system is more easily performed on the ground than at 40 feet (12.2 m) in the air. A Smith Chart exercise shows that the SWR on the transmission line between the feed point and inductor L is 5:1 at 7.2 MHz and 2:1 at 3.6 MHz. When RG-8/U is used, the additional loss incurred because of these SWRs is less than 0.5 dB at 7.2 MHz and is almost nonexistent at 3.6 MHz.

Performance

This antenna performs very well. Operation at K9CZB is primarily 80-meter cw, with some 40-meter ssb. Power output is nominally 100 watts. Signal reports on 80 have been uniformly good, with comments such as U R LOUDEST 9 ON BAND and VY FB SIG, VY STRONG. Voice operation on 40 has also resulted in good signal reports, although the praise has not been so lavish. This is my only 80/40-meter antenna, so direct comparisons were not possible. However, it appears to greatly outperform two previous antennas, a

*28-W-135 Hillview Dr., Naperville, IL 60540
[1]Notes appear on page 35.

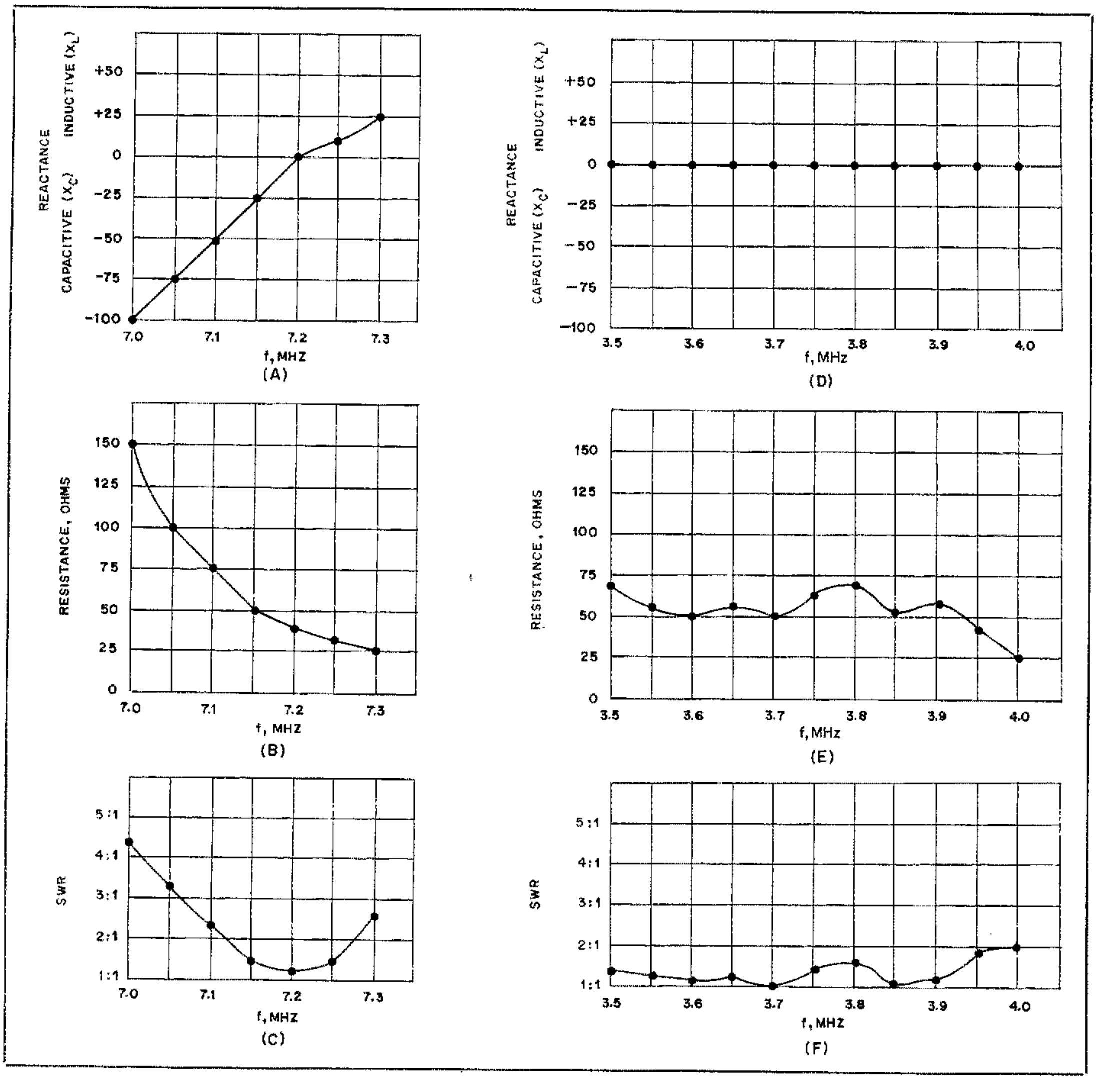


Fig. 2 — Loading characteristics of the antenna. The SWR curves were determined from a Smith Chart. Impedance values were measured with a noise bridge.

160-foot (48.8 m) end-fed wire and a trap dipole, both strung 30 feet (9.1 m) above ground. All in all, it is about what I expected from a half sloper.

This kind of performance is nice, but nothing to write an article about, since that has already been done. The real performance story about this antenna can be summed up in one word: bandwidth. A glance at the SWR curves in Fig. 2 will open the eyes of any 80-meter operator. As far as I know, this is unheard-of bandwidth for such a simple and compact antenna. It is a real treat to QSY 400 kHz and see the SWR meter needle barely move. This isn't a low-Q antenna — it's a *no*-Q antenna! The bandwidth on 40 is far less impressive and is, in fact, similar to what has been reported previously for half slopers.

Construction

During experiments with prototypes of this antenna, I noticed some sensitivity to feed-line placement and length. Therefore, in later versions I ran the feed line up the *inside* of the support mast to shield it from the antenna field. This precaution seems to be effective, for no such sensitivity has been observed since. (I can't help but wonder if this might improve the behavior of any cantankerous half sloper.) If a nonmetallic support is used, or if there is no possibility of placing the feed line inside the support, double-shielded coaxial cable should serve equally well, provided the outer braid is connected to the inner braid at the top of the tower and a ground is connected to the outer braid at the bottom of the tower.

I used standard 10-foot (3.05-m) TV mast sections for my support, simply because they were on hand. This results in a very flimsy and flexible mast in a 40-foot length, though. The first 20 feet must be

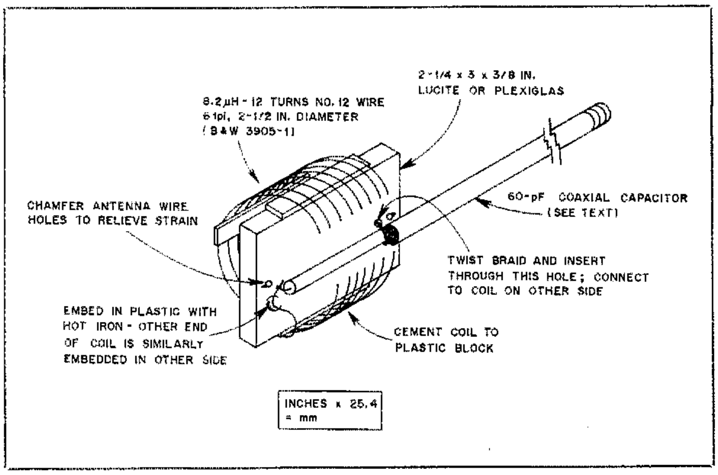


Fig. 3 — A simple, sturdy trap. The coaxial capacitor should be taped to the antenna wire after installation. It is not necessary to enclose the trap.

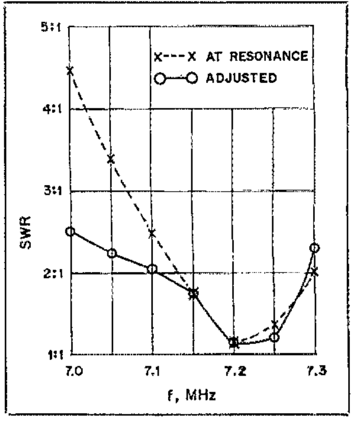


Fig. 4 — SWR curve for 40 meters, showing the effect of tapping L and adjusting feed-line length between L and the transmitter to obtain the best SWR curve. Such adjustments have little effect on 80-meter characteristics.

doubled up with long U-bolts if the mast is to be walked up. The price of six sections of TV mast is about the same as a 36-foot (11-m) telescoping push-up mast, but the latter is much sturdier and far easier to erect. If support materials are not already on hand, the telescoping mast is the better choice. I should mention that I took the trouble to bond all sections of mast together electrically to ensure good conductivity and to guard against TVI from rectification at joints after inevitable corrosion sets in. The base of the mast should be grounded. Effects from the guy wires can largely be avoided by breaking them into nonresonant lengths with strain insulators placed at the mast and every 19 feet thereafter.

The inductance and capacitance values shown in Fig. 1 must be used for the trap. Construction techniques for the trap are covered in *The ARRL Antenna Book*.[4] A novel and inexpensive method of trap construction has been described by WB9OQM.[5] I built my trap using the method shown in Fig. 3. Traps made in this fashion are much stronger than they appear. I've never had one break, even in high winds that caused property damage. In this antenna, however, the radiator also serves as one of the top guys. For that reason the trap was reinforced. Two 3/16-inch (4.8-mm) thick pieces of plastic were used with three layers of glass cloth and epoxy sandwiched between them. A rotary wire brush serves well to rough up the inner surfaces of the plastic to ensure good adhesion. However, one may use coarse sandpaper for that purpose. Glass cloth and epoxy are sold as a repair kit in many hardware stores.

Before the antenna wires are connected, the trap must be tuned to resonance. A dip meter or noise bridge can be used to measure the resonant frequency. Start with about 30 inches (762 mm) of RG-8/U for the coaxial capacitor. After connecting it to the coil, as shown, 26 or 27 inches (660 or 686 mm) of braid will remain. At this point, the resonant frequency should be below 7.0 MHz. Trim the braid at the far end, a little at a time, snipping off the center conductor as you go. Recheck the resonant frequency each time. As 7.2 MHz is approached, continue trimming the braid, but stop cutting the center conductor. To increase the leakage path, the polyethylene dielectric should extend beyond the braid 1/8 to 3/16 inch (3.2 to 4.8 mm) when the trap is resonated at 7.2 MHz. Very close to 24 inches (610 mm) of braid should remain at completion. Tightly tape this end with several layers of plastic electrical tape.

The component values for this trap are exactly the same as those used in the W3DZZ trap dipole,[4] so there are several commercially made traps that may be suitable for this antenna. Traps made for a five-band, two-trap dipole, 108 feet (32.9 m) long should have the proper values of capacitance and inductance.

In any antenna system, the radiator feed point impedance repeats itself every half wavelength along the transmission line. Inductor L must be inserted in the transmission line at a half-wave point in order to exactly cancel the capacitive reactance of this antenna system. It is, of course, advantageous to place L as close to the feed point as possible in order to minimize losses. A half wavelength at the lower frequency is as close as you can get without going to the feed point itself. The 90.2-foot (28-m) length of RG-8/U shown in Fig. 1 is an electrical half wavelength at 3.6 MHz for solid polyethylene dielectric coaxial cable *only*. If cable having a velocity factor other than 0.66 (e.g., foam-dielectric coaxial cable) is used, this length will have to be recalculated from the equation

$\ell = 492\ V/3.6$ feet

(Feet $\times$ 0.305 = m)

In this equation, V is the velocity factor of the cable to be used. Only RG-8/U or a similar type such as RG-213/U should be employed for this section of the transmission line in order to keep the losses low. If you don't mind a dB or so of loss on 40 meters, RG-58/U is acceptable. The loss on 80 meters will be negligible in any case.

The value of inductor L should be 1.75 μH, but I recommend that a coil having about 3-μH inductance be used to allow some latitude for final tune-up of the system. I mounted 12 turns of a no. 3018 Miniductor (1-1/4 inch or 32 mm in diameter, 8 turns per inch or every 25 mm) in a small Minibox with SO-239 coaxial connectors placed at each end. After tapping the coil for the best SWR curve on 40 meters, the entire assembly was sealed and waterproofed with bathtub caulk.

Tune-up

As seems to be characteristic of half slopers, this antenna can be very touchy to tune up. If the length of transmission line between the radiator and L is not an exact integral multiple of a half wavelength at 3.6 MHz, tune-up can be a real "can of worms." Since the oft-quoted value of 0.66 for the velocity factor of standard RG-8/U is only a nominal value and can vary appreciably from brand to brand (in cheap cable from lot to lot), this length should be determined with a noise bridge.

If a noise bridge is not available, the following procedure may be tried. Cut this section of cable about 6 feet (1.8 m) shorter than the calculated length. Prepare a section of RG-58/U, 12 feet long, with solderless connectors on each end. Connect it to both the shortened feed line, using a PL-258 double female connector, and to L. Tap L to obtain the best combination of SWRs at 3.6 and 7.2 MHz. Record the SWR figures and tap position.

Now shorten the RG-58/U by 6 inches and repeat — and repeat — until you are certain you have passed through the point where the SWR values simultaneously bottom out at both frequencies. Prepare a length of RG-58/U (from the same lot) exactly as long as the best experimental length, using permanent coaxial connectors. Seal and waterproof all connections. RG-58/U is recommended for relative ease of pruning. If you don't mind unsoldering a PL-259 each time, RG-8 could be used. However, the additional loss from such a short section of RG-58/U will be infinitesimal at these frequencies.

This procedure is obviously tedious, but it is necessary to obtain good performance on 40 if a noise bridge is not available.[6] In fact, some adjustment of this section of transmission line may be necessary even if a noise bridge is used to measure the electrical length to obtain optimum two-band performance. The exact half wavelength should always be used as a starting point, in any case.

Strangely enough, the above procedures are necessary only to optimize 40-meter performance. My experience has been that merely cutting the half-wavelength section of transmission line to the calculated length, then tapping L to obtain the best SWR at 3.6 MHz, is sufficient to obtain a ratio of 2:1 or less over the entire 80/75-meter band. So tune for 40, and 80 should take care of itself.

Once the antenna system has been resonated, it may pay to experiment with the value of L and the length of transmission line between L and the transmitter. Changing these values will change the shape of the 40-meter SWR curve somewhat. By so experimenting, you may be able to tailor the shape of the 40-meter SWR curve to your operating preference. Don't expect miracles, though, for the range of adjustment seems to be small. Fig. 4 illustrates the results of such an effort. These adjustments will have very little effect on 80-meter bandwidth within the range of acceptable SWR on 40 meters.

Further Thoughts

The first prototype was constructed close to my house, and I was therefore concerned that the performance might not be reproducible. The next prototype was erected in a far corner of my yard, over 100 feet from the house and even farther from any other structures or conductors. The final version was similarly located. Except for final tune-up parameters, all three behaved almost identically, even though a number of physical changes was made each time. As a final test of the soundness of the design, I built scaled versions for 40/20 and 20/10 meters. They exhibited very similar characteristics, although all parameters of the system seem to become very critical as the design frequency is increased.

The first two 80/40-meter systems were built using a 30-foot (9.1-m) mast, yet their behavior was not markedly different from the final version with a 40-foot (12.1-m) mast. Since the mast is an electrical part of the system, and since proximity to ground must play some role in the performance of the antenna, other heights, and supports that have beams attached, may yield different results.

The reactance of the trap at 3.6 MHz is 245 ohms. Therefore, there is a possibility of constructing an 80-meter-only version of this antenna by using a 10.8-μH inductor in place of the trap. This has not been tried, however.

Scaling up to 160/80 meters is an attractive possibility. Conceivably, a mast height as low as 50 feet (15.2 m) could be used. A starting point would be the doubling of all wire lengths, and using a 16.4-μH coil with a 120-pF capacitor for the trap to preserve the 245-ohms reactance at 1.8 MHz.

There also seems to be a possibility that a slight increase in trap capacitor value, to resonate the tap at 7.1 or 7.15 MHz, might allow better coverage of 40 cw, but probably at the expense of the phone portion of the band. Such a change might have little effect on 80-meter bandwidth, but another round of cut-and-try could prove necessary.

Conclusions

At this point, this is still an experimental design. Further development may eventually allow a cut-to-formula type of construction, but until that happens, be prepared to experiment. The dimensions given in Fig. 1 will put you in the ball park and should yield immediate results on 80.

The convenience of Transmatchless operation over all of 80/75, plus a reasonable portion of 40, coupled with an excellent radiated signal, is ample repayment even for many hours of cutting and trying. Once tuned up, this antenna is very well behaved and enjoyable to use. I would like to hear from others who construct antennas based on this design. QST

Notes

[1] Hopps, "A 75-Meter DX Antenna," *QST*, March 1979, p. 44.
[2] Atchley, "Putting the Quarter-Wave Sloper to Work on 160," *QST*, July 1979, p. 19.
[3] DeMaw, "Additional Notes on the Half Sloper," *QST*, July 1979, p. 20.
[4] *The ARRL Antenna Book*, 13th edition, 1974.
[5] Mathison, "Inexpensive Traps for Wire Antennas," *QST*, February 1977.
[6] [Editor's Note: A third alternative is to use a dip meter to determine an exact half wavelength of line. See Downs, "Measuring Transmission-Line Velocity Factor," *QST*, June 1979.]

Strays

I would like to get in touch with . . .

☐ amateurs with 2-meter gear to assist with the 1980 New York Special Olympics, to be held Friday, Saturday and Sunday, June 13-15, at Elmira, NY. Many amateurs are needed at the site. About 10,000 visitors from all over the U.S. are expected for the weekend. Contact Hal Mandel, WB2FSX, c/o NY State Special Olympics, 307 East Church St., Elmira, NY 14901, tel. 607-733-7359, evenings.

SISTER CITIES — INTERNATIONAL FRIENDSHIP THROUGH AMATEUR RADIO

☐ What do Fukaya City, Japan, and Fremont, California, have in common? Both cities were organized from five smaller cities; have dynamic growth-oriented, youthful leadership; have a Route 17 nearby; are semi-agricultural communities specializing in commercially grown flowers; and have residents that are interested in Amateur Radio.

Bob McGihon, WB6DMB, of Fremont, has had regular contacts with Tak, JK1OFI, and Akko Ohata, JK1OFH, of Fukaya City. Recently, Tak, speaking for his city's mayor, asked McGihon if Fremont would like to become Fukaya City's sister city. Several members of Fremont's South Bay Amateur Radio Association (SBARA) worked with the Sister City Committee of Fremont to make the necessary arrangements.

The result? Mr. Ohata was the guest of honor at the January Grand Ball, held at the Castlewood Country Club, in Pleasanton, California, to celebrate the union of the two cities. Nightly 0200 UTC contacts keep hams from the sister cities in touch with each other. — *submitted by Jane D. Bell, WD6GKN*

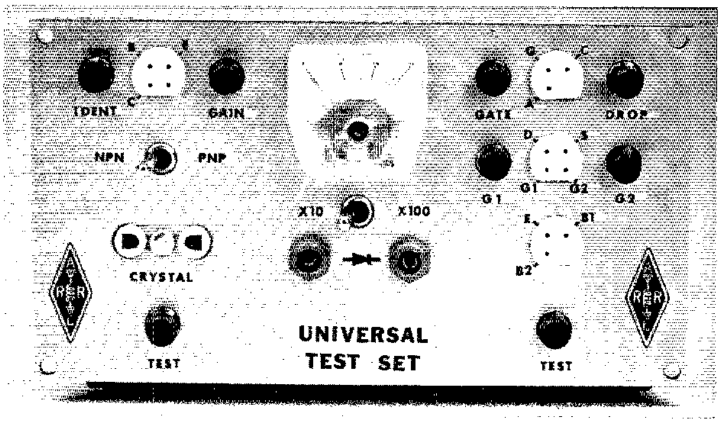
Dr. Walter Hashimoto (left) carried official "sister city" papers from Fremont, California to the sister city, Fukaya City, Japan. Bob McGihon, WB6DMB, helps friends in the sister cities keep in touch with each other through Amateur Radio. *(photo by Dino Vournas)*

• *Basic Amateur Radio*

The Checkerboard Checker

Have you ever looked at a transistor and wondered if it was good? Have you puzzled for hours over the polarity of a diode? Here is a simple, inexpensive project that will help you answer these questions and more!

By Peter O'Dell,* AE8Q and Robert D. Shriner,** WAØUZO



The absence of mounting nuts gives the front of the test set a "clean" look.

After coauthor O'Dell had been working in a two-way shop for about a month, the manager walked over to him, took a $2000 mobile radio unit out of his hand and hurled it about 12 feet through the air to the test bench. When the new, expensive radio hit, it bounced about 6 inches in the air and finally came to rest atop a roll of solder. Astonished, O'Dell looked at his boss with disbelief. The manager said, "The worst that can happen is that it will break. Big deal; then we'd have to fix it. That's what we do here. You hams are too gentle with your equipment."

What do you do when your equipment breaks? Do you troubleshoot and fix it yourself? Or do you let someone else do it for you, or throw away the equipment and buy new? If you answered yes to the last question, then we have another question for you: why? Being psychic, we know that most of you said the reason that you don't troubleshoot and repair it yourself is that you don't know how to test a component to tell if it is good or bad. Those few of you who said that you don't repair your own equipment because you've got too much money and don't know what to do with it, please contact us for details on obtaining your very own, personal bridge connecting two of New York City's finest boroughs.

In the olden days of tubes, a backyard technician could look at a tube to see if the filament was glowing. If not, the tube was definitely bad. If the filament was glowing, but the tube was still suspect, he could run down to the corner drug store and plug the tube into a "tube tester." With these simple machines he could determine if a tube was definitely bad or probably good. The final test was to substitute a known good tube for the suspect. We have yet to find a drug store that has a "transistor checker" installed, and you can't look at the filament of a transistor to see if it is glowing because the transistor doesn't have one. (If you've got a transistor that is so warm that it is glowing, chances are that it is defective.)

*Basic Radio Editor, ARRL
**Box 969, Pueblo, CO 81002

Return With Us to Yesteryear, Almost

Those of you who yearn for the simpler days take note. This month's project is a simple "checker" that you can use to test most discrete solid-state devices. We dubbed it the "Checkerboard Checker," because it is built on the Universal Breadboard with its checkerboard pattern. Since all the tests, except that for crystals, are done at dc levels, an occasional device that tests "good" may, in fact, be "bad" for the circuit that you want to use it in. In our experience, this should happen in no more than 2 percent of the cases.

The schematic diagram for the test set is given in Fig. 1. If you look closely at the diagram, you will note that it really is six different circuits wired in parallel to the meter and BT1. The simplest of these circuits is J2 (A and B), which is used to test

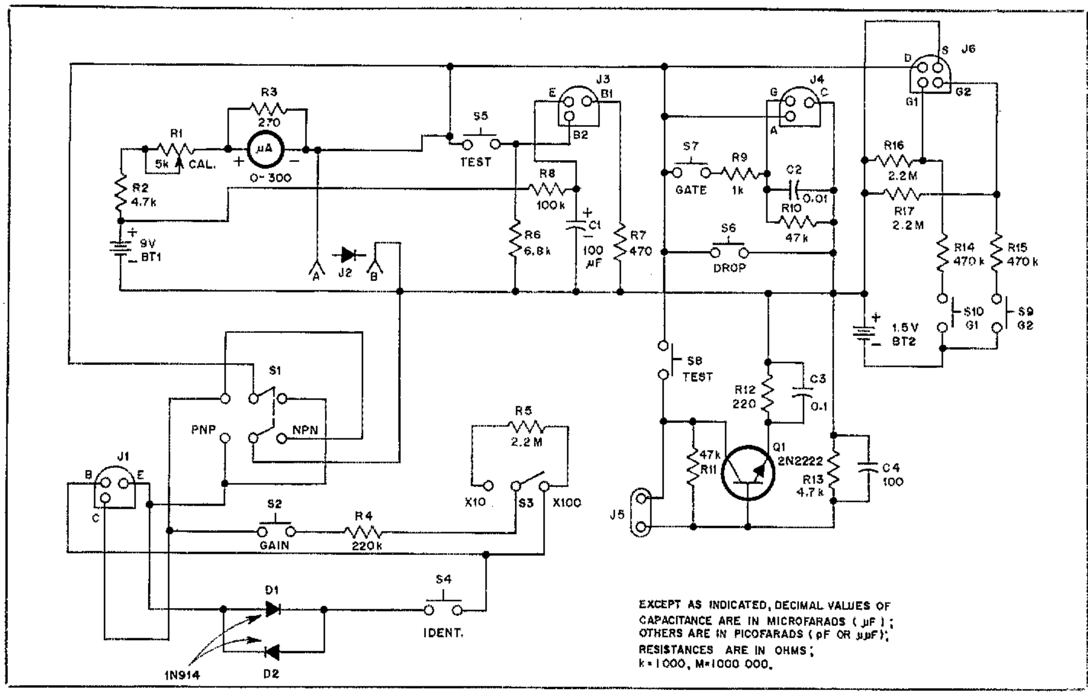


Fig. 1 — Schematic of test set. All capacitors are disc ceramic, except those with marked polarity. Fixed-value resistors are carbon composition, 1/2-watt or less. Sockets are depicted as viewed from the front of the panel. Part numbers inside parentheses are Radio Shack parts suitable for use in this circuit.

C1 — 100 μF, 10V tantalum.
C2-C4 — Numbered for text discussion and parts-placement purposes.
D1, D2 — 1N914 or equiv.
J1, J3, J4, J6 — transistor socket (Radio Shack 276-548 or other transistor sockets are suitable, but may require innovative mounting techniques).
J2 — 2 phone tip jacks (one each for A and B).
J5 — Crystal socket.
M1 — 300 μA.
R1 — 5-kΩ, thumbwheel pot (271-217).
R2-R17, incl. — Numbered for text discussion and parts-placement purposes.
S1 — Dpdt, (275-614).
S2, S4-S10, incl. — spst, momentary contact (275-1547).
S3 — Spdt (275-613).
Miscellaneous — hardware, solder, 1.5-V AA penlight cell, 9-V transistor-radio battery, battery holders.

diodes; with an auxiliary set of test probes, it can be used to test for continuity.

The components near J1 are used to check bipolar transistors. S1 is used to reverse the polarity on J1, thereby enabling the user to check both pnp and npn transistors. D1 and D2 are used to fix bias on the base at 0.7 V which permits the user to differentiate between silicon and germanium transistors. The components near J3 permit you to check the performance of a unijunction transistor in an oscillator circuit.

J5 and its associated components provide a convenient method of testing crystals. It is similar to the oscillator circuit that was used in the Universal Transmitter.[1] Notice that BT2 is used only with the circuit at J6. BT2 is wired in such a way that it provides cutoff bias for the gates of FETs.

The user is able to test small SCRs with the circuit near J4. By small, we mean those rated at 1 ampere or less. We tried checking the more common, larger (6- to 8-ampere) variety on the tester, but the results were not satisfactory. While the GATE switch, S7, was being held closed, the SCR fired; however, when the GATE switch was opened the SCR ceased to conduct, even though there still existed a voltage potential across the anode and cathode. We assume that the low current level, limited by the value of the resistors and the potential of the supply, is below the threshold of the SCRs. If you need a circuit for checking larger SCRs, you could devise one along these lines, (but with a higher voltage supply, larger wattage and, perhaps, different-value resistors).

Construction is straightforward.[2] In Fig. 2 we show the Universal Breadboard[3] and the rear view of the front panel. These boards are depicted side-by-side, even though they are mounted perpendicular to each other. Some new ideas were used in the construction of the prototype unit shown in the photographs. Notice that no mounting nuts are visible in the front view of the unit.

After making sure that each switch will fit through the hole provided for it, remove the nut from the first switch to be mounted. Place the nut over the appropriate hole *on the back side of the panel.* From the front side, insert an ordinary wooden pencil (sharpened) into the hole and screw it into the nut until it is tight. This should hold the nut in place while it is soldered to the backside of the panel. In some cases, it maybe be necessary to use an abrasive to "rough up" the surface of the nut to get it to take solder. Once the board is cool to touch, the switch may be screwed into the nut from the rear of the panel. When the switch is properly positioned, apply fast-setting epoxy cement to the shaft and nut, taking care to avoid getting any cement where it will interfere with the workings of the switch. Repeat this process for the other switches.

This style of construction will provide a front panel that is free of mounting nuts, resulting in a "cleaner" look. Like most of the other construction practices used in this series, there is nothing sacred about these procedures. If the builder is in a hurry or doesn't like the looks of this style, mounting the switches in the normal

[1]Notes appear on page 39.

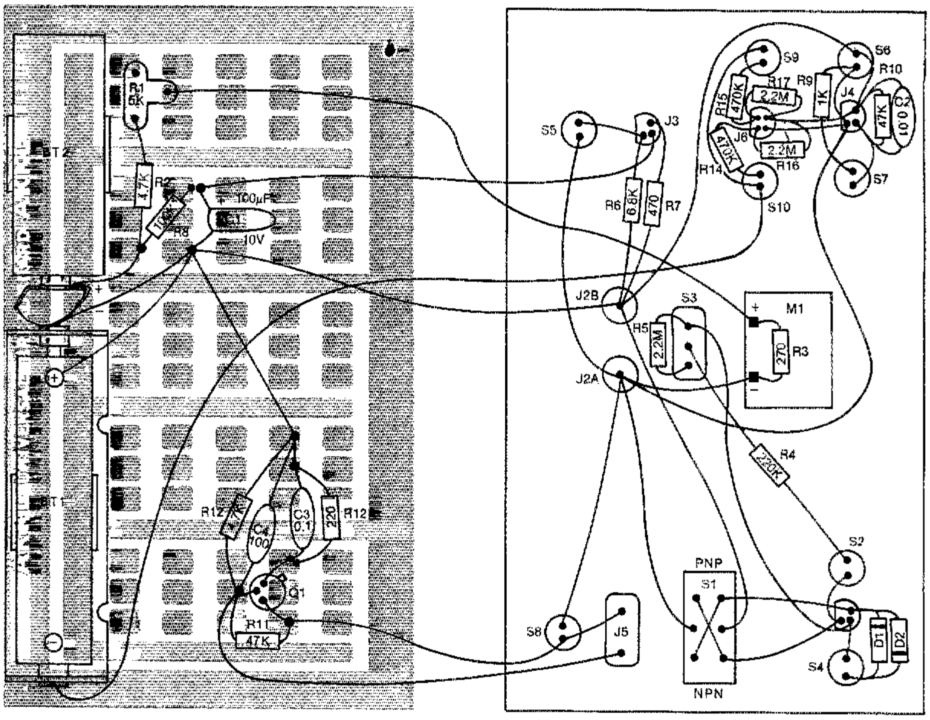


Fig. 2 — Parts-placement guide for test set. Parts are placed on the foil side of the breadboard and the back side of the panel. Unmarked lines indicate insulated-wire jumpers. Resistances are in ohms; k = 1000 and M = 1,000,000. Capacitors with whole-number values are in picofarads except those with polarity shown. Capacitors with decimal-value numbers are in microfarads. Sockets are depicted as viewed from the rear of the panel.

Test Instructions

To calibrate, press DROP switch (S6) and adjust R1 for full-scale reading. (If device to be tested will not fit in sockets, use test leads described in text). If the device you wish to test is completely unknown, try it in various sockets until you get a correct indication. No damage will result from placing a device in any of these sockets.

Bipolar Transistors

Insert the device into J1, and operate S1. A reading of zero indicates proper bias (i.e., npn or pnp), any small reading indicates leakage. Press S2 (GAIN). If reading is off scale, switch S3 to its x100 position. Hold GAIN switch down and press IDENT (S4); a small drop in the meter indication signifies germanium, while a drop to zero indicates silicon.

SCRs (up to 1 ampere)

Insert the device in J4. The meter should still read zero. Press and release GATE switch (S7); the meter should now read near full scale. Press and release DROP switch (S6); the meter reading should drop to zero. Repeat several times to verify that the device is good.

FETs

Either single-gate or dual-gate FETs can be tested. If you are testing a single-gate FET, you may use either gate socket. When you insert the device in J6, the meter should swing upscale to near full scale. Press the appropriate gate switch and watch for the meter to drop. If you are checking a dual-gate device, check the second gate after checking the first one. In a dual-gate device, the drop should be the same for both gates.

Unijunction Transistors

Insert the device in J3. Depress and hold S5 (TEST). The meter should read about 10. While keeping the TEST switch depressed, watch for the meter to "pulse" up scale. The first pulse should come around two seconds after the switch is depressed; after this, the rate should be about one per second.

Diodes

Insert diode in J2 and watch for an upward deflection of the meter. Reverse the leads and watch again. The meter should deflect with the diode in one direction only (when it does polarity will be indicated by the etching on the front panel). No reading either way means that the diode is open. A reading in both directions means that it is shorted.

Crystals

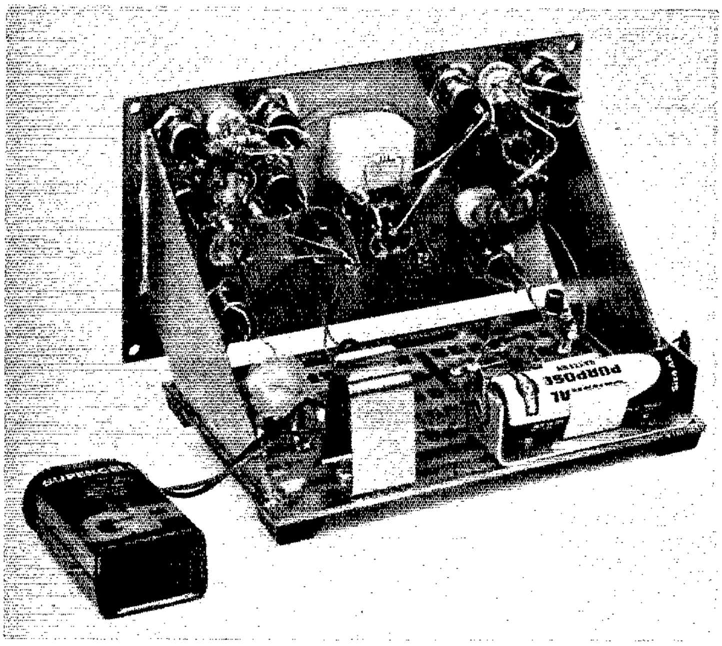
Press TEST switch (S8) and look for a reading in the range of 5. Insert crystal in J5 and depress S8 again. A meter reading above 10 indicates a good crystal.

Continuity

Plug a set of test leads in the diode sockets (J2) and use as a continuity tester.

When All Else Fails

If you have a component that checks good in the tester, but does not work in the circuit, replace it with one that is *known* to be good.



When viewed from this angle the wiring of the test set looks a bit like a can of worms. A close examination of Figs. 1 and 2 reveals that it is quite simple and straightforward. Note the mounting nuts soldered to the back side of the panel.

way will not affect the operation of the circuit. If you are positive that you will never need to check one or two of the listed devices, you may omit the appropriate jack and its circuitry without harm to the other test circuits.

The battery holders are fastened to the Universal Breadboard with no. 4 hardware. The meter and the transistor sockets are held in place with fast-setting epoxy. A set of probes can be constructed for testing devices that will not fit into the sockets. Cut off one end of a small alligator clip jumper (e.g. Radio Shack 278-1156) and strip the insulation from one-half inch of the wire. Solder the wire to a short piece of stiff wire, such as the lead from a 1/4-watt resistor. The stiff wire is plugged into the transistor socket, and the alligator clip is attached to the appropriate terminal of the device to be tested. Make four of these jumpers of different colors and you will be able to test any discrete device regardless of package format.

The Beginning

Now that you have your own semiconductor test set, you are in a position to begin troubleshooting and repairing your own equipment. Additionally, you can take advantage of unmarked "specials" at the next hamfest with the knowledge that you will be able to figure out just what they are without benefit of package markings.

Some of you are wondering just how long it took O'Dell to troubleshoot and repair the mobile unit that his former boss threw across the room. There wasn't a thing wrong with it when it was checked out! You may be saying, "So what? Everybody knows that commercial equipment is built tough." A few years back we toured the plant of an American manufacturer of amateur equipment. The final test on each unit before it was shipped was to strap it to a vibrating platform like those used for mixing paint. After a minute of shaking loose anything that could be shaken, it was again tested to see if it still met factory specifications. If so, it was boxed and shipped. If not, it went back for more work. Most amateur equipment is built tough, too. We aren't advocating that you abuse your equipment, but don't be afraid to touch it either. You hams are too gentle with your equipment. QST

Notes

[1]Shriner and DeMaw, "Transmitter Fundamentals," December 1979 *QST*, p. 11.
[2]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.
[3]Etching pattern for the Universal Breadboard appears on page 47 of September 1979 *QST*.

Strays

DANGER, HIGH VOLTAGE

☐ Joe Johnston told fellow members of the WR3ACU net that he had experienced a sudden rash of burned out electric light bulbs in his home. He had checked the line voltage and was surprised to find that it registered 132 volts. The electric company made necessary adjustments when notified. "Don't," Joe warned, "think that second bulb burning out is just a coincidence. Check it out." — *Jane Johnson, K3RIH, Upper Darby, Pennsylvania*

EXAMS — WHAT TO STUDY?

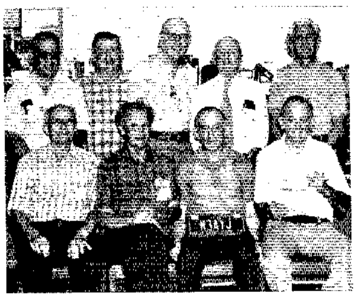
☐ We've received many letters and phone calls at Headquarters asking about comparisons between the new and the old FCC Study Guides and how they will affect Amateur Radio examinations.

General language and organization of required information is easier to work with in the new Study Guides. Topics have been shifted between different classes of licenses, and new items of study have been introduced.

If you haven't noticed, the "In Training" column in May 1980 *QST* (page 64) contains important information concerning the new tests and Study Guides. The Guides themselves, as released by the FCC, are in March *QST*, pages 55-58. Instructors and anyone planning to take an exam should check this information. — *Bill Grim, WØMHK*

I would like to get in touch with . . .

☐ hams interested in spreading the next Friendship Earthalite message, to be transmitted on June 22, 1980, the longest day of the year. Contact George H. Byer, 35099 W. Florida D-8, Hemet, CA 92343.



A group of Bayonne's old-timers recently met in the Civil Defense and Disaster Control Center at the 16th Street firehouse in Bayonne, New Jersey. Some of the old-timers had not seen each other in about 45 years. Those gathered were, front row, left to right: W2CBY, W2ESB, W3AYJ and K3RFL. Standing: W2FQF, SWL Aaron, W2AZR, W2GNM and W2DYH. *(photo by K3RFL)*

Transmitter Keying Circuits for CW

Do you have a tube-type transmitter and a solid-state transmitter? Would you like the convenience and economy of safely keying both with one key — without having to move the plug?

By D. Howard Phillips,* W6FOO

How do we connect one key to a grid-block keyed, tube-type transmitter and a solid-state transmitter at the same time?

As with most things in life, there is at least one wrong way and at least one right way to accomplish this objective. Wiring the two transmitters in parallel with the key (Fig. 1) can create a dangerous situation. Damage may result if the two keying lines are connected without regard to the voltage sensitivity of the semiconductor devices used in the keying circuit of the solid-state transmitter. Should a short develop in the solid-state transmitter, the tube transmitter could become lock keyed, resulting in the destruction of the final amplifiers.

*1345 Arizona Ave., Milpitas, CA 95035

The Right Way is the Safe Way

The circuit shown in Fig. 2 allows effective and safe keying of the two transmitters. This is accomplished by using only two diodes in a diode-clamp circuit.

Transmitter 1 is keyed by passing current through D1 when the key is closed. During the key-down condition, the key is

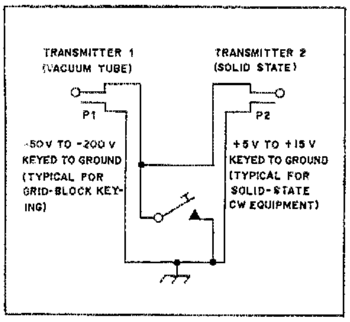


Fig. 1 — *Wrong way!* Connecting the keying circuits of the two transmitters in parallel may result in damage to either or both.

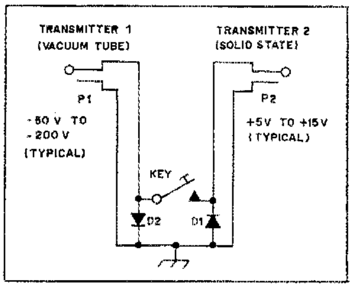


Fig. 2 — *Right way!* The diode-clamp circuit allows a single key to control two transmitters which require the keying of opposite-polarity voltages. (See text for specifications of D1 and D2.)

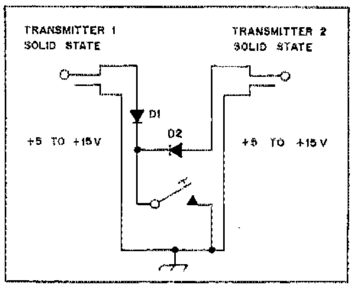


Fig. 3 — This circuit can be used to connect one key to two transmitters having the same polarity on the keying line. The transmitter not intended for use should be turned off or in the standby mode. D1, D2 — see text.

at a potential of approximately −0.7 volt (the potential difference across the forward-biased D1, assuming that silicon diodes are used). D2 must have a minimum peak-reverse-voltage (PRV) rating of approximately twice the keying voltage developed by transmitter 1, as D2 is reverse biased by transmitter 1 during key-up conditions.

Transmitter 2 is keyed by passing current through D2 when the key is closed. During the key-down condition, the key is at a potential of approximately +0.7 volt (the potential difference across the forward-biased diode, D2). D1 must have a minimum PRV rating of approximately twice the keying voltage developed by transmitter 2, as D1 is reverse biased by transmitter 2 during key-up conditions. The current rating of almost any diode will be more than adequate for this circuit, as most transmitter keying circuits operate at maximum (key down) currents of less than 50 milliamperes. The transmitter not intended for use should be turned off or in the standby mode while keying the other transmitter.

This circuit has worked well for more than a year, while being used with a Swan 500 (vacuum-tube transceiver) and a Kenwood TS-700SP (solid-state transceiver). The diodes contain both junction capacitance and bulk resistance, thereby "softening" the keying waveform, to minimize the tendency for key clicks. During the time this circuit has been in use, it has not been necessary to add R-C filters to the keying circuit to modify the keying waveform.

Two Solid-State Rigs?

The circuit in Fig. 2 will work only in cases where the two keying lines are opposite in potential. Thus, if the reader desires to connect two solid-state or two tube-type transmitters safely, a slightly different circuit must be used. In Fig. 3 a diode is connected in series with each of the two keying lines and the keying lines are connected in parallel. These diodes effectively isolate the voltages. Again, the transmitter not intended for use should be turned off or in the standby mode while the other unit is being keyed.

One final note is that both of these circuits will work with a manual key or an electronic keyer utilizing a relay in the output circuit. The circuit in Fig. 3 should work with a keyer having electronic switching in the output; however, the circuit in Fig. 2 should not be used with this kind of keyer. It will be necessary to add a relay to the keyer in order for it to work with the circuit in Fig. 2.

Now that you have seen a couple of different ways to safely connect two voltage sources you may want to consider other equipment in your shack that can be simplified. Where else can you use diodes to isolate one voltage source from another? QST

Strays

ARRL FILM BOOKING INFORMATION

☐ The new ARRL film, "The World of Amateur Radio," is distributed on 16-mm film by Modern Talking Picture Service, Scheduling Center, 5000 Park St. North, St. Petersburg, FL 33709, Tel. 813-541-6661. For regular ordering, three weeks or more before show date, mail your order to the scheduling center. For short notice showings, 10 days to three weeks before show date, telephone your order to the scheduling center. If possible, indicate acceptable alternate show dates. If the agency cannot supply the film for a convenient date, contact your division director (see *QST*, page 8), who has a print that may be available. — *Marge Tenney, WB1FSN*

ATTENTION AFFILIATED CLUBS!

☐ Do you know that an officer of your club receives a quarterly newsletter, "Radio Club News," from the ARRL Club and Training Department? If it's addressed to you, why not pass it around to the rest of your club? — *Sally O'Dell, AE8P*

MILLIWATT FIELD DAY TROPHY

☐ *The Milliwatt* Field Day trophy is still being offered to ARRL Field Day participants. The award is limited to one-transmitter, two-operator stations using a maximum output of 5 watts. To compete for the trophy, interested people should submit a copy of the official ARRL FD summary sheet along with a declaration that a power output of 5 watts was not exceeded. Also send an indication whether or not operation was portable, away from home QTH, and type of power source used.

Scoring is one point per QSO times power multiple (5-watt output = × 4, one watt output = × 5) times 1.5 for battery/solar/wind power, plus 150 bonus points for full portable operation. Send applications to Ade Weiss, K8EEG, 83 Suburban Estates, Vermillion, SD 57069.

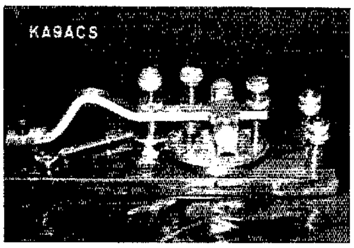
LIFETIME NOVICE?

☐ Charles Royall, WD5CJI, has been a Novice for four years and plans to remain a Novice. In his words: "I have no desire to work any mode other than cw." He goes on to say: "It's against all teachings. Supposedly, a person should be wanting to upgrade, but not me. I enjoy being a Novice and helping other Novices." He

Charles Royall, WD5CJI, of Denver, Colorado, has used this antenna arrangement to obtain WAS on 15 meters. His next objective is DXCC. *(WD5CJI photo)*

has 120 hours of radio theory and copies 100% at 40 wpm, but just likes being a Novice!

Charles began using the mobile antenna shown in the photograph when he moved to Denver, Colorado. It is mounted on a metal picnic table on the veranda of his second-floor high-rise apartment. With the mobile antenna he has obtained WAS on 15 meters, plus 25 countries. DXCC is his next objective. Charles also operates mobile cw with his Swan Astro 150 while his wife drives the family car. He says that Novices get a kick out of working his Novice mobile cw station. We're sure he'd like to hear from other Novices who operate mobile — if there are any!



This handcrafted, all brass, straight key is the work of Charles L. Wertz, KA9ACS, of Antioch, Illinois. Made from 1/4-inch brass, the handsome unit is mounted on a black walnut base. *(KA9ACS photo)*

Technical Correspondence

Conducted By
John C. Pelham,* W1JA

The publishers of QST assume no responsibility for statements made herein by correspondents.

AIRCRAFT ELT MONITOR CONTROL FOR REPEATERS

☐ A 1974 law passed by Congress requires that all piston-powered aircraft be equipped with an ELT (*E*mergency *L*ocator *T*ransmitter) that, in the event of a crash, automatically transmits a distress signal on 121.5 and 243 MHz. This law has undoubtedly been beneficial in saving lives. The fallacy in the law, however, is that there are no provisions made to require monitoring for these emergency signals. As a result, many people have died simply because no one was listening.

I have a solution to remedy the problem, provide a public service and gain personal satisfaction: Install ELT 121.5-MHz receivers and control systems at our repeater sites around the United States. The plan works like this: When a signal breaks the ELT monitor receiver squelch, and continues for at least 6 minutes, the control-board circuit keys the repeater transmitter for a 2-minute period and transmits a low-level audio alert tone. This alerts amateurs that an aircraft is down and needs immediate help. Twenty-four-hour monitoring stations equipped with decoders tuned to the repeater alert tone, direction-finding (DF) antennas and aircraft with DF gear are just a few of the things that can aid the program.

The schematic diagram of the control circuit is shown in Fig. 1. The input to the circuit, at J1, is to be connected to a point in the ELT receiver that goes positive (0.5 to 5 volts) when a distress signal is received. Q1 is a Darlington pair, providing gain for lower input voltages and minimum loading of the ELT receiver circuit. Q2 is an inverter which enables U1. The timing components for U1 are selected to produce eight pulses in a 6-minute period. When eight pulses have been received from U1, the output of the pulse counter, U2, goes high, enabling U3. Timing components for U3 are selected for an on time of 2 minutes. The high output from U3 turns on Q3, which turns on the repeater transmitter via contacts on K1. U3 also enables U4, a tone oscillator, which is fed to the audio input of the transmitter via another set of contacts on K1.

All the parts for this circuit were obtained at Radio Shack, so the project should be easy to reproduce. Several months of operation under all kinds of conditions have been gratifying. I used point-to-point wiring on a Vectorbord for my construction, but the circuit is a natural for a pc board. — *Edward S. Kimber, W7VEW, 590 Bonnie Brae St., Lander, WY 82520*

POISON IN THE HAM SHACK

☐ Radio amateurs may be poisoning themselves with one of the most insidious chemicals produced in the last 50 years. The chemical may be present in the oil of oil-filled capacitors and transformers. It contaminates everything it touches. It can be absorbed directly through the skin into the bloodstream. It does its subtle damage over a period of months or years. Because of this, its effects are seldom detected until long after any possible corrective or preventive treatment is possible.

The poison involved is PCB, short for polychlorinated biphenyl. This chemical is frequently added to mineral oil or glycerine to improve the dielectric properties of these organic solvents for use in capacitors and transformers. Almost all such devices built in the 1950s and 1960s contain some of this compound. The transformer oil often used in rf dummy loads probably contains PCB.

PCB may enter the body by ingestion, inhalation and absorption through the skin. It tends to accumulate in body fats and is poorly metabolized. In the U.S. population, background levels of PCB are 5 to 20 parts per billion in body fluids and 500 to 5000 parts per billion in fatty tissue. In human exposure studies, body fluid levels of 50 parts per billion have been associated with skin lesions, hyperpigmentation (spots on the skin) and abnormal liver function. Children born to mothers exposed at this level are of low birth weight, may be hyperpigmented and may develop skin lesions from PCB in their mother's milk.

Because of these dangers, federal legislation in 1976 mandated that the manufacture and distribution of PCB in this country cease within 2-1/2 years, and that all nonenclosed use of this chemical be banned. However, since much equipment containing PCB is still in use, exposures may still occur.

Most publicity about PCB poisoning has centered around contamination of livestock feed and subsequent high levels of the compound in meat, poultry and milk. Usually contamination occurs from leaking power transformers in the feed plants.

As long as PCB-containing oil remains sealed inside its container, be it a capacitor, transformer or dummy load, it is safe. But if any of these devices leak, a serious hazard ex-

*Asst. Technical Editor, *QST*

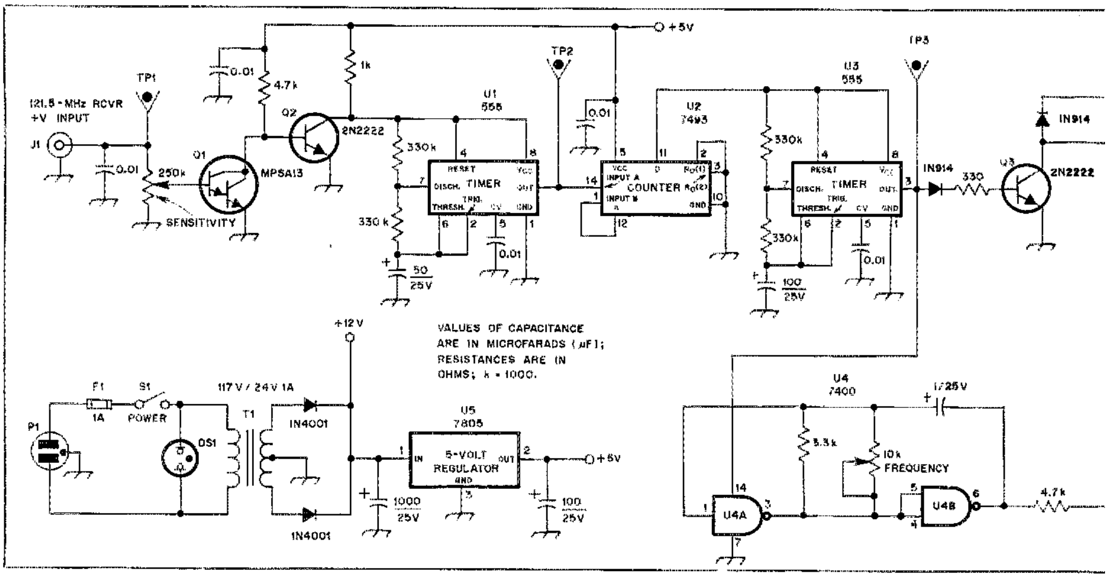


Fig. 1 — The W7VEW ELT monitor control circuit. See parts identification above. Resistors may be 1/4 watt.

ists and the object should be disposed of immediately. Disposal of leaking devices and any other contaminated objects or storage containers should be done with great care to avoid spreading the contamination to soil, watersheds and ground-water sources. The only safe economical method of disposal is to seal the contaminated material in a watertight, impervious container and bury it in a landfill that is approved by health authorities for disposal of hazardous waste. Amateurs are also cautioned to keep all oil-filled devices of this nature, even if not visibly leaking, inaccessible to children or pets. — *Larry W. Strain, N7DF, Box 213, Fort Duchesne, UT 84026.*

[Editor's Note: Current regulations of the Environmental Protection Agency (EPA) require that any amount greater than 6 pounds of PCB or PCB-contaminated material (this would include a 1-gallon dummy load if it contained PCB-contaminated oil) must be disposed of by placing it in a 55-gallon drum filled with sawdust. The drum must then be transported to an EPA-approved disposal site. Unfortunately, these regulations had industrial PCB users in mind rather than the individual radio amateur. Such an individual would be well advised at least to seal any leaking or suspect components in an impervious container such as the author mentions while awaiting a proper means of disposal.]

SSB OPERATING FREQUENCY

☐ I would like to make a few comments on "The Nitty-Gritty of Simple Receivers," March 1980 *QST*. First, I get the impression that there is a tendency to confuse what is defined as the "operating frequency" of an ssb signal. Amateurs have always used the carrier frequency as the operating frequency, whereas the military and possibly others use the center of the passband of the transmitted frequencies as the operating frequency. The writings about a 1.5-kHz offset (page 24, center column) and Fig. 5C in the article imply that we are leaning toward the latter! Is this intentional? I vote for keeping the carrier frequency as the operating frequency (even if it is suppressed). This would replace Fig. 5C in the article with Fig. 2 here. Notice that the BFO frequency would not be

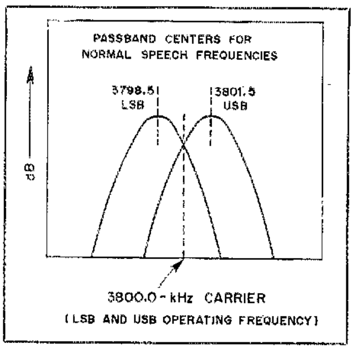
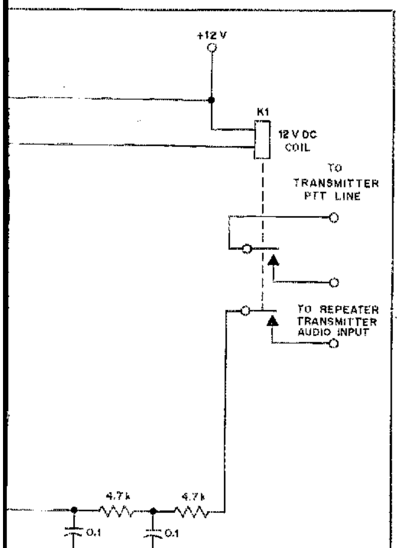


Fig. 2 — The operating frequency of an ssb signal in Amateur Radio is the carrier frequency — it is the same for lsb and usb. In a direct-conversion receiver (which does not give single-signal reception), a VFBO frequency equal to the operating frequency will allow correct demodulation of these lsb and usb signals.

changed for usb or lsb reception, but the receiver rf tuning would be slightly changed (if at all necessary with these simple receivers). On page 24, left column, where a presumed ssb signal of 3580.0 kHz is stated, one 3580.0-kHz crystal would be all that is needed for either usb or lsb reception in a direct-conversion receiver.

Second, on page 24, center column, usb and lsb are switched around in a sentence. The correct statement should read: "The VFBO is tuned slightly above the desired ssb signal for lsb reception, or slightly below it for usb reception." Note also that the ssb signal referred to here is that of the sideband frequencies, *not* that of the carrier, which must always be zero beat with the VFBO. Correct Fig. 7 in the article to label the 8998.5-kHz crystal for usb and the 9001.5-kHz crystal for lsb.

I hope these corrections and suggestions help to establish the frequency of an ssb signal as used in Amateur Radio. Future confusion is bound to exist if this matter is not defined specifically. — *Franklin Swan, W9SIA, 15933 Grove, Oak Forest, IL 60452*



A TWIST CALLED "TWIST"

☐ Those who built the "First-Class Touch-Tone Encoder" in February 1979 *QST* may have had some trouble getting their units to access the repeater autopatch. I had such a problem. However, a bit of asking around narrowed the problem to something called "TWIST." TWIST is the allowable difference in amplitude between the two tones leaving the encoder, and is specified by Bell as no more than 4.5 dB. The MC14410 tone generator is described by Motorola as having typically 2.5 dB of amplitude difference between the two tones. By the time these tones go through the transceiver audio circuitry, the repeater receiver circuitry, etc., it's not hard to visualize exceeding the 4.5-dB limitation.

The cure is very simple: Change the 10-kΩ summing resistor from pin 15 of the MC14410 to 15 kΩ. This equalizes the two tones and clears up the problem.

I have also shown in Fig. 3 a monitor circuit which may be added to your encoder. With this addition you can listen to all of the beeps and whistles as you punch them in. The penalty to be paid, however, is an increase in supply cur-

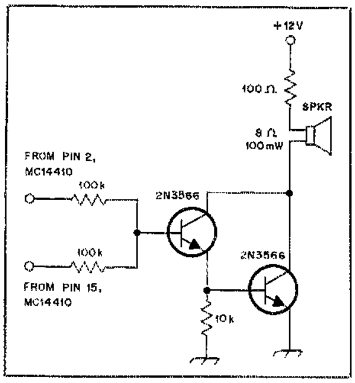


Fig. 3 — Circuit for a monitor that can be added easily to an existing encoder.

rent from approximately 15 mA to about 100 mA; still a very small drain on the battery. I used an imported 1-1/2 inch (38 mm) diameter loudspeaker glued to the inside of the encoder case. It provides sufficient volume. The two transistors should be high-gain types, but are otherwise uncritical. — *Ken Grant, VE3FIT, 46 Merryfield Dr., Scarborough, ON, Canada M1P 1J9*

Feedback

☐ In "The Nitty-Gritty of Simple Receivers," March 1980 *QST*, Fig. 9, page 26, a 100-Ω resistor should be added from pin 6 of U1 to the switched 12.6-V bus. In Fig. 11 on page 27, the 100-kΩ resistor connected from G2 to S of Q1 should be 10 kΩ. The 180-Ω resistor connected from the 12-V bus to a pad above Q2 should be 100 Ω.

☐ In the Hints and Kinks presentation of "FT-101ZD Final Amplifier Current Monitoring," May *QST*, page 40, the shunt resistor connections are incorrectly shown on the solder side of the board; they should be moved (one to each side) of the cut pc foil cathode connections immediately above. Thanks to George Tyler, W6CUI.

☐ An error was made in the listing of the 1979 Field Day results by the Monroe County (MI) Radio Communications Association. Their score should have been listed as 6424 points, making them the 8th call area leader in the 4-A category.

☐ There are some errors in "The NOR-Gate Break-in" (May 1980 *QST*, pp. 23 and 24). In Fig. 2, the "connecting dot" between pin 4 of U2B and the 330-kΩ and 2.2-kΩ resistors was omitted. Capacitor C4 is a 22 µF, 25-V electrolytic. Resistor R4 is 1 MΩ instead of 100 kΩ as shown on the parts-placement guide. The parts-placement guide should show pin 4 of U1 connected to pins 8 and 9. In Fig. 5 an arrow from C of Q2 "to Volume control" was omitted. The *dah* 10-kΩ resistor should go to U1A, pin 2 and the *dit* 10 kΩ resistor should go to U1B, pin 5. On page 26 U1A, pins 1 and 2 are reversed in portions of the text.

Product Review

Conducted By Paul K. Pagel*, N1FB

The IRL FSK-1000 RTTY Demodulator

Perhaps the present atmosphere of technical interest and innovation among RTTYers can be traced to an old-fashioned attitude. Not so many years ago, all RTTY stations were homebuilt to a greater or lesser extent because commercial demodulators tailored to the amateur market did not exist. Fortunately, that situation has changed. Yet, because many "green key" aficionados are latent homebuilders at heart, they are not content to accept their appliances without scrutiny.

One would think that the process of converting an RTTY signal into current pulses to drive the selector magnets of a printer is a simple process that can be done only one way. Ask two different RTTYers the best method for accomplishing this and you will get four different views! Most advanced TUs (terminal units) are sharp skinning knives — narrow, fixed-frequency audio filters centered on the standard mark-and-space frequencies. Although this tool will secure the greatest amount of information, there are those who prefer the phase-locked loop — an electronic meat cleaver — cheap and quick, but wasteful in tight spots (QRM).

For many years, the beginning RTTYer started his operating career with a phase-locked loop, then graduated to a high-quality, fixed-frequency TU. He soon found that copying different shifts or drifting signals is sometimes more difficult with an advanced demodulator.

IRL's FSK-1000 could be called a third option. Tunable sixth-order Butterworth bandpass filters give one the flexibility of a phase-locked loop TU and the selectivity of a fixed-frequency version. The bandwidth of both mark and space filters is selectable (55 Hz or 100 Hz) to permit operation at data rates of up to 110 Baud (a possible future ASCII standard) or for times when the QRM situation becomes difficult. By coupling these flexible filters with separate, large tuning meters for both mark and space, the FSK-1000 was able to copy a variety of Baud rates at many shifts. One immediately recognizes the 850/425/170-Hz switches. Yet the operator is not limited by preset mark-and-space filters. A delta tuning control permits varying the space filter center frequency from 50 to 1000 Hz. Thus, nonstandard shifts and drifting signals are tuned in with little difficulty. Further flexibility is afforded by the ability to select the mark signal alone, the space signal alone, or a combination of both for normal FSK operation. It is thus possible to use the "low tones" (1275- to 2275-Hz) version for use with an hf transceiver, and utilize the "mark only" mode to copy "high tone" (2125-to 3125-Hz) vhf transmissions. This feature might also prove useful for make-and-break (A1) transmissions used on various satellite-communication links.

Such shining flexibility does entail a slight design compromise, however. Most receiving conditions require some audio limiting before the mark-and-space filters to aid in counteracting the effects of fading and noise. Most fixed-frequency TUs employ a narrow-bandpass input filter before the limiter; otherwise, a strong adjacent signal will tend to capture the limiter and make copy difficult. A close analogy would be the capturing of a repeater by an extremely strong carrier. Because the space filter in the FSK-1000 is tunable from 50 to 1000 Hz, there is no bandpass input filter in the audio input line. The FSK-1000 did an excellent job of separating signals of equal amplitude, but strong QRM captured the limiter and obliterated copy. IRL's solution is ingenious: A control is provided that varies the amount of limiting so if the above situation occurs, it is possible to reduce the level of limiting to the point where capturing will be prevented. An LED is used to indicate the limiting reduction required for AM operation. Some of the time, this procedure was effective. However, this reviewer feels that when the FSK-1000 is used with a receiver lacking a good 400-Hz i-f filter, it would be advisable to insert a homebuilt audio bandpass filter between the receiver and the demodulator. This addition would allow hard limiting under a much wider range of QRM conditions. An audio filter is simple to construct and would provide the operator with the best of both worlds.

The FSK-1000 also features decision-level correction circuitry to compensate for selective fading, automatic PTT, an internal 60-mA (170 V) and RS-232 loop supply, and station-control circuitry. One unique and welcome feature of this TU is the ability to switch between mark-only autostart and FSK autostart. In the latter mode, both mark and space signals are required to start the machine. This mode was found to be nearly immune to triggering by cw and ssb signals. A front panel-mounted threshold control acts as an RTTY "squelch," but it was found to be not quite as effective as autoprint circuitry which is designed to prevent the machine from running open before the motor is shut off.

The FSK-1000 is a well-constructed and attractive piece of equipment. Most components are mounted on a single glass-epoxy pc board that is well laid out and readily accessible. IRL also offers both AFSK (FSK-1020) and video-terminal options. The price class of the FSK-1000 is $400. Further information can be obtained from IRL, 700 Taylor Rd., Columbus, OH 43230. — *Chris Schenck, W1EH*

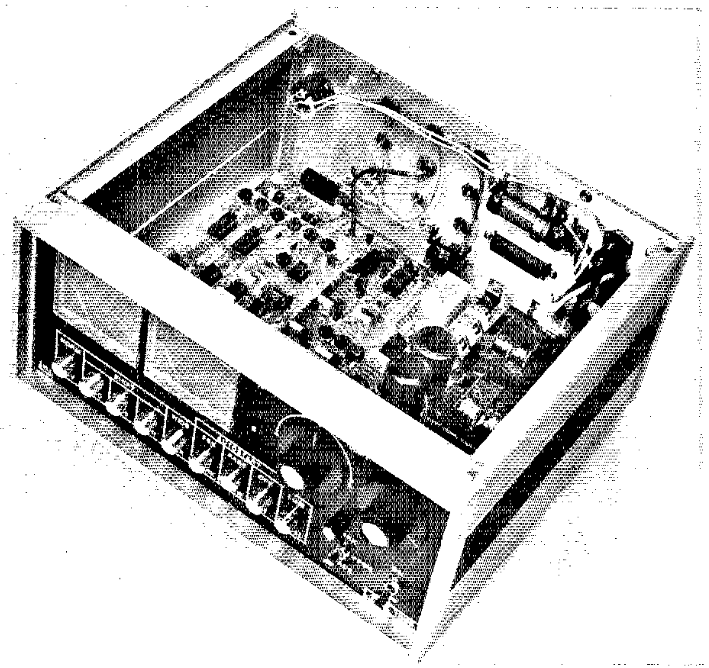


Fig. 1 — The IRL FSK-1000 with the top cover removed. Note the neatness of the internal component layout. The large front-panel meters are easy to read, even at a distance.

*Assistant Technical Editor, ARRL

THE HEATH IM-2215 HAND-HELD DIGITAL MULTIMETER

If you've been looking for an accurate, portable, digital multimeter (DMM) at a price you can afford, Heath has the answer. The IM-2215 is a hand-held, battery-powered, DMM exhibiting a high degree of accuracy and featuring a 3-1/2 digit, liquid-crystal display (LCD). The LCD numerals are large and easy to read (old-timers take note!) — the problem associated with reading an LED display in high ambient light areas is virtually nonexistent. The display also offers automatic decimal-point placement (depending upon the measurement range selected) and polarity indication. A LO BAT display warns you of a low battery condition and is activated during the last 20% of the life of the battery. With an alkaline battery, typical operating lifetimes of up to 200 hours may be expected. Approximately 100 to 150 hours of operation will be provided by the zinc-carbon battery types.

Ac and dc voltages and currents as well as resistance-measurement functions are provided. Within the specified limits, the meter is protected against overloads and transients by either a resistor-diode network or an internal clip-mounted fuse (no unsoldering necessary). Overload and over-range indications are relayed to the user by a flashing minus sign and a blanking of the display except for the most significant digit (MSD).

The '2215 may be line operated by using one of the optional 120- or 220-V Heath converter/chargers which are available. Advertised as "line cords," the units are more popularly known as "wall transformers." With the '2215, these converter/chargers operate as battery eliminators and *will not* charge the internal battery. The battery is disconnected when the converter is plugged into the DMM. Another available option is a leather carrying case with an attached belt loop.

Assembly of the '2215 may be accomplished within one evening. Total construction time for the unit assembled by this reviewer was approximately 5 (interrupted) hours. This included time taken to check each resistor, diode and transistor with an ohmmeter and scrape the component leads with a pen knife prior to soldering the part into the circuit board. Heath (thoughtfully) supplied a small plastic magnifying glass to enable the assembler to read the component markings. Unfortunately, the magnifying glass was difficult to focus, so I resorted to using my own illuminated hand-held magnifier. I'd recommend using a magnifying glass no matter how good your eyesight may be; it comes in handy when checking the solder connections on the pc board.

This is the first time that assembly of a unit required me to wash my hands first! The construction manual outlines a couple of important steps which should not be overlooked: Clean hands, handling of the main circuit board by its edges and avoidance of excessive rosin build up are procedures to be followed if contamination of the main circuit board is to be avoided. Heath warns that should contamination occur, the completed DMM may not meet the listed specifications when operated in certain environments, such as one with high humidity conditions. Should it be determined the circuit board is contaminated and requires cleaning, a simple procedure is outlined in the manual.

The components used in the '2215 are of the highest quality. I was pleased to find that even

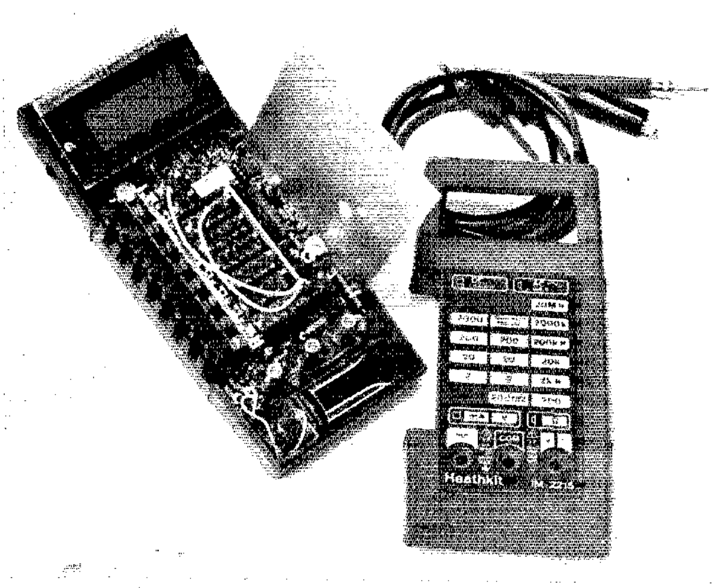


Fig. 2 — The Heath IM-2215 digital multimeter. The vertical panel to the right of the meter case is a flexible shield that is secured over the switch assembly during construction. The switch assembly requires the only point-to-point wiring necessary.

the test leads mated quite securely with their respective jacks, which are tubular aluminum types. There are a few specially selected components employed and these are mentioned during the construction process. You might notice the LCD digits flashing during handling of the display assembly. It's not your imagination; static electricity is causing this. No difficulties were experienced during construction with the exception of the test-point pin pc board holes being too small to allow the pins to pass properly and seat on the board. The two holes were enlarged using a no. 51 drill to permit a snug fit for the pins. A few changes had to be made to the manuals with information supplied by the accompanying errata sheet. One capacitor location on the board is marked incorrectly, but this is mentioned in the appropriate construction step. There is very little point-to-point wiring involved: five wires! Everything, with the exception of the battery and battery connector/fuse-holder, mounts either on the main or read-out circuit board. The meter is ready for calibration after a few operational tests to ensure proper circuit functioning.

Two calibration methods are possible: internal, using the built-in standards, or laboratory, by means of external voltage sources. The latter method requires the amplitude of the calibration voltage to be controlled to a great degree of accuracy ±0.05% for a resultant meter accuracy of ±0.25%. I used the internal-standards method and with two voltage mesurements and corresponding adjustments, calibration was completed in less than five minutes. The internal references used to calibrate the '2215 are in themselves highly accurate. One reference voltage is obtained by using a selected low-voltage reference device made by Micro Power Systems, Inc. (MPS5010). The reverse-breakdown voltage for the device, which is used for dc calibration, has been measured accurately and recorded. This device is packaged separately with the reference voltage value noted on the envelope. The voltage value is transferred to a label which is affixed to the inside of the meter for referral during recalibration procedures. The ac mode is calibrated by using the rectified backplane signal of the A/D converter.

The user should read the operations section of the manual carefully. Although the DMM is protected, there are some practical limits to the degree of protection of the '2215. High-voltage and rf probes may also be used with the meter and such use is explained thoroughly. Three ranges of the meter do not produce a full-scale measurement voltage sufficient to forward bias silicon junctions, but there are three others that do. The latter ranges are useful when checking and matching diodes and transistors, while the former ranges may be used to make in-circuit resistance measurements.

When measuring voltages, the display reading is in millivolts or volts. For dc voltages, negative polarity is indicated by the appearance of a minus sign to the left of the MSD. The absence of the minus sign indicates a positive polarity. No sign is displayed during ac-voltage measurements, except during recovery from an extreme overload. During current measurements, the foregoing polarity rules apply. Current readings are displayed in milliamperes. No polarity sign will be indicated during ac measurements, except during an overload recovery. When measuring resistances, the display is expressed in ohms, kilohms, or megohms with no polarity sign exhibited. The possible exception may occur during connection of the meter to an energized circuit. The overload/overrange condition is indicated by the blanking of all display digits except the MSD "1". It is normal for the units position of the display to alternate one digit above and below a reading. This does not indicate a malfunction. During the measurement of ac voltages, it may take a few seconds (typically 8 to 10) for the display to stabilize at a ± 1 count indication and this, too, is normal.

It was noted that the '2215 was susceptible to RFI when operated close to an operating 300-watt transmitter that had been removed from its case. This came as no surprise. The degree of interference was greatly reduced when the meter was placed on the desk rather than being held in the hand.

The external and internal appearance of the '2215 bear a striking resemblance to another multimeter which is currently available. On the "other" unit, the on/off switch is reversed and access to the battery and protective fuse is by means of a sliding plate on the rear of the multimeter; the '2215 requires the rear of the case be removed for access to these two components. There are some circuit differences and (of course) a price difference, too.

The IM-2215 has been a pleasure to construct and use. It has become a mainstay of my "shack." With its $95 price class, the IM-2215 will occupy a prominent position in the hand-held DMM market. The IM-2215 is available from the Heath Co., Benton Harbor, MI 49022. — *Paul K. Pagel, N1FB*

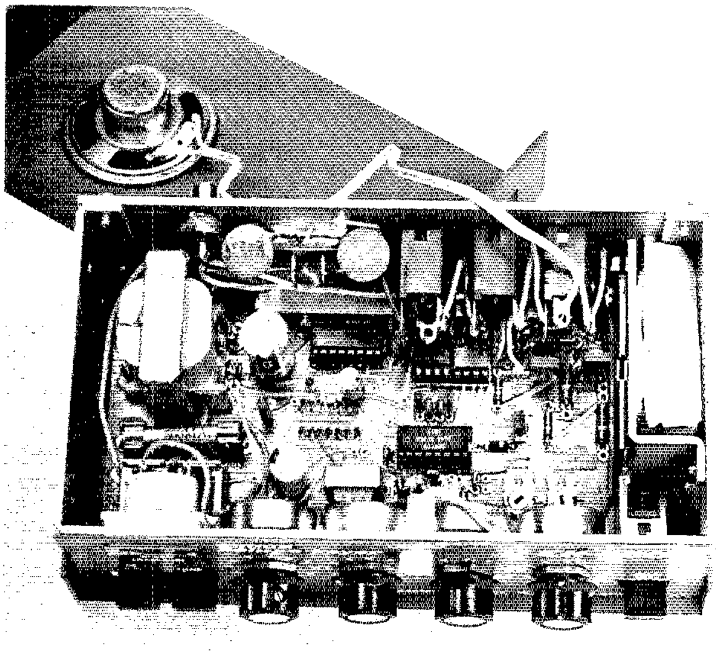


Fig. 3 — The Curtis EK-480M keyer. This keyer features a built-in speed-indicating meter and is well protected against harmful voltages and RFI.

THE CURTIS EK-480M CMOS DELUXE KEYER

The Curtis 8044 "keyer-on-a chip" is available in many forms, from the 8044 IC alone to one of the latest additions to the line, the EK-480M. The 8044 is an LSI CMOS IC which was designed specifically for use as a keyer. According to the manufacturer, this single chip replaces eight standard IC's in addition to many other discrete components and related interconnections. The circuitry of this single chip provides automatic dits, dahs (both with memories), key debouncing, sidetone generation and provisions for variable weighting. The variable weighting, sidetone pitch/volume and speed adjustment are made possible by connection of external components connected to the chip. The IC is protected from harmful voltages applied through the paddle and manual key leads by means of opto-isolators. The LEDs of the opto-isolators are in turn protected by silicon diodes. Protection circuitry is extended to include reverse-polarity protection diodes at the output circuit as well. RF immunity is provided by effective bypassing. When W1FB mentioned that he'd had some RFI problems on 10 and 15 meters with another keyer that he was using, I asked him to try the '480M. At a kilowatt input level with no provisions made for grounding the keyer chassis (a necessity with the other keyer), no problems were encountered with RFI.

The '480M is designed to key ± 300-volt, 100-mA circuits. Keying polarity is switch-selected at the rear of the unit. The current handling capability of the output circuits may be increased to 200 mA, if required, by the addition of a resistor to either one or both of the output keying circuits. Circuit-board mounting holes are provided for such a circumstance. (If the keyer is powered by a battery, this modification will decrease the battery life by 20 to 30 percent.) One precaution is to be observed when accommodating a negative key line: The shield common for the paddle and/or straight key is at the keyer power supply positive voltage potential. This means the key frames must be prevented from shorting to other equipment or the keyer power supply will be shorted. A length of cable (three-conductor only) and connectors are provided for interconnection of the keyer to the key(s) and transmitter. Standard 1/4-inch (6.4 mm) jacks and plugs are used for the key inputs and an external speaker output. The key line output is a phono jack. An accessory socket (14-pin DIP socket) is accessible from the bottom of the keyer cabinet through a rectangular cut-out; no mating connector was supplied with the review model.

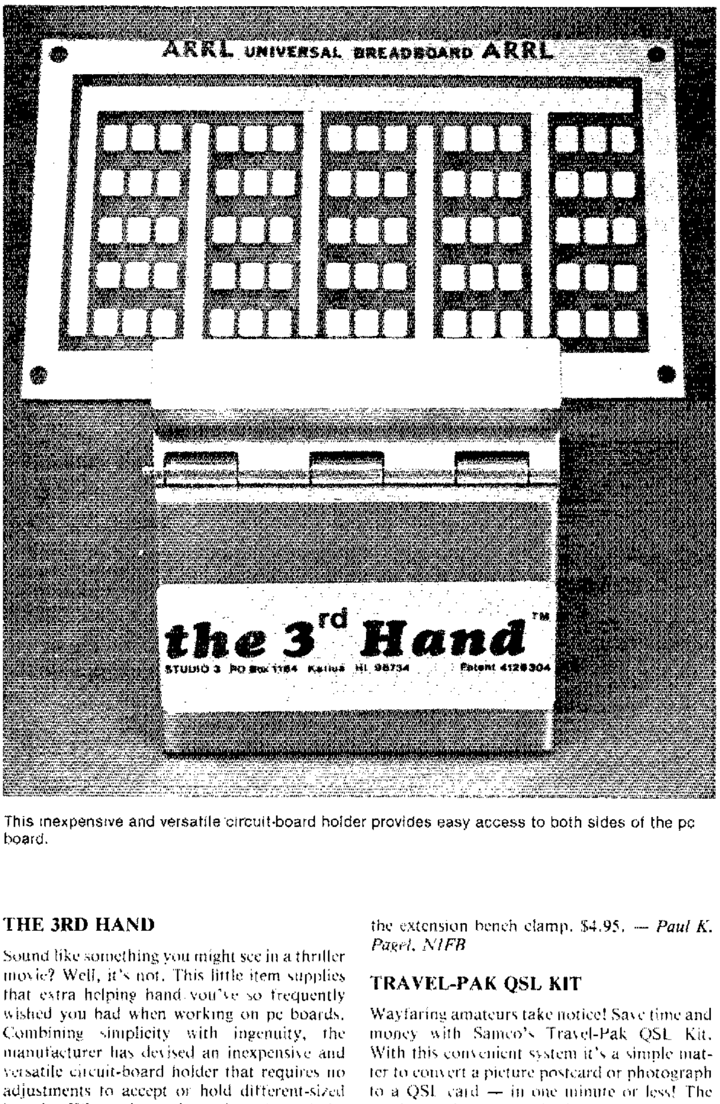
The '480M may be operated from a standard 117-V ac line, internal 9-V battery or an external battery. A carbon-zinc battery will provide up to 15 hours of operation. For protracted operational periods requiring battery usage, alkaline or mercury batteries are recommended. The ac cord supplied is a TV "cheater cord" type which plugs into a rear-panel socket. Battery or line operation is switch selected from the front panel.

A TUNE switch on the front panel provides a continuous key-down condition for transmitter-tuning adjustments. At the opposite side of the panel, a SELF TEST switch disables the key line output while leaving all other keyer functions normal. With this feature, the operator need not disconnect any cables or operate other switches when making keyer adjustments practicing with the keyer.

The internal sidetone generator of the keyer produces a healthy amount of output to either the self-contained, top-mounted speaker or to an external, plug-in speaker. Both the pitch (variable from approximately 250 Hz to 15 kHz) and volume are adjustable from the front panel, as are the speed and weighting. (A weighting control position beyond the 2:30 o'clock position had virtually no effect; just a "blurb" of sound was produced during keying.) The speed range is factory-adjusted for a nominal 6 to 50 wpm. The upper end of this range may be adjusted higher or lower by means of an internally mounted potentiometer. If speeds of 30 wpm or less are to be used, the upper end of the speed range should be reduced to allow a smoother speed adjustment over the control range.

The "M" in the model number stands for "meter." This keyer has a speed readout meter nestled in the upper left-hand corner of the front panel. The meter scale markings run from 0 through 5 and the resultant indication is multiplied by a factor of ten to produce a fairly accurate means of judging one's sending speed. A rapid string of three or four dits or two or three dahs will "hang" the meter long enough to enable the operator to discern the speed of transmission. The meter needle doesn't bounce except at very slow speeds, typically below 10 wpm.

The keyer is housed in a sturdy gray, U-shaped, aluminum cabinet. The accompanying manual is 12 pages long and includes operating instructions, circuit feature descriptions and some trouble-shooting procedures. Price class is $150. The EK-480M is available from Curtis Electro Devices, Box 4090, Mountain View, CA 94040. — *Paul K. Pagel, N1FB*



This inexpensive and versatile circuit-board holder provides easy access to both sides of the pc board.

Fig. 4 — Sample of an existing QSL card that was modified to include VP2MFW and the QTH, "Montserrat."

THE 3RD HAND

Sound like something you might see in a thriller movie? Well, it's not. This little item supplies that extra helping hand you've so frequently wished you had when working on pc boards. Combining simplicity with ingenuity, the manufacturer has devised an inexpensive and versatile circuit-board holder that requires no adjustments to accept or hold different-sized boards. When clamped to the edge of the workbench, it holds the board at a convenient angle to allow placement of parts on the board and then flips forward for access to the solder (or wire-wrap) side of the board.

The model we received is a manufacturer's sample, identical to the commercial model except in length (about 1-1/4 in. shorter). Secured to the bench mounting bracket is a hinged aluminum channel. Within the aluminum channel is a section of spring-loaded PVC gasket. The circuit board edge is simply slid into the PVC gasket and is held firmly by the spring action; there are no arms or knobs to adjust. The 3rd Hand is manufactured in three different sizes. There's also an extension bench clamp which allows the work to be placed further back from the front edge of the bench. The 3rd Hand is available from Studio 3, P. O. Box 1184, Kailua, HI 96734. Price class: Model 3 B/C (4 in.), $9.95; Model 3 A/C (5-3/4 in.), $12.50; Model 3 C/C (7-5/16 in.), $14.95; and the extension bench clamp, $4.95. — *Paul K. Pagel, N1FB*

TRAVEL-PAK QSL KIT

Wayfaring amateurs take notice! Save time and money with Samco's Travel-Pak QSL Kit. With this convenient system it's a simple matter to convert a picture postcard or photograph to a QSL card — in one minute or less! The results can be very professional.

The reviewer had a need for a limited number of QSL cards each year after vacationing on the various islands of the Caribbean. Some years the DXpedition is merely a token type of exercise, with skin diving and other tropical activities dominating. As a result, fewer than 100 or 200 QSL cards are required to confirm contacts with those who need a new country. The cost of having quality QSL cards printed, plus the wait for delivery, can be discouraging. A speedy and low-cost technique for developing QSL cards was discovered while reading *QST* Ham Ads. An inquiry to Samco brought a hasty response, complete with samples.

How does the technique work? Well, your call is printed on clear acetate strips which are adhesive-backed. Similarly, the QTH line (or lines) is printed on a similar strip. The protective backing is peeled away easily, then the strip is affixed to a postcard, photograph or existing QSL card. Fig. 4 shows how the VP2MFW call and the word "Montserrat" were added to the existing W1FB cards. A standard-format report strip is also available. These are handy for pasting on the back side of postcards which are converted to QSLs.

There are three letter-size choices for the call letters (5/8-, 1/2- and 3/16-inch heights — 16, 13 and 5 mm, respectively). Color choices are white, red, blue, gold, green, black and copper. A variety of prices is listed for various kits, but the "quantity discount kit" gives you 250 calls, QTH lines and report forms (enough to make 250 QSL cards) for $15. This reviewer chose to order 100 calls and 100 QTH lines, but no report forms. The cost was $6, postpaid.

Those who take vacations in the USA and operate Amateur Radio from various states and counties may find this type of QSL card fabrication excellent for use with picture postcards from the area where the operation took place. You can mail the QSL card right from the location without delay!

The quality of the product is excellent. It was a wonderful surprise to get both the samples and the order a couple of days after the requests were sent. In both instances the merchandise was shipped the day the order was received! A few more amateur equipment merchandisers could benefit from that kind of turnaround time!

A brochure and samples are available at no charge, provided an s.a.s.e. accompanies the request. The address is Travel-Pak QSL Kit, Box 203, Wyantskill, NY 12198. — *Doug DeMaw, W1FB*

THE 1980 *ARCHER SEMICONDUCTOR REPLACEMENT GUIDE*

There's a new 1980 edition of the *Archer Semiconductor Replacement Guide* available at your nearby Radio Shack dealer or store. This 224-page, 8-1/4 × 11-inch book features cross-reference and substitution listings for over 100,000 devices. These listings have been totally computer generated and based on careful analysis of the important parameters of the listed devices. Information is given relating to transistor testing, case styles and dimensions, the care and handling of transistors and integrated circuits, optoelectronic devices and displays. A glossary of words, symbols and abbreviations relating to semiconductor devices is included, too. A pair of pages is devoted to major semiconductor components and lists the name of the device, the circuit symbol, electrical characteristics and major applications. Some typical applications and circuit diagrams are given for a number of ICs. The new guide is priced at $1.99. — *Paul K. Pagel, N1FB*

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

VK2SV MODIFICATION FOR THE HEATH NOISE BLANKER/75S-3 COMBINATION

The fitting of a modified Heathkit noise blanker in the 75S-3 was well covered by Doc Lask, K6CUF, in February 1979 *QST*. The modification really works. In my case, because I had updated my 75S-3 to fully solid state by means of a set of Tubesters, a further modification became necessary. Use of the Tubesters, supplied by Jim Bowles, W6DLQ, means that the 11-volt supply for the blanker could not be obtained from the cathode of the 6BF5 output tube.

A small pc board was made to fit into the space left by the omission of the edge connectors. An 11-volt regulated voltage-doubling supply powered by the 6.3-volt line was fabricated. See the accompanying drawing. To enable the circuit to be peaked at the center of the i-f passband, a further essential modification had to be made. Accordingly, a 5- to 60-pF trimmer capacitor placed across L3, instead of the 36-pF capacitor suggested by Doc Lask, did the trick. To permit the blanker to be switched in when necessary, a miniature push-button switch mounted on a small bracket located under the finger hole in the top cover has been added.

Installing the noise blanker in the KWM-2 proved to be a much simpler project than expected, for Collins engineers have thoughtfully provided a pair of phono jacks (J22 and J23). These are normally jumpered between the first and second receiver mixers. Additionally there is a noise-blanker power plug (J24) that provides a circuit to the noise blanker switch on the front panel.

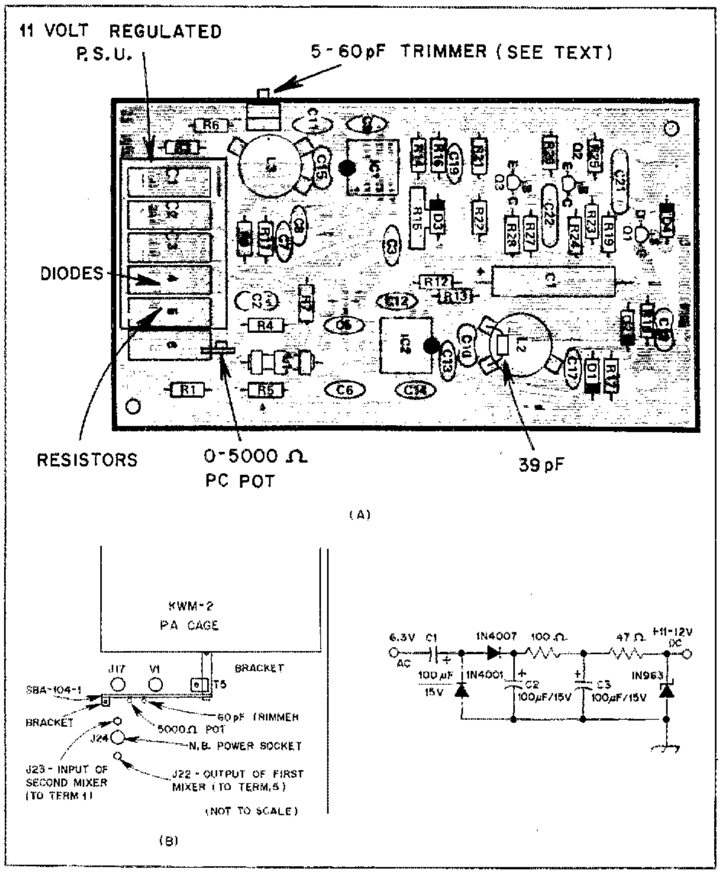
Remove the jumper and install a pair of short, shielded cables, terminated in phono plugs, from the SBA-104-1 to jacks J22 and J23. I used a small voltage-doubler supply powered by the 6.3-volt line available at the noise blanker socket.

A 5000-ohm pc-board potentiometer, mounted in a vertical position at the no. 6 edge connector position, serves for setting the desired blanking level. Both the 60-pF trimmer and this potentiometer are positioned such that adjustments can be made when the blanker board is installed in the KWM-2. Do not remove R3, 33 ohms.

The SBA-104-1 is mounted in a vertical position immediately in front of V1 and L9, and behind J23 and J26. A small bracket attached to the bottom left-hand corner of the board is fastened to a protruding coil-can bolt and raises the board about 3/8 inch (10 mm) above the chassis. Another bracket from the top-right corner of the board is fastened to the PA cage. No wiring changes to the KWM-2 are made, no holes are drilled, and operation of the blanker is made via a properly designated knob on the front panel.

To summarize the modifications to the SBA-104-1, discard L4, R29, the edge connectors and the 6-pin connector. Add a 5- to 60-pF trimmer capacitor across L3. Place a 39-pF capacitor across L2 and add a 5000-ohm potentiometer between terminal 6 and the NB (noise blanker) switch to ground. *Do not remove* R3 (33 ohms).

This arrangement provides 20 to 25 dB of blanking. As with the 75S-3, the results are quite impressive. The performance of an already fine piece of equipment is further enhanced. — *T. A. Dineen, VK2SV, ex-VE7SV, ex-ZS6TP, Port Macquarie, NSW, Australia*



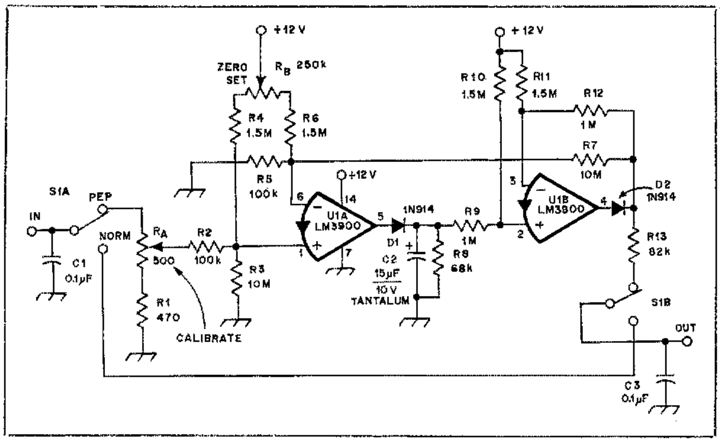
The VK2SV modification for adapting the Heath SBA-104-1 noise blanker to a Collins KWM-2. Location of parts on the SBA-104-1 circuit board is shown at A. The blanker board may be mounted adjacent to the KWM-2 PA cage as shown at B. J24 is the noise-blanker power socket. A suitable power-source circuit is shown at C. See text.

PEP WATTMETER MODIFICATION

This modification of the PEP Wattmeter, described by George Rice (December 1976 *QST*), may be of interest. It is designed around the LM3900 Norton operational amplifier and appears to be much less susceptible to the effects of strong rf fields such as mentioned in Rice's article. Also, it only requires a single supply line (rail) and performance of the decay circuit is predictable since it depends almost entirely on external component values rather than on the input impedance of the operational amplifier.

U1A is a dc amplifier with gain determined by R2 and R7. C2, D1 and R8 form a peak detector with the decay time determined principally by C2 and R8. U1B is a unity-gain buffer amplifier with D2 providing a level shift, enabling the output voltage to fall almost to zero. Common mode biasing is applied to both amplifiers via R4, R6, R10 and R11, with R_A providing the means for adjusting for zero-voltage output when zero-voltage input is applied. There is virtually no interaction between

*Asst. Technical Editor, *QST*



The 6Y5HJ modification of George Rice's PEP Wattmeter circuit (December 1976 *QST*). With this arrangement, the writer finds the wattmeter is less susceptible to the effects of strong rf fields. Resistance values are in ohms.

this zero-set control and the calibrate (CAL) control.

The unit is installed in a Heath SB634 station console. A PEP/NORMAL switch is fitted immediately to the right of the meter-selector buttons. Operating voltage (12 V at 9 mA) is taken from the digital-clock supply. This voltage passes through a dropping resistor and a Zener-diode regulator.

There was no particular desire to improve upon the circuit provided in Rice's article. My design came into being because I had the LM3900 on hand rather than the specified LM1458.

Acknowledgements are due the National Semiconductor Corporation for their comprehensive "Linear Application Notes." I found these to be invaluable as a means of learning how to design around this versatile operational amplifier. — *Jack Hollingsworth, 6Y5HJ, Kingston, Jamaica*

THINK CLEAN

Many of us, at one time or another, have had experience with fluctuating grid drive and plate current, erratic antenna loading and a variety of intermittent problems. The first inclination is to plop the rig on the workbench, warm up the test gear and start checking tubes, components, circuits and whatever else is suspected of causing the problem.

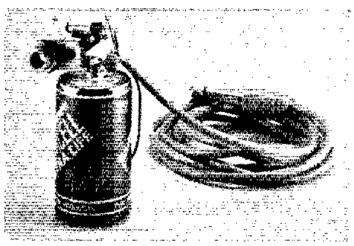
As the result of some years of experience, I have adopted what I term "the medical approach" to such situations. My number-one rule is: "before performing surgery, clean the patient thoroughly." I have frequently found that dirty and corroded switches and controls are the prime causes of problems, especially in the case of intermittents. Often, after a good cleaning with contact cleaner/lubricant, some of the most frustrating troubles will disappear. In performing the cleaning operation, a good grade of cleaner must be used. The cheapest is not always the best. — *Ken Johnson, W6NKE, Canoga Park, California*

A KEYING-POLARITY INVERTER

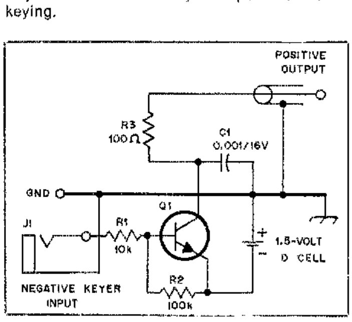
While operating the Ten-Tec Triton IV on Field Day, WBØJYT brought over his programmable electronic keyer to alleviate the cw stress. After being educated in the use of the new gadget, I was dismayed to find it would apparently key only a negative potential toward ground. Most of the newer solid-state rigs have positive keying.

I formulated an ultrasimple circuit, shown in the diagram, to solve the problem. I was back at the FD operation after about 20 minutes of basement construction.

As the transistor provides an input/output



The transistorized circuit atop this battery, rigged by KØYQX, answered an urgent Field Day need to convert a keyer for positive-line keying.



A simple circuit for adapting an electronic keyer designed only for negative keying. Q1 may be any general-purpose, small-signal npn transistor.

polarity inversion in the common-emitter configuration, the keyer simply keys the base while the collector keys the rig. Note that the schematic diagram is drawn to show the ground graphically as the center line — plus polarity above and minus polarity below. The dry cell negatively biases the emitter and also completes the circuit for the very nominal keying current. With the direction of current flow defined as from negative to positive, note that the cell current flows into the emitter and then to *both* the keyer, via the transistor base, and to the rig, via the transistor collector.

The keyer we used has the capability of being converted to the opposite polarity internally. Since it was Field Day and I was not the owner of the keyer, a quick external fix was needed; the inverter unit seemed the best alternative. — *John Bipes, KØYQX, Mankato, Minnesota*

FLOWER POT HIDES DUMMY ANTENNA

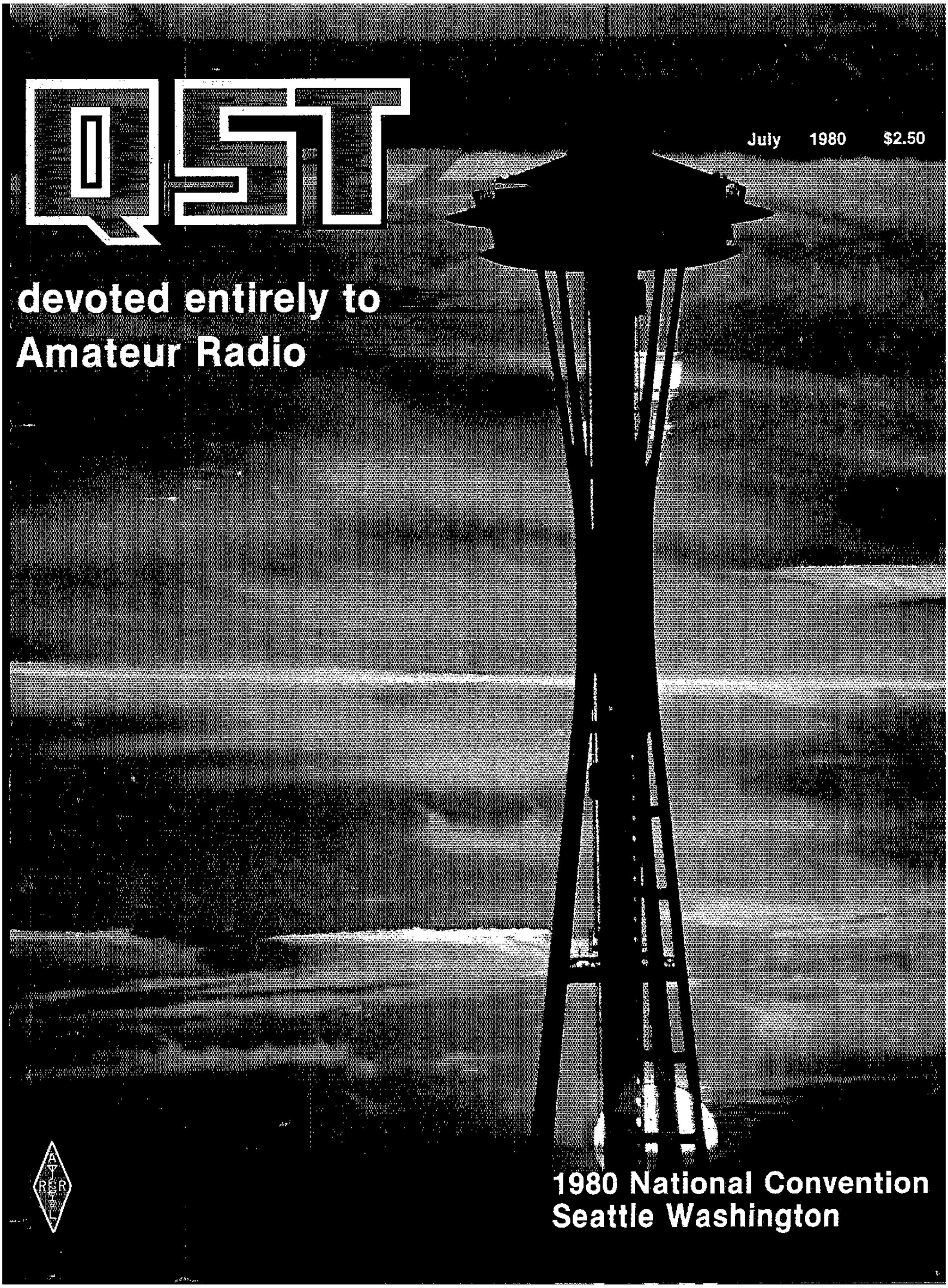
After several years of cussing tuner-uppers for their long-term carriers and their subsequent whistle solos, Tarzanian yelling of "Hellllooooooo" and practicing arithmetic with "one-two-three-three-two-one," I bought a bucket-of-oil type dummy antenna. About the time oil splatters appeared on my operating desk in the den, my wife came home from a shopping trip with a pair of large clay flower pots. She wanted me to hang these from the rafters in front of the den window. While installing the necessary hooks, one of which was close to where my antenna coaxial cables enter the den wall, I had an idea. Why not put the dummy antenna inside one of the pots? My wife, a ham helper for 49 years, agreed to the idea.

The bucket of oil is well hidden in the pot. A length of RG-58/U extends through the den wall into the coaxial switch. Out of sight, but not out of mind, that can of oil is outside the house where leakage can do no harm to the desk, shelves or carpet. My wife planted growing flowers in one pot and stuffed plastic flowers around the dummy in the other one. The hanging pots look good from the street. Now I can whistle and yell "hellllooooooo" while I tune up without someone thinking (or saying) "get a dummy, you dummy!" — *Don Hutchins, KB6DQ, Pomona, California*

THE OLD TIMER'S NOTEBOOK: CHASSIS AND PANEL LAYOUT

A common practice in the machine-shop and sheet-metal industries is to coat the metal to be fabricated with a blue-colored alcohol-base dye, known as "layout blue." The dye enables the worker to scribe accurately the dimensions of holes, bending lines, etc. Once the item is fabricated, the layout blue is removed with either paint thinner or a commercial vapor degreaser.

I recently discovered that the common felt-tipped Magic Markers available in most stationery, five-and-dime, or drug stores will work exactly like layout blue. Using the marker pencil, it is possible to color areas where drilling, punching or bending is required. Scribe lines as required and proceed with the fabrication. When finished, remove the ink with common nail-polish remover. This technique lends itself to more professional and accurate chassis and panel work. — *Robert F. Aherle, W2QPP, Carle Place, New York*, January 1963 *QST*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THE COVER

This is just one of the many splendid sights available to those who make their way to Seattle for the 1980 National Convention, July 25-27. *(photo courtesy Rudy B. Schroeder, W7FCB)*

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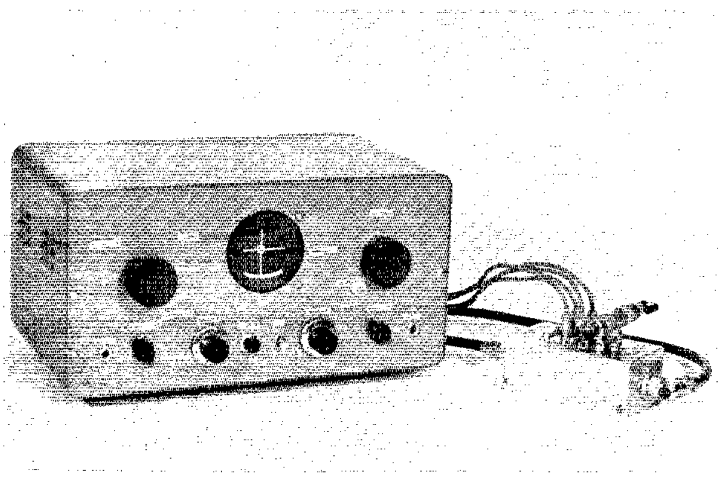
The Impedance-Match Indicator

Use this rf-impedance and phase-angle indicator instead of an SWR bridge to match antennas quickly and conveniently. Painless theory is included so you'll know the "why" as well as the "how."

By David Geiser,* WA2ANU



The impedance-match indicator, control unit on the left and sensor unit on the right. The control unit uses a novel surplus dual-movement meter, mounted in the center of the front panel.

The impedance-match indicator (IMI) gives a person tuning an antenna or transmission line more helpful information than a standing-wave ratio (SWR) bridge does, but is not much more difficult to build. Tuning is easier with the IMI, and the adjustment can even be made automatic using the IMI output.

Though the basic IMI is more than 30 years old and in fairly common use by the military, amateur use has been rare. This article gives the basic theory and construction of a simple IMI designed for use with transmitters rated at 50- to 500-watts output over the frequency range of 3.5 to 29.7 MHz. The IMI is calibrated by, and is almost as accurate as, the station dummy load.

*R. D. 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413

[1]Notes appear on page 16

The SWR bridge tells its users the degree of mismatch a transmitter or transmission line sees, but does not tell the user how to correct the match. The IMI tells the user whether the impedance is too high or too low, and whether it looks capacitive or inductive.

Introduction

A matched transmission-line load is a set resistance, usually 50 ohms for amateur transmitters. If the resistance is greater or less, or if there is some uncompensated inductance or capacitance in the load, the match will not be perfect. (A perfect match is indicated by a 1:1 SWR.) A small mismatch (a 1.2:1 SWR, for instance) can be tolerated by almost all transmitters, and many will operate well with larger mismatches.

Any load is made up of resistance and perhaps either capacitive or inductive reactance at a given frequency. The combination, called impedance, is simply E/I, and is indicated by a circuit in the IMI that determines whether the ratio is more than, less than, or equal to 50. The IMI also indicates phase angle. The phase angle is the difference between the phases of the rf voltage and current, and results from the presence of uncompensated capacitance or inductance. If the current lags the voltage, the load is inductive. If the current leads, the load is capacitive. If there is no phase difference, the load is purely resistive.

Sampling Voltage and Current in the IMI

Three voltage-sampling methods are shown in Fig. 1. A resistive voltage-divider (A) may be used, but resistors tend to be troubled with shunt capacitance, and they dissipate power. The inductive or autotransformer divider (B) may be troubled with stray capacitance and self-resonance. The capacitive divider (C) was chosen as the starting point because capacitors are easily found that have low loss and little inductance (air-variable and silver-mica capacitors, for example).

Two current-sampling schemes are shown in Fig. 2. In A, a small-value resistor is placed in series with the coaxial center conductor and the developed voltage is proportional to the current.[1] This sample, however, is above ground potential at the full rf voltage and, when rectified, may be difficult to return to rf ground.

Another method of sampling current, using inductive pickup from the coax line, is shown in Fig. 2B. A coil or single-turn loop with its axis parallel to the magnetic field of the center conductor will pick up a usable signal. Unfortunately, the sample voltage is proportional to both the current and frequency. This means that 1 ampere of rf at 29.7 MHz would give a sample 8.5 times larger than that given by 1 ampere of current at 3.5 MHz. This is acceptable,

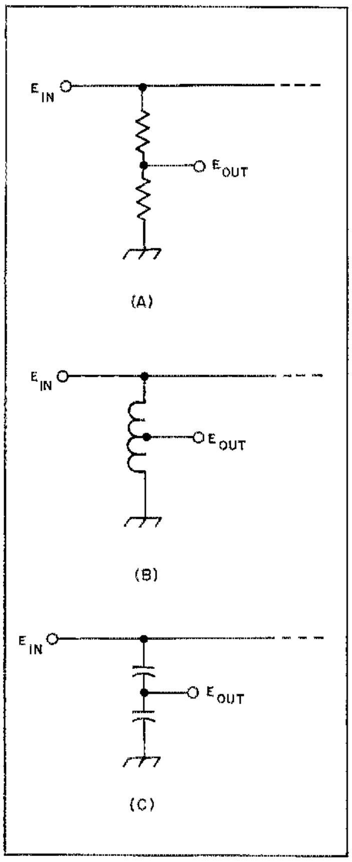


Fig. 1 — At A, a resistive voltage divider, at B, an inductive voltage divider, and at C, the capacitive voltage divider used in the IMI.

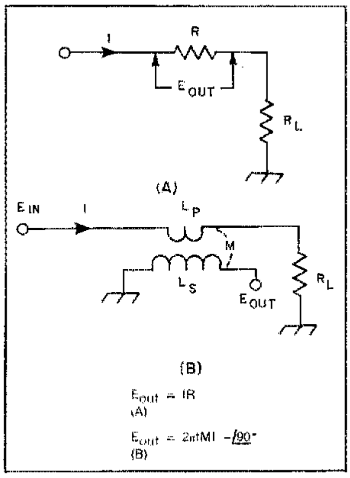


Fig. 2 — At A, a resistive current sensor, and at B, the inductive current sensor used in the phase indicator. Note the frequency sensitivity. M is the magnetic coupling between L_P and L_S.

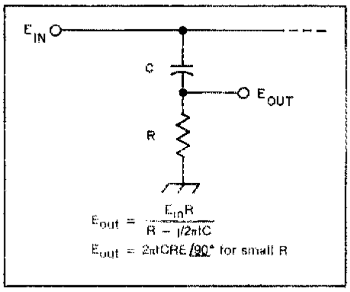


Fig. 3 — An R-C voltage sensor. Note the frequency sensitivity.

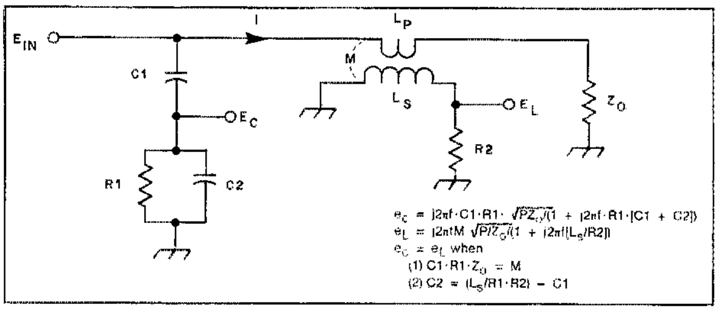


Fig. 4 — The frequency-compensated voltage (E_C) and current (E_L) sensors used in the impedance indicator.

however, since the modified capacitive sampler shown in Fig. 3 has the same response. Note that when the voltage sample in Fig. 3 ($2\pi fCRE\angle 90°$) is divided by the current sample from Fig. 2B ($2\pi fMI\ -\angle 90°$) to determine impedance, the term for frequency cancels out.

An increase of 3.16 times in both voltage and current will occur as the power level is increased from 50 to 500 watts (the IMI power-level design range). This means that if a sample of 1 volt were obtained at 3.5 MHz from 50 watts of rf, we could expect the sample to be 27 volts at 500 watts and 29.7 MHz. With an appreciable SWR, the voltage could be even higher. This makes the choice of diode rectifiers critical. Thus, a flattening of the sampler frequency response would be very desirable.

A bit of ingenuity was required to produce the circuit of Fig. 4. The voltage sampler (left) and the current sampler (right) give equal outputs when the equalities shown, (1) and (2), are satisfied. When the denominators of the sample-voltage equations (E_C and E_L) have an absolute value of about 2 at the lowest design frequency, the output flattens rapidly with increasing frequency. My goal was to have the output only about 25% higher at 29.7 MHz than at 3.5 MHz.

Measuring Impedance (The E/I Ratio)

Because of the way the samplers are set up, a 50-ohm impedance at any phase angle would give the same sample rf voltages. These voltages, when rectified to dc, would also be independent of phase. With voltages equal, the same type of rectifier can be expected to respond equally to each sample.

These samples could now be provided to a divider microcircuit which, after considerable processing, would display a good big number "50." There is, however, a much simpler way to determine if the sample voltage ratio is 1:1 (50 ohms). Make one of the samples (E_C, for instance) positive and the other negative. Add them. If the result is zero, the ratio is 1:1. If the result is positive, then E_C is too high for the load to have been 50 ohms or less. If the result is negative, the impedance is less than 50 ohms. If the dc output of both samples were made positive, then a microammeter (used as a millivoltmeter) could be connected between the two outputs to determine which is larger.

Note that neither of the methods will calculate the exact impedance, but only whether the impedance is above, below, or exactly 50 ohms. Zero-center microammeters are ideal for the display, and may usually be found at flea markets for two or three dollars. Uncalibrated ones are just fine, for the only really important point on the scale (zero current) can be calibrated by turning the rig off!

Phase Indicator

In order to determine the unknown phase, we must have two independent sets of samples, one whose output is always in phase with the voltage being sampled and one whose output is phase dependent. The capacitive voltage divider in Fig. 1C provides the former set of samples. For the latter, the inductive current sensor from Fig. 2B is useful. The rf sample (when feeding a resistive load in the primary circuit) lags the primary current by 90°. If we reversed the secondary winding, that sample output voltage would lead the primary current by 90°. Fig. 5A shows the capacitive voltage sampler connected to one normal and one reversed current sampler. Here we obtain equal rf outputs (E_{lead} and E_{lag}) when we feed a purely resistive load, as in Fig. 5B. (That isn't strictly true, but is true enough if the reactance of L_P is very small compared to R_L.) When these rf voltages are rectified and compared, as in the impedance meter just discussed, they will indicate zero when there is zero phase angle between the load voltage and current.

The picture changes when the load becomes somewhat capacitive. The load current leads the load voltage by some angle, A° in Fig. 5C. The current-sensing samples E_{M1} and E_{M2} tilt the same amount, and now E_{lead} is greater than E_{lag}. The dc output corresponding to E_{lead} is greater, and I chose polarities to swing a zero-center meter to the right. For an inductive load, conditions reverse, with E_{lag} now larger, and the meter swings left of zero. (This is done as a memory aid: Left = L = inductance.)

The frequency sensitivity of the phase-indicator sample voltages distressed me (remember they change 8.5:1 from 29.7 to 3.5 MHz) until I reexamined Fig. 5. In the worst case (pure inductive or capacitve load), the greatest difference possible between E_{lag} and E_{lead} is twice E_C. The solution came in a flash: Make E_C smaller than either E_M at the lowest operating frequency. This can be done by making C3 smaller, C4 larger, or both. Remember, E_C is not frequency sensitive, so the maximum output difference for a given impedance is *not* frequency sensitive.

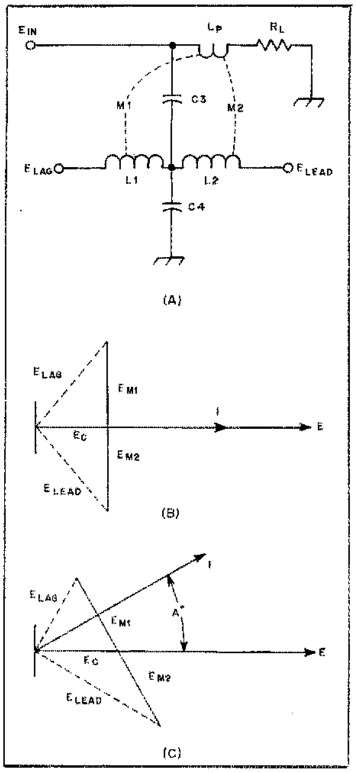


Fig. 5 — Phase sensor circuit and phase relations. Vectors with E and I in phase are shown at B. At C is the effect of current-leading phase.

Adding and Displaying Indicator Signals

The dc sampling voltages may be "added" with a pair of resistors. In Fig. 6, if R_A and R_B are equal, the deflection of the meter will be proportional to the sum of E_1 and E_2. Of course, if the two voltages have opposite polarity the deflection is proportional to their difference. With a 50-ohm impedance and zero phase angle, the voltages will be equal but opposite, so the deflection ideally would be zero.

Variations in components used, frequency, or power can be expected to make some change in the sensor output voltages. The resistor-value ratio can be changed to still give zero indication at "ideal" conditions, the easiest way being the replacement of the two equal resistors with a potentiometer, as shown in Fig. 6B.

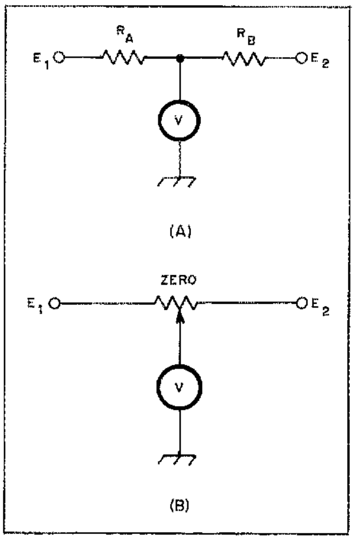


Fig. 6 — An analog addition circuit. A potentiometer, as shown at B, allows meter zeroing with somewhat unequal voltages of opposite polarity.

Construction Details

The schematic of the fully evolved IMI is shown in Fig. 7. The two critical parts are the transformer and the sensor case. The core from the Amidon kilowatt balun kit was chosen because many amateurs have one or more spares in the junkbox. If not, it is still available from the manufacturer. This core will fit snugly in the standard-size box chosen for the sensor assembly, with good winding separation. Coupling to the coaxial center conductor is low, but this is even something of an advantage. After the transformer was wound, the critical secondary and mutual inductances of the impedance-sensing current winding measured 1.72 and 0.104 μH, respectively.[2] Details of the transformer are given in Fig. 8. Since the case is part of the transformer primary circuit, the case cover must be held securely in place. The case screws must also be tight; if one of the self-tapping screws strips the mating hole in the case, get a larger screw and make a tight joint. Sensor wiring should be concentrated along the case walls to minimize unwanted inductive pickup by the wiring. Sensor dc outputs should be bypassed with capacitors having short leads. This should be done very close to the output connectors.

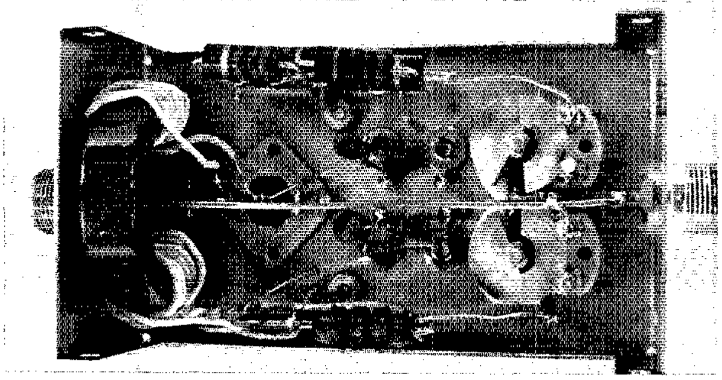
Variable capacitors C1 and C3 may be compression-mica or glass-piston types if the power level in use is 200 watts or less. Although the IMI works well with a fixed capacitor for C2 as shown in Fig. 9, there is some advantage in making C2 variable. As may be noted from the equations in Fig. 4, (conditions 1 and 2), practically every factor in the impedance-indicator section of the IMI may be balanced if C1 and C2 are both variable. I used 680-pF ceramic capacitors for C5 through C10. This value was used mainly because they were available; any value up to 0.001 μF is fine.

A moderate amount of power is dissipated in R1 and R2 when operating at the kilowatt power level or with a high SWR. Each of these resistors was made of four 2-watt composition resistors. R1 consists of four 220-ohm resistors in a series-parallel combination. R2 is four 100-ohm resistors in parallel. (R2 may also be a pair of 50-ohm CB dummy loads paralleled with a coaxial T adapter.)

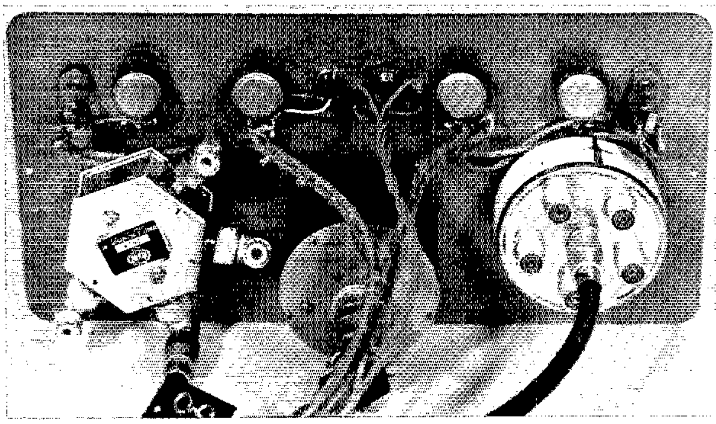
Since any adjustment of the load tends to make both meters swing, I like to have the meters as near each other as possible to avoid getting cross-eyed! Meters whose sensitivity ranges from 50-0-50 to 500-0-500 μA should be suitable. The low-current meters may have to be shunted to keep from pinning the needle. High-current meters should have a long scale so that small deflections can be seen easily.

The indicator unit that I built for fixed-station use uses an aircraft blind-landing indicator having two microammeters (250-0-250 μA) in one case at right angles to each other.[3] An AN (or MS) 3100-14S-2S plug and an AN (or MS) 3057-6 (or -6A) cable clamp adapter can be used to mate with this meter. However, it is not necessary to use these military connectors for this meter. The pins may be contacted with a wire wrap, or with the correct-size contacts salvaged from a non-mating connector.

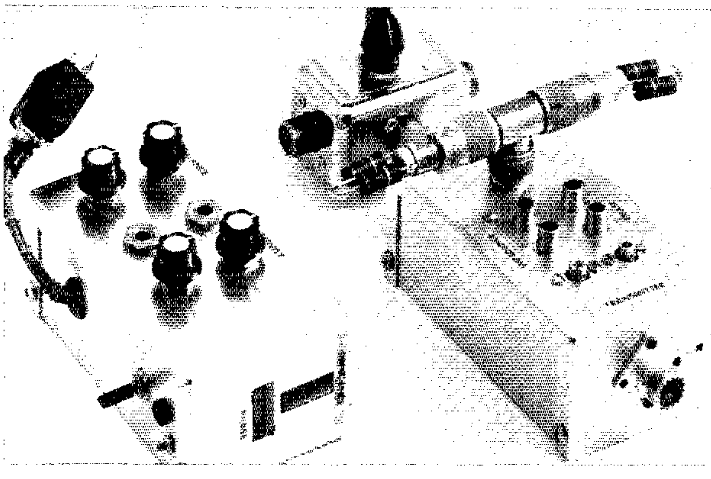
Dc leads from the sensor to the indicator unit were made of shielded audio patch cords which, because they are quite



An inside view of the rf sensor. The toroidal transformer is against the antenna end of the sensor case and may be held in place with whittled slabs of Styrofoam inside the core.



A rear view of the control panel. Liberal use of shielded wire minimizes rf pickup by the dc circuits.



At the left is a stripped-down balancing and indicator section for mobile use. Note that on the near end of the surplus tuning indicators are mounted close together and at right angles to each other. S1 has been replaced with a dpdt center-off switch (Radio Shack 275-664) to permit either remote keying or tuning motor operation. A 1.5-V battery, 15-mA lamp and push-button switch are included for night-time meter illumination.

lossy at rf, provide additional filtering. I also built a smaller indicator unit for mobile use, and used two surplus fm tuning indicators (100-0-100 µA) instead of the cross-pointer meter.

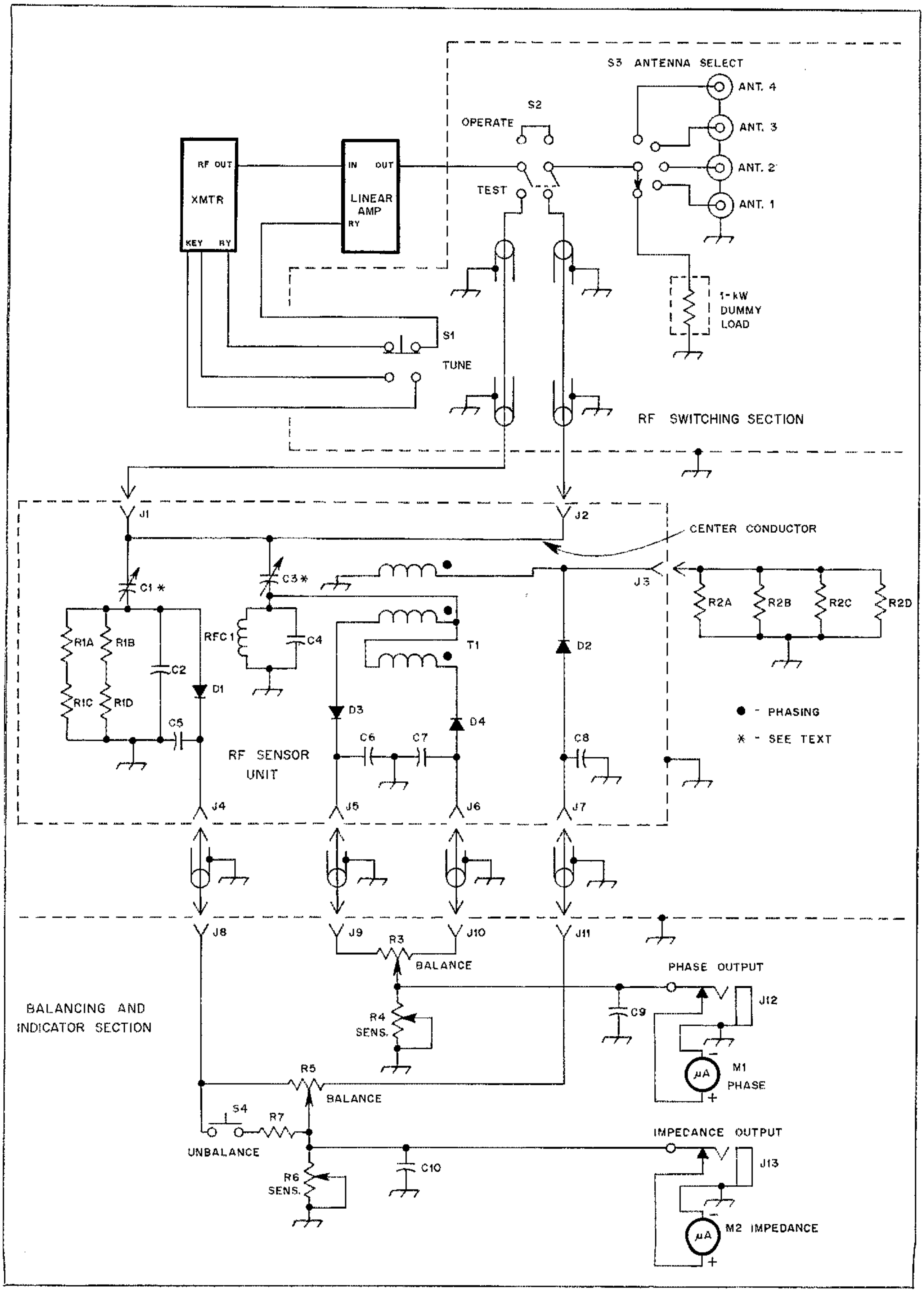
Added Features

I put a test switch, S1, on the indicator unit so the transmitter could be keyed (with the linear amplifier, if any, turned off) from the test position. With a little practice using this test switch, it is possible to perform the full tune-up with a few one-second squirts of rf. S2 is a transfer switch to remove the IMI completely from the circuit. The detector diodes will generate some harmonics, and any harmonics that might cause TVI are too much for my taste. S3 is an antenna-changing switch. It permits calibration by the station dummy load and permits easy change to the antenna or transmission line under test. S4 unbalances the impedance-balancing potentiometer to check for the presence of rf when testing into the dummy load or other well-matched load.

An output jack is provided so the mismatch dc signals can feed an automatic control system which retunes the antenna or transmission line when changing frequency or load.[4] It is good to use capacitors that will rotate 360 degrees when a motor-driven automatic control system is used, for while the motor may drive it in the wrong direction for half a

Fig. 7 — The IMI schematic and connections to related equipment. Much of the rf switching section is optional (see text). Details of T1 are given in Fig. 8. All balancing- and indicator-section wiring is run in shielded cable such as Radio Shack no. 278-1277. The sensor unit case is a 5-1/4" × 3" × 2-1/8" aluminum box (Radio Shack 270-238). Part numbers below are Radio Shack unless otherwise indicated.

C1, C3 — Air variable, 4-35 pF (see text).
C2 — Silver mica, 300 pF, 500 V, 10% tol.
C4 — Silver mica, 510 pF, 500 V, 10% tol.
C5-C10 incl. — Disc ceramic, 680 pF, 500 V (see text).
D1-D4, incl. — 1N4148, 276-1122. For a low-power IMI, use 1N34, 276-1133.
J1-J3, incl. — SO-239 coaxial jack, 278-201.
J4-J11, incl. — Phono jack, 274-346.
J12, J13 — Telephone jack, two-conductor, closed-circuit, 274-255.
M1, M2 — Dual 250-0-250 µA zero-center meter, Signal Corps I-101D (see text).
R1A-R1D, incl. — Composition, 220 Ω, 5% 2-watt. A single 220-Ω, 2-watt resistor will suffice for an rf power level of 100 watts or less.
R2A-R2D, incl. — Composition, 100 Ω, 5% 2-watt (see text).
R3, R5 — Carbon control, 10 kΩ, linear taper, 271-1715.
R4, R6 — Carbon control, 500 Ω, linear taper, 271-226.
R7 — Composition, 10 kΩ, 1/4 watt, 271-034.
RFC1 — 1-mH, 3-pie rf choke, J. W. Miller type 4662.
S1 — Momentary switch, two-circuit NO/NC, Alcoswitch MPA-206R.
If only key function is desired, use Radio Shack 275-609.
S2 — Coaxial rf transfer switch, B&W model 551A.
S3 — Coaxial 5-position antenna switch, B&W model 590G.
S4 — Push button, NO, 275-609.


S3 ANTENNA SELECT
ANT. 4
ANT. 3
ANT. 2
ANT. 1
S2
OPERATE
TEST
RF OUT
XMTR
KEY
RY
IN
OUT
LINEAR AMP
RY
S1
TUNE
1-kW DUMMY LOAD
RF SWITCHING SECTION
J1
J2
CENTER CONDUCTOR
J3
C1 *
C3 *
R2A
R2B
R2C
R2D
R1A
R1B
R1C
R1D
C2
RFC1
C4
T1
D1
D2
D3
D4
C5
C6
C7
C8
RF SENSOR UNIT
• - PHASING
* - SEE TEXT
J4
J5
J6
J7
J8
J9
J10
J11
R3
BALANCE
PHASE OUTPUT
J12
C9
R4
SENS.
μA
M1
PHASE
BALANCING AND INDICATOR SECTION
R5
BALANCE
S4
R7
UNBALANCE
R6
SENS.
C10
IMPEDANCE OUTPUT
J13
M2 IMPEDANCE

turn, it rotates in the proper direction for the other half.

Alignment

Connect the IMI as shown in Fig. 7, but install a coaxial T adapter at J2. Connect the cable from S2 (or dummy load) to one port of the T adapter. The other port will be used in a later test. Unplug the cables at J8 and J11 and temporarily connect the center contacts of J8 and J11 together. Connect an ohmmeter from this connection to ground, and adjust the IMPEDANCE BALANCE potentiometer, R5, for a minimum ohmmeter reading. (This current goes through the indicator, so use a low-current ohmmeter.) The ohmmeter reading should be in the vicinity of 5 kΩ. Reconnect the cables to J8 and J11.

Load the transmitter into the dummy load at about 3.5 MHz and adjust C1 for an impedance-meter indication of zero. Switch the transmitter to 28 MHz and readjust R5 to cut the meter deflection in half. Switch back to 3.5 MHz and repeat the C1 adjustment. Go back to 28 MHz for a repeat of the R5 adjustment. It may be necessary to adjust R5 to exactly zero-current on a particular band of interest (see "Operation" paragraphs), but the adjustment should hold over that entire band. (If C2 is adjustable, it should be used instead of R5 for the rf adjustments.)

If there is a problem, check the voltages at J4 and J7 with a 20,000-ohm/volt voltmeter. They should be approximately equal in value but of opposite polarity. If they are not equal, the transformer inductances may not have duplicated mine, or there may be a loose case screw. Moderate differences may be corrected by changing the value of C2 slightly. If the voltages are not of opposite polarity, one diode is reversed.

Key the transmitter at 3.5 MHz, and adjust the PHASE BALANCE potentiometer, R3, for a phase meter indication of zero. Make up two capacitors (or calibrate two air-variable capacitors) for the values of 640 pF and 107 pF approximately, and connect them across the open port of the T connector at J2. These will cause an equal SWR and phase mismatch at 3.5 and 21 MHz. Starting with C3 at minimum, note the phase deflection at 3.5 and 21 MHz; the two should be approximately equal. Increase the value of C3 (but not above 10 pF) for greater deflection and recheck at the two frequencies. If the deflections are no longer equal at the two frequencies, the value of C3 should be reduced until they are.

The test capacitors cause a 2:1 low-impedance capacitive SWR temporarily, so the test transmitter used should be able to withstand the mismatch or be lightly loaded. Both needles of the IMI will be deflected into the low-impedance capacitive region: This will give a check on the meter movement connection polarity. Disconnect the test capacitors and remove

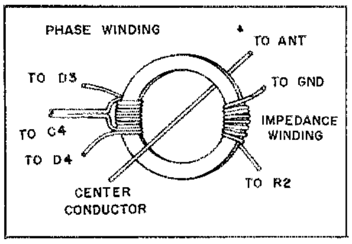


Fig. 8 — The core of T1 is an Amidon T-200-2. This is the same core as used in the Amidon kilowatt balun kit. The primary is a straight length of no. 14 A.W.G. wire connected between the center contacts of two SO-239 connectors, which are centered in opposite ends of the sensor case. The impedance-indicator secondary is eight turns of no. 20 A.W.G. wire. The phase-indicator secondary consists of two bifilar windings. Each winding is five turns of no. 20 A.W.G. wire.

the T connector after the adjustment of C3 is completed.

If there is a problem with the phase-indicator section, check the open-circuit voltages at J5 and J6. They should be equal but opposite, as in the impedance-indication section. The balance should be best on the lower frequencies. A marked difference here is a clue that one of the halves of the winding has one more turn than the other.

Operation

It is best to install the IMI just before the antenna tuner. Indications will then be directly related to the tuning or matching adjustment without having to take transmission line effects into account. It is almost as helpful to have the IMI at the transmitter if you remember that the connecting length of transmission line might make high impedances look low, reactances change from capacitive to inductive and vice versa. In that case, the most important thing to remember is that when the IMI says the line is 50 ohms and purely resistive, it really is, regardless of the length of interconnecting transmission line.

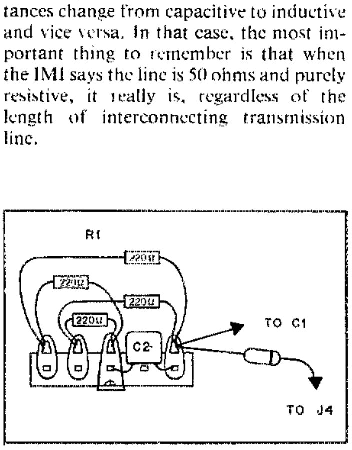


Fig. 9 — The four resistors of R1 are wired as shown to display as low an inductance as possible. A five-lug terminal strip is used. Their distributed capacitance forms a part of C2. The resistor values shown are in ohms.

The IMI procedure recommended is to first switch the IMI to the station dummy load, turn on the transmitter and adjust the BALANCE potentiometers, R3, and R5, for a meter indication of zero. Calibration will hold for that band, at least. Next, switch the IMI to the antenna for a brief rf burst. You can learn much in a one-second rotation of an antenna-tuner variable capacitor. Another burst is given while tuning the other capacitor. (It is not a good idea to tune a roller inductor with full power!) The two capacitor swings should tell you if circuit inductance is approximately correct. Ideally between the swings, the indicated impedance should change between high and low, and the reactance change type. If not, inductance change may be needed and should be done without rf power applied.

When the desired change is seen and the meter indicators approach center, longer bursts should allow exact zeroing (using the antenna tuner) without danger to the rig. Remember that exact meter zeroing means the IMI is seeing the same load impedance and phase as that presented by the station dummy load. Less than 20 pF of shunt capacitance is added by the IMI when it is in the line. This will increase the SWR seen by the transmitter to no more than 1.2:1 at 29.7 MHz. Switching out the IMI after tuning presents the perfect load to the rig.

One good rule to remember: Conduct antenna tests at the lowest possible power and for the briefest possible time. This protects equipment and causes the least interference.

Afternote

As this article is going to press we note that surplus automatic antenna tuners for 2 to 22 MHz have come on the market.[5] While the average amateur may find the 28-V dc and 400-Hz power requirements impossible, the components (including the sensor head) are available separately and should be an excellent foundation for an 80- to 15-meter automatic tuner. This article is dedicated to Virgil True and the many other engineers and amateurs who have worked with this idea for the past few decades.

Notes

[1] The M. C. Jones (Bendix) Micromatch SWR bridge Model 261 does this successfully.

[2] A description of the method of measurement and resulting impedance sensor design procedure will be furnished by the author if the request includes a self-addressed, business-size envelope with postage for one ounce.

[3] The I-101D has been a stock item at Fair Radio Sales for more than 20 years. At the time this goes to print it is offered for $5 reconditioned, and $2.95 with broken glass. They do offer an unused similar item, the ID-304/APA-70C at $7.95. Herbach and Rademan, Inc., offers a similar indicator, TM21K840 (Catalog Vol. 45 No. 4), for $7.50. Both sources are subject to prior sale.

[4] Imamura, "An Automatic Antenna Tuner," *QST*, April 1980.

[5] Fair Radio Sales offers the CU-991 antenna coupler and several of its components in their catalog WS-79, pages 1 and 36.

Active Filters

Why not build one of these nifty filters or use the design information to customize your own!

By Alan Bloom,* N1AL

One of the triumphs of modern technology is that you can build "tuned circuits" and all kinds of other filters entirely without coils. Those generations of RTTY enthusiasts who grew up depending on the ubiquitous 88-mH toroidal inductors might be shocked to discover that you can replace up to four of these bulky items with a single IC. Besides their size and expense, coil-capacitor filters at audio frequencies are notoriously hard to tune — it's just hard to find variable coils or capacitors big enough to do the job. Many active filters can be tuned with an inexpensive potentiometer.

What *is* an active filter? Well, what is a *filter*? We generally consider a filter to be any circuit designed to attenuate some frequencies more than others. A *high-pass* filter passes high frequencies with little attenuation while providing greater attenuation to the lower frequencies. See Fig. 1A. The *cutoff frequency* of a high-pass filter is the lowest frequency that passes with relatively little attenuation. The region above the cutoff frequency is the *passband,* and the region of high attenuation is the *stopband.* A *low-pass* filter has its passband below the cutoff frequency and its stopband above. A *band-pass* filter has two stopbands — one above and one below the passband, and a *band-stop* filter has a stopband between a pair of passbands. See Fig. 1B.

An *active* filter is simply a filter that uses an active device to improve the attenuation characteristics. That Q-multiplier in your old receiver is an early type of active filter. While most active filters these days use operational amplifiers (op amps),[1] you can make some type of active filter with almost any device that has power gain.

RC Active Filters

It's quite possible to design active filters using coils. We've already mentioned the antediluvian Q-multiplier as one example, and we'll look at a couple of others later. But today, most people try to design inductors *out* of their circuits, at least at audio frequencies. As previously mentioned, coils for audio frequencies are often large and frequently expensive. Although passive LC (inductance-capacitance) filters require no power supply, you have to design them carefully to minimize loss, paying careful attention to input and output impedance matching. Active filters, on the other hand, can easily be designed for almost any desired input and output impedances, and can give considerable gain to boot! RC (resistance-capacitance) active filters are especially useful at low audio frequencies where the large inductances needed for LC filters become impractical.

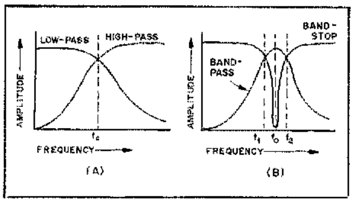


Fig. 1 — At A, plots of relative output versus frequency for high-pass and low-pass filters; f_c is the cutoff frequency. At B, plots of relative output versus frequency for band-pass and band-stop filters; f_0 is the center frequency. The area between f_1 and f_2 is the passband of the band-pass filter and the stopband of the band-stop filter.

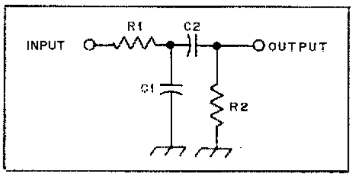


Fig. 2 — A passive RC band-pass filter. Maximum Q obtainable is only 1/2.

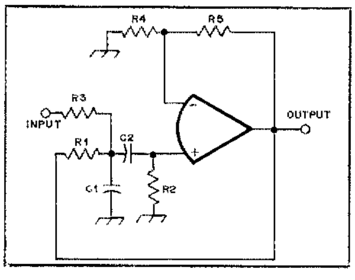


Fig. 3 — An active RC band-pass filter. To design a filter using this circuit, make all the frequency-determining resistors and capacitors equal: R1 = R2 = R3 and C1 = C2. Choose a convenient value for C and then $R = \sqrt{2}/(2\pi Cf_0)$, where R is in kΩ, C is in μF, and f_0 is in kHz. $Q = f_0/B$, where B is the 3-dB bandwidth in kHz. R4 and R5 determine the Q: $R5/R4 = 3 - (\sqrt{2}/Q)$. The voltage gain is $2Q\sqrt{2} - 1$.

Band-Pass RC Active Filters

You *can* make an RC filter without any active devices. Look at Fig. 2. At high frequencies, most of the signal is shorted out by C1. At low frequencies, most of the signal is blocked by C2. Thus the circuit of Fig. 2 is a band-pass filter. The limitation is that the maximum Q possible with this type of filter is only 1/2.

Those familiar with Q-multipliers or regenerative detectors may recall that one way to increase the Q of a tuned circuit is to introduce a little positive feedback around it. (If you apply too much feedback, the circuit will oscillate.) The same trick works for an RC bandpass filter. See Fig. 3. Here R3 has been added to couple in the signal. You can use a number of different resistor and capacitor values to achieve the desired filter characteristics, but for simplicity we usually make the two capacitor values the same and also let R1 = R2 = R3.

Let's say we want a 1-kHz band-pass filter with a 3-dB bandwidth of 600 Hz. The bandwidth is just the center frequency divided by the Q so we have $B = f_0/Q$ or $Q = f_0/B = 1000/600 = 1.67$. So using the equations from Fig. 3, $R5/R4 = 3 - (\sqrt{2}/1.67) = 2.15$. The actual values of these resistors are not too important — it's the *ratio* of the two that determines

*2425 Corby Avenue, Apt. 7, Santa Rosa, CA 95401
[1]Notes appear on page 21.

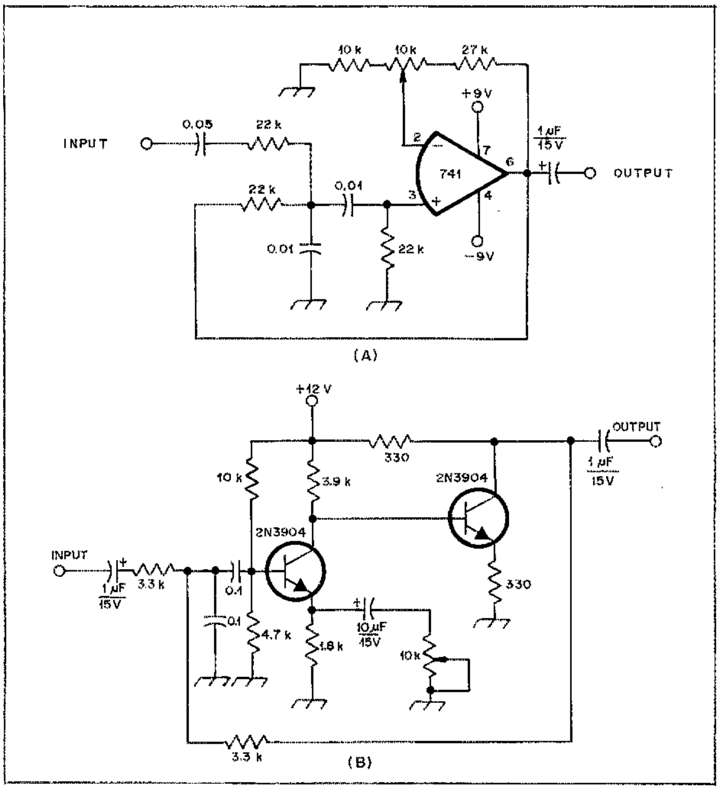


Fig. 4 — A practical audio filter is shown at A, based on the design in Fig. 3. The Q can be varied by adjusting the 10-kΩ potentiometer. A band-pass filter using discrete transistors is shown at B. R2 in Fig. 3 is the parallel combination of the 4.7-kΩ and 10-kΩ resistors in Fig. 4B (about 3 kΩ).

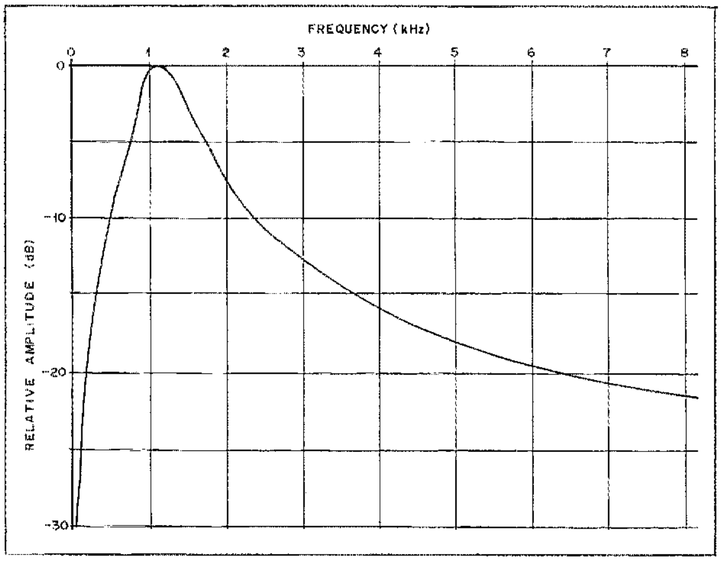


Fig. 5 — Measured frequency response of the filter of Fig. 4A. The center frequency and bandwidth are not exactly as predicted because of component tolerances.

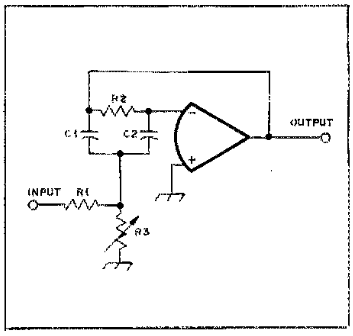


Fig. 6 — A tunable band-pass filter. After choosing a value for C (C1 = C2), then R2 = 1/(πBC), where R2 is in kΩ, C is in µF, and B is the bandwidth in kHz. R1 (kΩ) = R2/2G, where G is the desired numerical voltage gain at resonance.

$$R3\ (k\Omega) = \frac{1}{2\pi C\,[(2f_0^2/B) - BG]}$$

where f_0 is in kHz. Insert the minimum and maximum values of f_0 into the above equation to get the maximum and minimum values for R3.

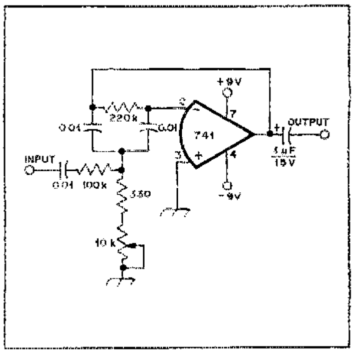


Fig. 7 — A practical band-pass filter that tunes from 350 to 2000 Hz.

the Q and gain. Let's choose R4 = 15 kΩ. Then R5 = 2.15 × 15 kΩ = 32 kΩ. (If R5/R4 = 3, the Q is infinite and the circuit becomes an oscillator.) To allow for resistor tolerances you usually use a potentiometer to adjust the gain to get the exact Q you want. See Fig. 4A. With the potentiometer set to the middle of its range, the effective values of R4 and R5 are 15 kΩ and 32 kΩ respectively, as desired. Next, choose a value for R or C. Let's let C = 0.01 µF. (All of the formulas in this article express capacitance in microfarads, resistance in kilohms, and frequency in kilohertz.) Then R = $\sqrt{2}/(2\pi C f_0)$ = 22.5 kΩ or about 22 kΩ. Fig. 5 shows the measured frequency response of the circuit in Fig. 4A. You can raise or lower the Q by adjusting the potentiometer. If you want to tune this

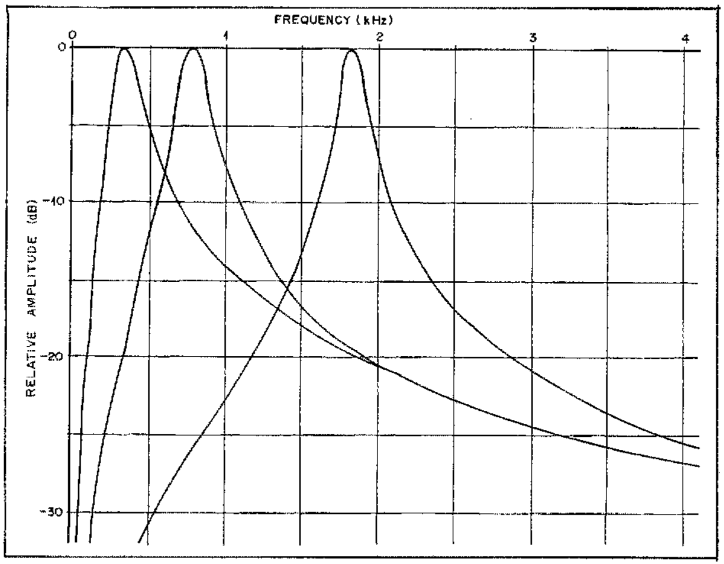


Fig. 8 — Measured frequency response of the circuit of Fig. 7 for three settings of the potentiometer.

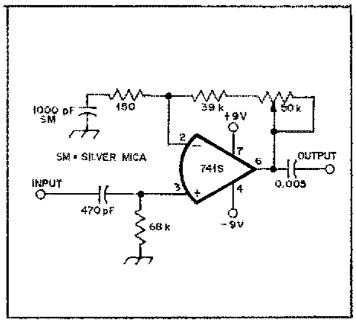


Fig. 13 — A 50-kHz band-pass filter. Calculated voltage gain is 200 and the Q is 10, giving a bandwidth of 5 kHz. Since a standard 741 op amp does not work well above 10 kHz, a high-slew-rate version is used. To design for other frequencies, first choose a value for C1, then $R2 = GB/(2\pi C1 f_o^2)$, where GB is the gain-bandwidth product of the op amp (1000 kHz for a 741 or 741S). Choose Q using $Q = f_o/B$ or $Q = Gf_o/GB$. Then

$$R1 = \frac{R2 f_o}{GB}\left(\frac{1}{Q} - \frac{f_o}{GB}\right).$$

The highest possible Q is GB/f_o and the highest possible gain is QGB/f_o.

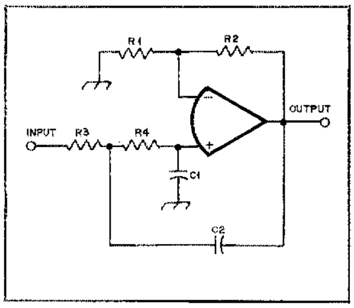


Fig. 9 — A low-pass active filter. For Q greater than one, a low-pass filter has a peak in the frequency response similar to that of a band-pass filter. For relatively narrow bandwidths, Q is approximately f_o/B. $R2/R1 = 2 - (1/Q)$. For a given value of C ($C1 = C2$), $R3 = R4 = 1/(2\pi f_o C)$, where R is in kΩ, C is in µF, and f_o is in kHz. The gain at f_o is $3Q - 1$.

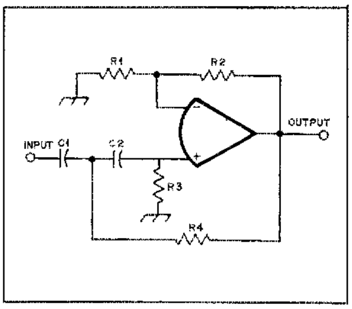


Fig. 11 — A high-pass filter. For fairly narrow bandwidth (high Q), the Q of a high-pass filter is approximately f_o/B. $R2/R1 = 2 - (1/Q)$. For a given value of C ($C1 = C2$), $R3 = R4 = 1/(2\pi f_o C)$, where all quantities are expressed in the same units used in the previous examples. The gain at f_o is $3Q - 1$.

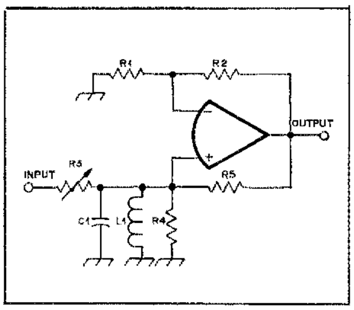


Fig. 14 — A band-pass LC active filter. $Q = f_o/B$. Choose a convenient value for L1, then

$$C1 = \frac{1}{(2\pi f_o)^2 L1}$$

where L1 is in henrys and C1 is in µF. $R3 = QX$, where X is the inductive or capacitive reactance in kΩ ($X = 2\pi f_o L$). The gain is $1 + R2/R1$. $R2/R1 = R5/R4$. R4 includes the losses in L1.

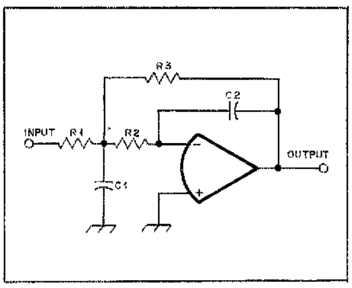


Fig. 10 — Another low-pass filter. Choose C2, then $C1 = C2(3Q)^2$. $R1 = R2 = R3 = 1/(2\pi f_o \sqrt{C1C2})$, where R is in kΩ, C is in µF, and f_o is in kHz. The gain is equal to Q.

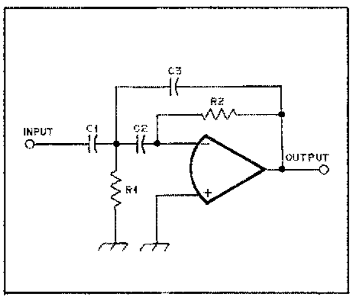


Fig. 12 — Another high-pass filter. Choose R1, then $R2 = R1(3Q)^2$. $C1 = C2 = C3 = 1/(2\pi f_o \sqrt{R1R2})$. The gain is equal to Q.

filter without changing the Q, you would need three ganged potentiometers to replace R1, R2 and R3.

Don't get the idea that all RC active filters must be made with op amps. The design of Fig. 3 works fine using a pair of transistors. Fig. 4B is a practical example. The center frequency is about 700 Hz, and the bandwidth is determined by the setting of the 10-kΩ potentiometer.

The filter of Fig. 6 has the interesting property that you can tune the center frequency without changing the gain by varying a single resistor, R3.[2] In addition, the

Q increases with frequency in such a way that the bandwidth stays constant for all tuning settings — a sort of "poor man's passband tuning!"

To design one of these filters, you first choose the bandwidth (B), gain (G) and the lowest and highest frequencies to be tuned (f_{min}, f_{max}). Let's say you want to tune 350 to 2000 Hz (0.35 kHz to 2 kHz) with a bandwidth of 150 Hz (0.15 kHz) and a gain of one. Again we'll choose 0.01 µF for the capacitor value. From the formulas in Fig. 6, $R2 = 1/(\pi \times 0.15 \times 0.01) = 212$ kΩ, R1 = 106 kΩ and the minimum and maximum values of R3 turn out to be 300 Ω and 10.7 kΩ. Using the nearest standard resistor values, we get the circuit of Fig. 7. Fig. 8 indicates the measured frequency response for the circuit. If your calculations give you a negative value for R3, then your lower frequency limit is too low or your gain is too high. Choose new values and recalculate.

Low-Pass RC Active Filters

If you need attenuation of *higher* frequencies only (such as adjacent-channel ssb interference), a low-pass filter will fill the bill. Representative designs are given in Figs. 9 and 10.

The circuit of Fig. 9 can be tuned by ganged potentiometers at R3 and R4. The Q can be adjusted by inserting a potentiometer between R1 and R2 as in Fig. 4A.

While it's not as easy to tune, the circuit of Fig. 10 has better stability than that of Fig. 9. For high values of Q, the gain and Q of the latter filter will change markedly for small changes in any of the resistor or capacitor values. If you need only a fixed-frequency filter, the one in Fig. 10 is a better choice.

High-Pass RC Active Filters

In principle, you can convert any RC low-pass filter into a high-pass filter by substituting resistors for all the capacitors and capacitors for all the resistors. The circuits of Figs. 11 and 12 correspond to the low-pass filters in Figs. 9 and 10, respectively. Their characteristics are similar except that they are high-pass in nature. Actually, for high values of Q, the frequency responses of band-pass, low-pass and high-pass filters are pretty much the same close to the peak frequency. It's only when you get well away from the passband that you start to notice differences in attenuation.

Fig. 13 is a band-pass filter that uses the internal frequency compensation of the op amp to replace one of the capacitors in the feedback network. This circuit has very high gain at low frequencies. Even at 50 kHz, the tuned i-f amplifier shown has a gain of about 200, which requires careful attention to circuit layout to

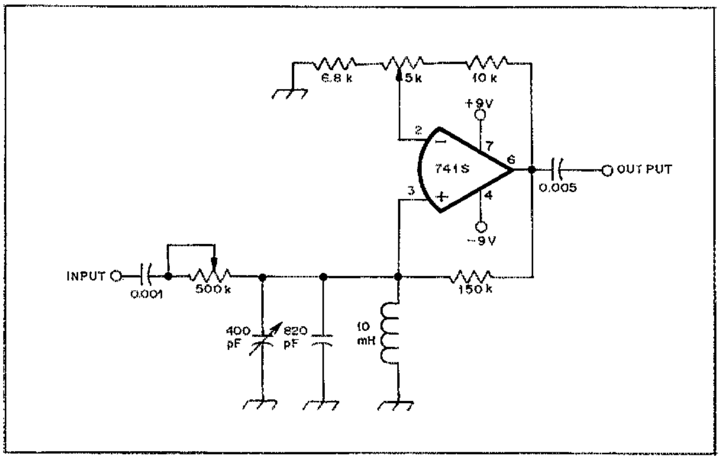


Fig. 15 — A tunable 50-kHz amplifier patterned after the circuit of Fig. 14.

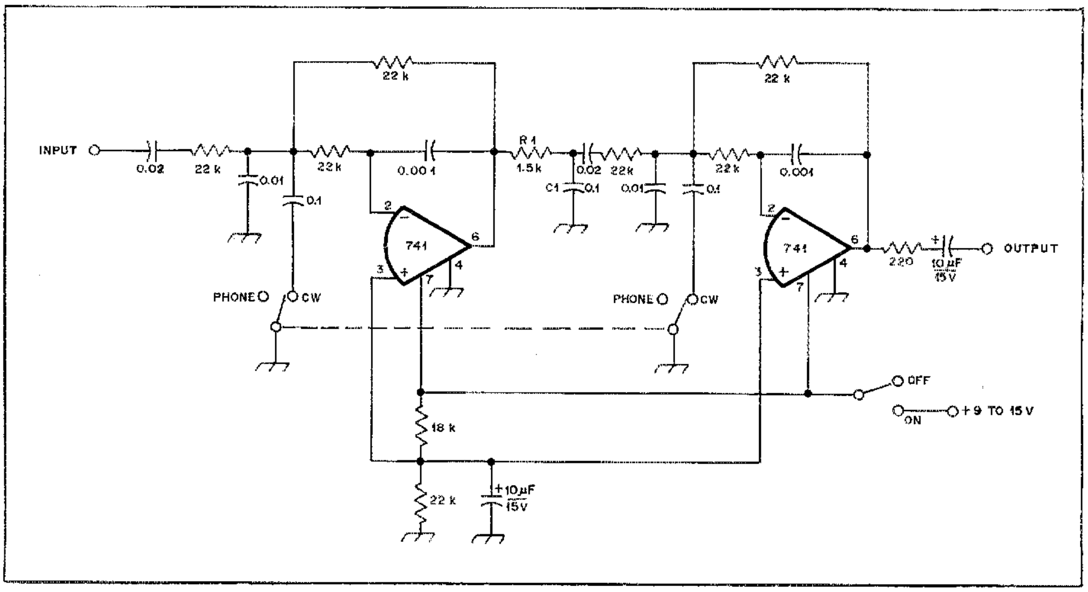


Fig. 16 — A combination phone and cw audio filter.

ensure stability.

LC Active Filters

One of the big advantages of active filters is that you can build high-Q filters without coils. On the other hand, if you *like* coils, you can still use them in active filter designs. In fact, this will sometimes result in a more stable and reliable circuit. Fig. 14 is an example. This band-pass filter circuit increases the effective Q of the coil by means of positive feedback through R5. You can set the Q by adjusting R3. In this circuit, changing the bandwidth does not alter the gain. When properly adjusted, this filter is more stable and easier to use than some RC circuits, especially at high frequencies.

For example, you can build a practical 50-kHz tuned amplifier (Fig. 15) that is less critical to construct than one based on an RC design. My 10-mH coil had a measured Q of only 37 at 50 kHz, but it was easy to obtain bandwidths less than 370 Hz, indicating an effective Q of over 130. To align this filter, disconnect the input and adjust the 5-kΩ potentiometer until the circuit is on the verge of oscillation with the variable capacitor adjusted for the desired center frequency. With the input reconnected, the filter should be unconditionally stable.

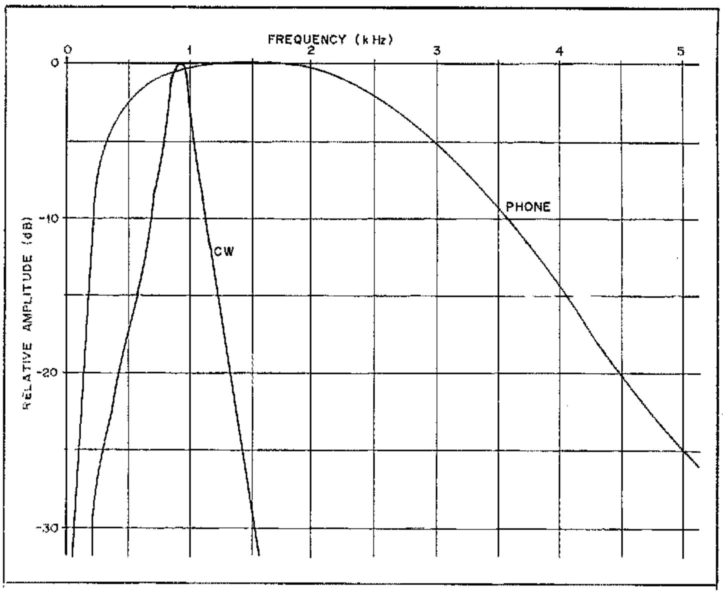


Fig. 17 — Frequency response of the phone/cw audio filter. In the phone mode, the frequency response is 250 to 3100 Hz with a measured gain of 0.85. On cw, the gain is about eight, with a 6-dB bandwidth of 300 Hz centered at 920 Hz.

Cascading Active Filters

Cascading passive filters can create problems, in that connecting the output of one filter to the input of another causes the impedances to interact, affecting the frequency response in ways you might not expect. Cascading active filters, however, is easy because the high-impedance input of each op amp doesn't affect the low-impedance output of the preceding stage. The total frequency response is the product of the responses of the individual filters — that is, the total attenuation (in dB) at any frequency is the sum of the attenuations of the individual stages. Cascading filters greatly improves the stop-band attenuation. For example, if one filter has 20-dB attenuation at some frequency, two such filters in cascade will have 40 dB, three filters will have 60 dB, and so on.

Let's Build One

Enough theory; let's build one! Fig. 16 shows a useful circuit consisting of a pair of cascaded filters of the type described in Fig. 10. With the switch in the "phone" position, each section is a 2300-Hz low-pass filter with a Q of about one. R1 and C1 were added to further reduce the high-frequency response. Switching to cw adds extra capacitance, which not only lowers the resonant frequency to about 800 Hz, but also raises the Q to about 3.5. The two 0.02-µF coupling capacitors roll off the frequency response below 300 Hz, which helps to block any hum present on the input. The frequency responses for both modes are plotted in Fig. 17.

The filter may be driven by any audio source having less than about 2-kΩ output impedance and a voltage swing less than about 8 volts pk-pk on phone and 1 volt pk-pk on cw. (The gain is about one on phone and about eight on cw.) The output is sufficient to drive headphones of any impedance, but you should add an amplifier to drive a speaker.[3]

By the way, it's not necessary to use two separate integrated circuits to build this filter. You can buy ICs with two or even four op amps to the package. For example, the Motorola MC1747 and MC4741 are the dual and quad versions of their MC1741 operational amplifier.

I hope this article has given you some idea of what can be done with active filters. In fact, there isn't much gear in the average ham shack where one of these little gizmos *wouldn't* come in handy. Drop one into your next construction project and see! QST

Notes

[1]Woodward, "A Beginner's Look at Op-Amps," *QST*, April 1980, p. 15 and June 1980, p. 25.
[2]Nicosia, "Adjustable Audio Filter for Cw," *Ham Radio*, August 1970.
[3]Shriner, "A Handy Audio Amplifier," Hints and Kinks, *QST*, December 1979, p. 56.

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[1]Budak, *Passive and Active Network Analysis and Synthesis*, Houghton Mifflin, 1974.
[2]Lam, *Analog and Digital Filters*, Prentice-Hall, 1979.

Strays

Apart from the usual "long and short of it," wouldn't it be great to have this chap available on that next antenna-erection exercise? The photograph shows ARRL Technical Secretary Marian Anderson, WB1FSB, after she tried to persuade "Shorty" to lend a hand with some roof-top antenna work she has planned for this summer. He was a promotional attraction in the entrance area of IEEE ELECTRO/80 at the Hynes Memorial Auditorium in Boston. Marian served as chairperson for the ARRL-organized technical sessions 5 and 8 on May 14.

Maverick Trackdown

You can be effective in locating the source of malicious ham-band interference! A simple loop antenna with preamplifier will help you find the "outlaws" in your area.

By Doug DeMaw,* W1FB

We amateurs seem to have a surplus of "who-dunnits" in our hf and vhf bands these days — persons unknown, who, because of some personality quirk, derive satisfaction from causing malicious interference to net operations on 40, 75 and 80 meters. These same skulkers focus their attention on DX QSOs in the 10-, 15- and 20-meter bands. This scofflaw attitude is not new to our amateur spectrum: It's been prevalent for decades. But as the number of licensed (and unlicensed) operators grows, the problem seems to become more pronounced. It appears necessary to develop area task forces to track down those persons who are bringing shame to the good name of Amateur Radio in the USA.

FCC, in these days of federal budget-cutting, lacks resources to deal with all the problems that come to its attention. If, however, well-disciplined local interference committees can do the initial investigation of malicious interference, solve some of the less-severe cases through persuasion, and catalog operating habits, hours, days of the week, frequencies and general vicinity from which the interference is coming, FCC may be able to use its diminishing forces more effectively on the hard cases. Conversations between Jim McKinney, new chief of the Field Operations Bureau, and Carl Smith, W0BWJ, and Gar Anderson, K0GA, of ARRL's Ad Hoc Committee on Malicious Interference, have been most encouraging.

The Technique of Triangulation

Let's assume that an interference committee has been formed and that the members are equipped with receivers and directional, rotatable antennas for the hf band in question — 10, 15 or 20 meters. (We'll deal with the lower frequencies later in this article.)

If the source of the malicious interference is within the ground-wave contour of the maverick-hunters' stations, and if the "hunters" are a few miles apart, triangulation can be used to determine the general location of the maverick. This is illustrated pictorially in Fig. 2. Stations 1, 2 and 3 rotate their beam antennas to obtain maximum response from the maverick's signal. The beam headings are noted, compared, and plotted on an area map. At the point where the three headings converge is the approximate location of the maverick.

This kind of exercise is rather impractical when dealing with sky-wave signals. The QSB complicates things by preventing accuracy in obtaining a peak signal reading on the receiver S meter. Furthermore, the beamwidth of an hf-band beam is too broad to yield good resolution at great distances. So, what is our next step in pinpointing the exact geographical point from which the offending signal is being sent? We can comb the area at close range with hand-held loop antennas. This will enable us to find the exact neighborhood of the maverick, and finally nail him down at his QTH. This can be done with relative ease by placing an hf-band transceiver or receiver in an automobile, locating the vehicle in the general area of the interfering signal, then standing outside the car and rotating the loop for maximum signal response. The scheme requires two or three mobile stations which can be situated as shown in Fig. 2, but only a mile or less from the bandit. A pocket compass is necessary to determine the headings for correct triangulation. Coordination with other hunters can be effected by telephone as the committee closes in on the offender (*coded messages are not legal over the air*).

To avoid ambiguity from the bidirectional response of loop antennas we can build our direction finders to yield a cardioid (heart-shaped) response. This is done by adding a sense antenna to the loop, along with a phasing network. We'll see how that's done later in the article.

The problem of locating the bandits on 40, 75 and 80 meters is a bit more

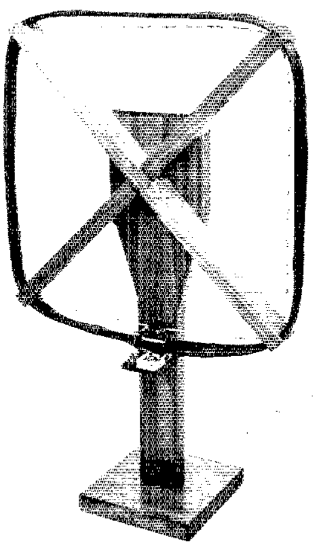
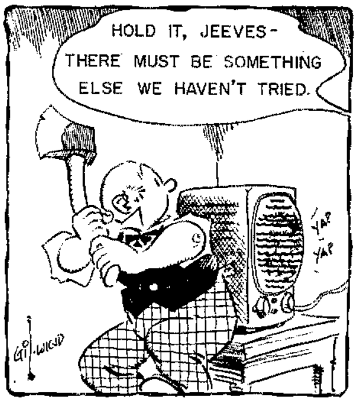


Fig. 1 — An assembled table-top model of the W1FB 4T-ES electrostatically shielded loop which is made from a length of RG-58/U cable.



Locating bandits on 40, 75 and 80 meters is a bit more complicated.

*Senior Technical Editor, ARRL

complicated. This is because beam antennas are somewhat impractical that low in frequency, even though some of the super DX stations have antennas of that type.

The practical answer to direction finding at these lower frequencies lies in the use of an Adcock antenna[1] for effective searching from one's home QTH. Alternatively, a small loop with sense antenna can be built for the frequency of interest. It should be used out of doors so that house wiring and plumbing will not "confuse" the loop while a correct compass heading is sought. This may require placing a receiver on a table in the back yard and running an extension cord to it for power. Once a triangulation has been effected, it will be time for the committee to move afield with the mobile units for close-in bandit hunting.

Loop Circuits and Criteria

A somewhat comprehensive article on the subject of loop antenna design was presented earlier in *QST*.[2] It described frame loops, ferrite-rod loops, sense antennas and loops with electrostatic shielding. Other data can be obtained from the references given in the bibliography.

No single word describes a loop of high performance better than "symmetry." In order for us to obtain an undistorted response pattern from this type of antenna we must build it in the most symmetrical manner possible. The next key word is "balance." The better the electrical balance, the deeper the loop null and the sharper the maxima.

The physical size of the loop is not of major consequence: a 4-foot (1.2-m) loop will exhibit the same electrical characteristics as one which is only 1 inch (25 mm) in diameter. The smaller the loop, however, the lower its efficiency. This is because its aperture samples a smaller section of the wave front. Thus, if we use very small loops, we will need to employ preamplifiers to compensate for the reduced efficiency.

Loop Choices

The earliest loop antennas were of the "frame antenna" variety. These were unshielded antennas which were built on a wooden frame in a rectangular format. The loop conductor could be a single turn of wire (on the larger units) or several turns if the frame was small. Later, shielded versions of the frame antenna were popularized to provide electrostatic shielding — an aid to noise reduction from such sources as precipitation static.

Some years after wire loops gained widespread application, we began using magnetic-core loop antennas. The advantage was reduced size, and this appealed to the designers of aircraft and portable radios. Most of these antennas contain ferrite bars or cylinders, which provide

[1]References appear on page 25.

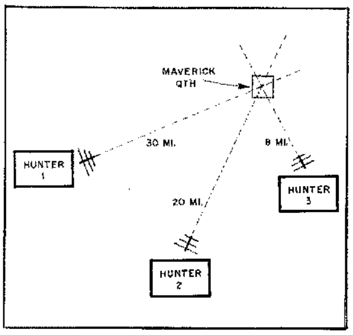


Fig. 2 — Method for triangulation when locating a signal source.

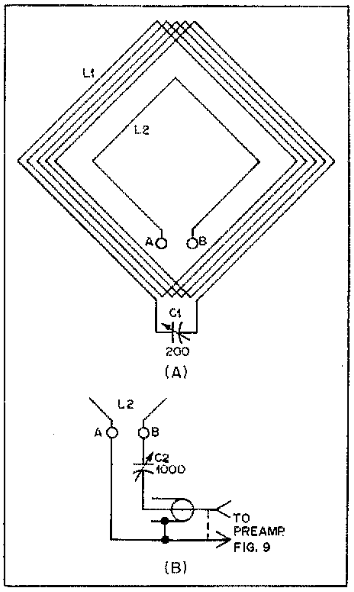


Fig. 3 — A multiturn frame antenna is shown at A. L2 is the coupling loop. The drawing at B shows how L2 is connected to a preamplifier.

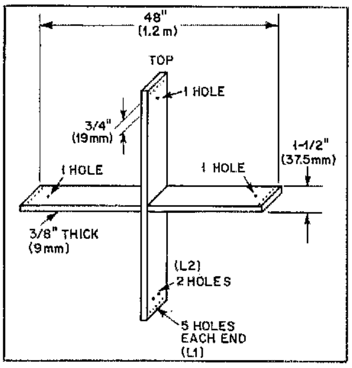


Fig. 4 — A wooden frame of this type can be used to contain the wire of the loop shown in Fig. 3.

high inductance and Q with a small number of coil turns. A 7-inch (178-mm) rod, 0.5-inch (13 mm) OD, of Q2 ferrite (μ_i = 125) is suitable for a loop core from the bc band through 10 MHz. Maximum response is off the *broadside* of a rod loop, whereas the maxima occurs in the *plane* of a frame type of loop. The performance of the two antennas is otherwise similar.

Frame Loops

Fig. 3 illustrates the details of a practical frame type of loop antenna. The circuit at A is a 5-turn system which is tuned to resonance by C1. If the layout is symmetrical, we should be able to obtain good balance. L2 helps to achieve our objective by eliminating the need for direct coupling to the feed terminals of L1. If the loop feed was attached in parallel with C1, which is common practice, the chance for imbalance would be considerable.

L2 can be situated just inside or slightly outside of L1; a 1-inch (25-mm) separation works nicely. The receiver or preamplifier can be connected to terminals A and B of L2 as shown at B of Fig. 3. C2 controls the amount of coupling between the loop and the preamplifier. The lighter the coupling, the higher the loop Q, the narrower the frequency response, and the greater the gain requirement from the preamplifier. It should be noted that we are making no attempt to match the loop impedance to the preamplifier: The characteristic impedance of small loops is very low — on the order of 1 ohm or less.

A supporting frame for the loop of Fig. 3 can be structured as shown in Fig. 4. The dimensions given are for a 1.8-MHz frame antenna. For use on 75 or 40 meters, L1 of Fig. 3A will require fewer turns, or the size of the wooden frame will have to be made somewhat smaller than that of Fig. 4.

Shielded Frame Loops

If electrostatic shielding is desired we can adopt the format shown in Fig. 1 (W1FB "4T-ES Loop," Ref. 2). In this example, the loop conductor is made from RG-58/U coaxial cable with ample turns to permit resonance at the operating frequency. A 3-turn link connected to the loop feed terminals can be probed with a dip-meter to check the resonant frequency (tuning capacitor C1 of Fig. 3A must be connected and set at midrange for this test).

Larger single-turn loops of this kind can be fashioned from aluminum-jacketed Hardline, if that style of coax is available. In either case, the shield conductor must be opened at the electrical center of the loop, as shown in Fig. 5 at A and B. The design example is based on 1.8-MHz operation.

In order to realize the best performance from an electrostatically shielded loop

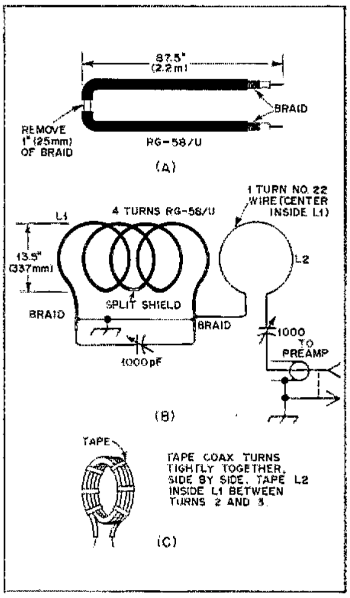


Fig. 5 — Components and assembly details of the 4T-ES shielded loop.

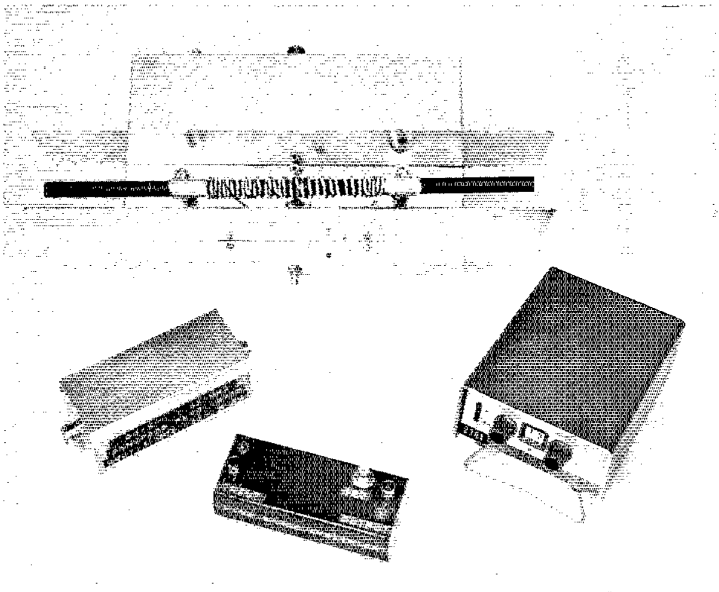


Fig. 7 — The assembly at the top of the picture is a shielded ferrite-rod loop for 160 meters. Two rods have been glued end to end (see text). The other units in the picture are a low-pass filter, broadband preamplifier (lower center) and a Tektronix step attenuator (lower right). These were part of the test setup used when this type of antenna was evaluated.

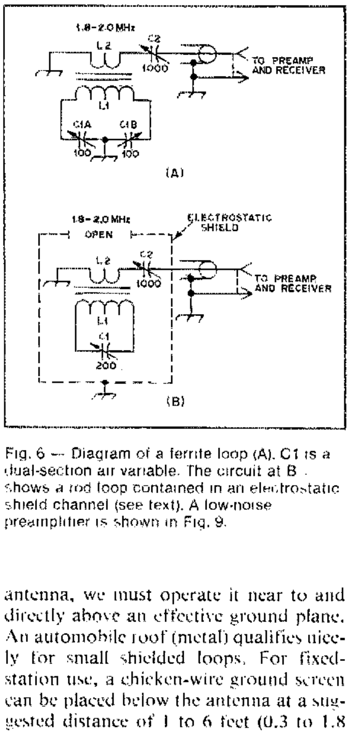


Fig. 6 — Diagram of a ferrite loop (A). C1 is a dual-section air variable. The circuit at B shows a rod loop contained in an electrostatic shield channel (see text). A low-noise preamplifier is shown in Fig. 9.

antenna, we must operate it near to and directly above an effective ground plane. An automobile roof (metal) qualifies nicely for small shielded loops. For fixed-station use, a chicken-wire ground screen can be placed below the antenna at a suggested distance of 1 to 6 feet (0.3 to 1.8 m).

Ferrite-Core Loops

Fig. 6 contains a diagram for a rod loop. The winding (L1) has the appropriate number of turns to permit resonance with C1 at the operating frequency. L1 should be spread over approximately 1/3 of the core center. Litz wire will yield the best Q, but Formvar magnet wire can be used if desired. A layer of 3M Company glass tape (or Mylar tape) is recommended as a covering for the core before adding the wire. Masking tape can be used if nothing else is available.

L2 functions as a coupling link over the exact center of L1. C1 is a dual-section variable, although a differential capacitor might be better toward obtaining optimum balance (not tried). We can control the loop Q by means of C2, which is a mica compression trimmer.

Electrostatic shielding of rod loops can be effected by centering the rod in a U-shaped aluminum, brass or copper channel which extends slightly beyond the ends of the rod loop (1 inch or 25 mm is suitable). The open side (top) of the channel can't be closed, as that would constitute a shorted-turn condition and render the antenna useless. This can be proved by shorting across the center of the channel with a screwdriver blade when the loop is tuned to an incoming signal. The shield-braid gap in the coaxial loop of Fig. 5 is maintained for the same reason.

A photograph of a shielded rod loop is offered in Fig. 7. It was developed experimentally for 160 meters and uses two 7-inch (178-mm) ferrite rods which were glued end-to-end with epoxy cement. The longer core resulted in improved sensitivity during weak-signal reception. The other items in the photograph were used during the evaluation tests and are not pertinent to this discussion. All of the loops we have discussed thus far have bidirectional responses (∞ patterns).

Obtaining a Cardioid Pattern

Although the bidirectional pattern of loop antennas can be used effectively in tracking down the mavericks by means of triangulation, an essentially unidirectional loop response will help to reduce the time spent when on a "hunting" trip. Adding a sense antenna to our loop is simple to do, and it will provide the desired cardioid response we need.

Fig. 8 shows how this can be accomplished. The link from the rod loop or frame loop is connected via coaxial cable to the primary of T1, which is a tuned toroidal transformer with a split secondary winding. C3 is adjusted for peak signal response at the frequency of interest (as is C4), then R1 is adjusted for minimum back response of the loop. It will be necessary to readjust C3 and R1 several times to compensate for the interaction of these controls. The adjustments are repeated until no further null depth can be obtained. Tests at ARRL hq. showed that null depths as

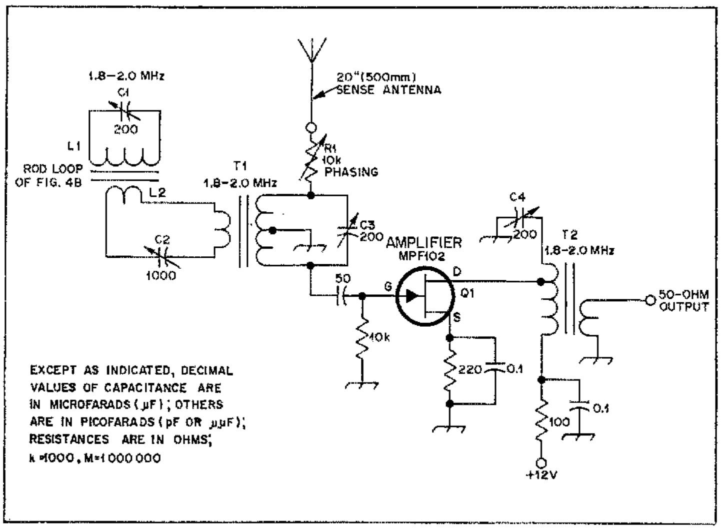


Fig. 8 — Schematic diagram of a rod-loop antenna with a cardioid response. The sense antenna, phasing network and a preamplifier are shown also. The secondary of T1 and the primary of T2 are tuned to resonance at the operating frequency of the loop. T68-2 or T68-6 Amidon toroid cores are suitable for both transformers. Amidon also sells the ferrite rods for this type of antenna.

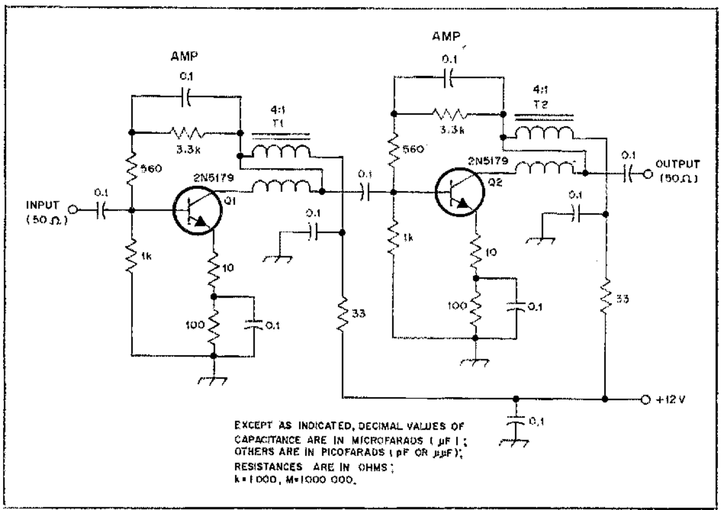
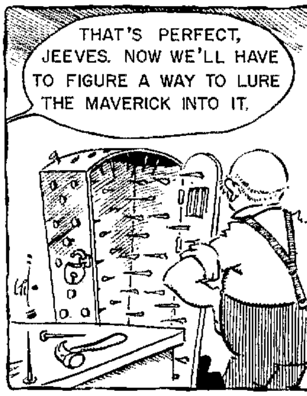


Fig. 9 — Schematic diagram of a two-stage broadband amplifier patterned after a design by W7ZOI. T1 and T2 have a 4:1 impedance ratio and are wound on FT-50-61 toroid cores (Amidon) which have a μ_i of 125. They contain 12 turns of no. 24 enam., bifilar wound. The capacitors are disc ceramic. This amplifier should be built on double-sided circuit board for best stability.



Never act like "night riders" — follow the "due-process" doctrine.

great as 40 dB could be obtained with the circuit of Fig. 8 on 75 meters. A near-field weak-signal source was used during the tests. The greater the null depth the lower the signal output from the system, so plan to include a preamplifier with 25 to 40 dB of gain. Q1 of Fig. 8 will deliver approximately 15 dB of gain. The circuit of Fig. 9 can be used following T2 to obtain an additional 24 dB of gain. In the interest of maintaining a good noise figure, even at 1.8 MHz, Q1 should be a low-noise device. A Siliconix U310 JFET would be ideal in this circuit, but a 2N4416, an MPF102, or a 40673 MOSFET would also be satisfactory. The sense antenna can be mounted 6 to 15 inches (150 to 380 mm) from the loop. The vertical whip need not be more than 12 to 20 inches (300 to 500 mm) long. Some experimenting may be necessary in order to secure the best results. It will depend also on the operating frequency of the antenna.

Summary

We have examined the options for building an effective tool for hunting down the hooligans who are bent on molesting the upright operators in our amateur bands. We urge coordination with your local interference committees as they are established. Above all else, we should never act like true "night riders" when we find the source of the interference. The committees will be following the "due-process" doctrine, which is the only way to resolve this worsening problem.

Once the offenders in your area are decommissioned, you can still use your loop antenna for low-noise reception on the 160- or 75-meter bands. It might be a neat gadget to have around the shack for later use during hamfest treasure hunts or when tracking down nearby sources of manmade noise! QST

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[1] Dorbuck, "Radio Direction-Finding Techniques," *QST*, August 1975, p. 30.

[2] DeMaw, "Beat the Noise with a Scoop Loop," *QST*, July 1977, p. 30.

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The New Look for QST's Antenna Patterns

Antenna radiation patterns can be very useful in Amateur Radio. But using the wrong coordinate system for the plot may obscure important pattern information.

By Jerry Hall,* K1TD

What's the front-to-side ratio of that new vertical phased array featured in *QST*? Perhaps you've noticed, the background grid for antenna patterns appearing in recent issues is new to *QST*. It's designed to let you determine answers to this kind of question easily. If you didn't notice the new coordinate system, you may want to peek again at page 19 of April 1980 *QST*,[1] and at page 32 of the May 1980 issue.[2] Why did we change to this particular grid? Some background information on this system of coordinates appears in the paragraphs that follow.

Let's examine Fig. 1 for a moment. Fig. 1A shows the theoretical azimuth plot of the signal radiated from a half-wavelength horizontal dipole antenna. Fig. 1B is the theoretical azimuth plot of two 1/4-wave vertical antenna elements placed 1/4 wavelength apart and fed equal currents 90 degrees out of phase. These two plots show the type of polar or circular grid-coordinate system which has been used for years in *QST* and other ARRL publications.

What Do These Plots Mean?

How do we interpret patterns? It's not difficult. Imagine that the horizontal dipole antenna is installed above a large, flat desert. At some distance away, say 20 wavelengths or more, we erect a horizontally polarized receiving antenna at the same height as the dipole. We excite our test dipole antenna with a transmitter — a watt or less is sufficient. Now suppose we somehow move our receiving setup in a large circle around the dipole, always keeping our receiving antenna pointed toward the dipole and always staying the exact same distance from the center of the dipole.

As we move around the dipole, the signal picked up by our receiving antenna will change in strength. The strength will be maximum when we are looking broadside at the dipole, and will be minimum (theoretically zero) when we are looking directly at either end of the dipole. The effect would be exactly the same if our receiving position were fixed and, instead, we rotated the test dipole.

The pattern of Fig. 1A tells us exactly this. The azimuth scale, indicated in degrees around the outside edge, shows us the angle of departure of our receiving setup from the reference or starting point. Broadside to the dipole conductor (0- and 180-degrees azimuth in Fig. 1A) we receive maximum signal. Ninety degrees away from broadside, off the ends of the dipole, we receive nothing. At intermediate angles the strength is somewhere between these two extremes. Here is where the circular coordinate system comes into play; we can read these intermediate signal strengths directly from the plot.

Calibration of the Polar-Coordinate Scale

Let's say we calibrate our test setup with the receiving antenna located broadside to the dipole. We adjust the transmitter power so that exactly 1 millivolt of rf is measured at the receiving antenna terminals. Fig. 1A now becomes simply a plot of the millivolt reading we would obtain at the receiving antenna as it is moved around the circle. The scale is linear, having a range of 0 to 1 millivolt.

If we were to increase our transmitter power to obtain a reading of 1 volt in a direction broadside from the dipole, the plot of the antenna pattern would remain unchanged. Here our coordinate system would simply represent the signal response on a linear scale of 0 to 1 volt. You see, everything is *relative* to the full-scale value of the plot! We could also prepare a plot in *absolute* values of signal strength, such as might be measured in microvolts or millivolts per meter, although very few amateurs have the test equipment needed to perform such measurements. The shape of the pattern would be unchanged.

Even if we were to reverse our transmitter and rf voltmeter locations, using the dipole to receive and our second antenna to "illuminate" the dipole with radiated energy, the pattern would not differ. This is true because the radiation pattern of a given antenna is the same whether it be used for transmission or for reception, assuming that proper terminations are maintained at both ends of the transmission line.

The plot of Fig. 1B reveals the same type of information for the phased vertical array. Imagine here that instead of being located in a desert, we place ourselves and the antenna array on a gigantic sheet of solid copper, a perfect conductor. Of course we now use a receiving antenna that is vertically polarized. As we move our receiving setup in a giant circle around the array (or as we rotate the phased-array system), the signal strength will vary with the angle of departure from the array axis as shown in Fig. 1B. Maximum signal is received when our receiving setup is in line with the two radiating elements and in the direction of the element having the lagging phase (0-degrees azimuth in the plot of Fig. 1B). In the opposite direction on the array axis (180-degrees azimuth) the signal strength is theoretically zero. The circular coordinate scale is again relative, as explained for Fig. 1A.

So what's wrong with this coordinate scale? Why change? A moment's reflection will reveal some good reasons. First of all, none of us ever bothers to trot an rf voltmeter out to the terminals of our antenna to measure signal strengths

*Technical Editor, *QST*

[1]References appear on page 28.

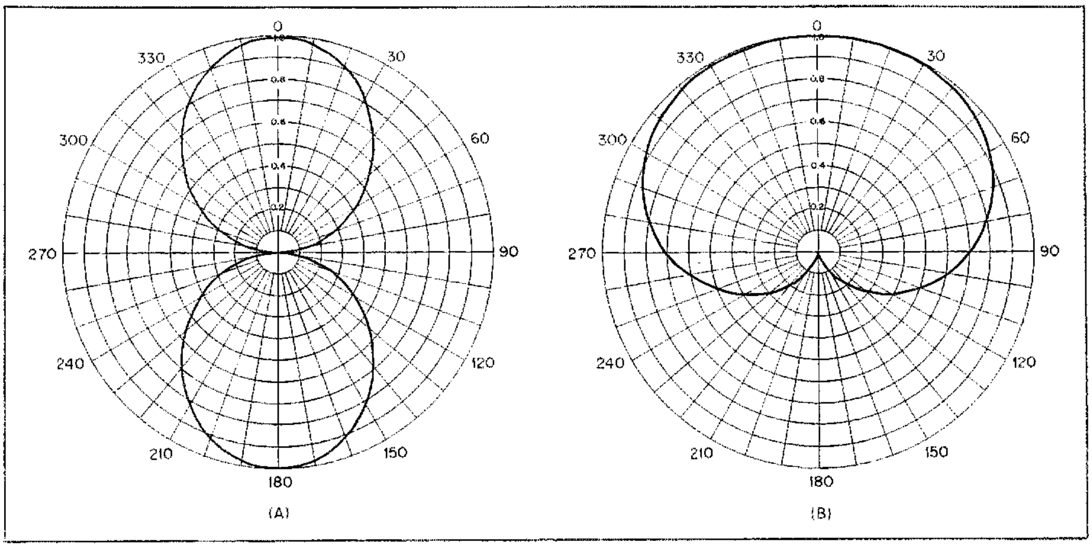


Fig. 1 — At A, a theoretical azimuth plot of the signal radiated from a horizontal half-wavelength dipole. The axis of the conductor lies along the 90/270-degree line on the chart. At B, the theoretical azimuth plot of two 1/4-wave vertical elements spaced 1/4 wavelength apart and fed 90 degrees out of phase. The two elements of the array lie along the 0/180-degree line, with maximum signal being radiated in the direction of the element that is lagging in phase. In these plots the linear system of concentric circles represents signal strength in voltage units, with zero at the center.

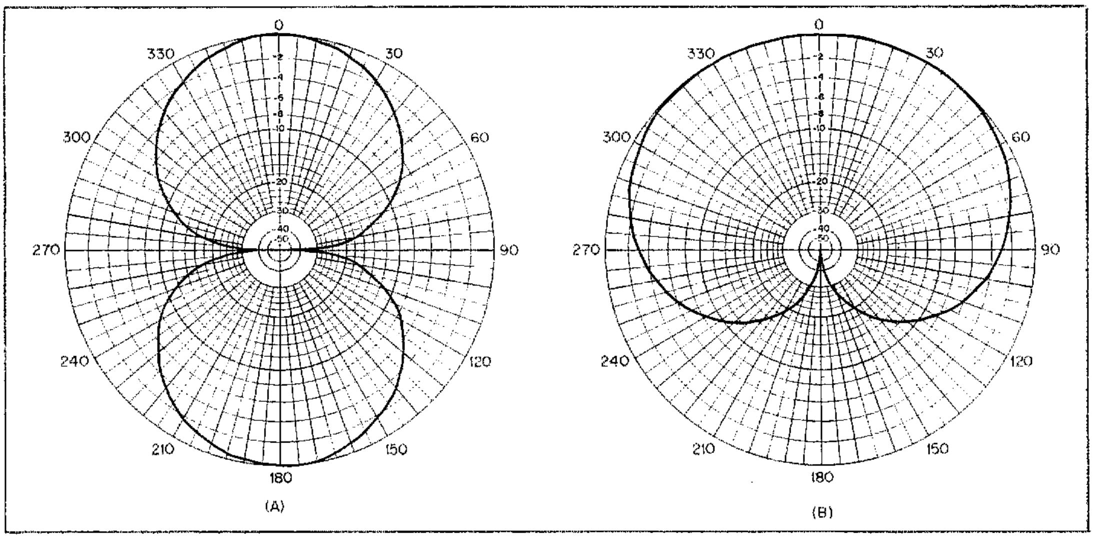


Fig. 2 — "New look" azimuth plots for the same antennas plotted in Fig. 1. The patterns have a slightly different shape but are quite recognizable to those who may be familiar with various antenna patterns. The log-periodic system of concentric circles represents signal strength in decibels relative to that in the direction of maximum radiation, with − 100 dB at the center.

because of the impracticality. As a result, we're just not accustomed to thinking of signal strengths in terms of rf millivolts, microvolts, or whatever, especially when everything is relative. Instead, most of us have become accustomed to thinking in terms of decibels, or dB. Receiver manufacturers have made it extremely easy for us to think in decibel terms, with every communications receiver that has more than bare essentials sporting an S meter. Nearly all of these meters indicate S units to S9, and indicate decibels above S9. How many times have you heard this kind of an expression? "You're 40 dB over S9 here, solid copy!"

The two plots of Fig. 1 don't give us much help directly if we're looking for relative information in dB. What's the front-to-side ratio of the phased vertical array? Or how much is my signal down at a particular DX station if he is 60 degrees away from broadside of my fixed dipole? Sure, we can find the answers to these questions by taking information from the plot and applying the familiar equation, dB = 20 log E_1/E_2. But why not plot the pattern on a coordinate system of decibels in the first place, and save all that trouble? This was the thinking which went on in our minds at ARRL headquarters as we were considering the change.

The New Look

Now please examine Fig. 2. These pattern plots are for the same antennas as those of Fig. 1. The only difference is that the plots are made on a nonlinear polar-coordinate system graduated in decibels.

We pondered various decibel-coordinate systems for quite a while before arriving at the chosen one. A linear scale in dB is easy to work with when making plots, for example, but has one serious drawback which I'll explain. In a real situation, a change from 0 to −3 dB in signal strength is far more significant than a change from, say, −20 to −23 dB. But on a linear dB scale these two changes would be represented by the same scale distance. No, we wanted something where a change from 0 to −3 dB was portrayed with a larger scale distance than −20 to −23 dB, which in turn should be represented by a larger distance than −50 to −53 dB.

A log-periodic coordinate system was the answer, where the graduations vary periodically with the logarithm of the signal strength (in voltage units). To cover the desired decibel range without severely distorting the pattern shapes from those of voltage plots (as shown in Fig. 1), we chose 0.89 for the periodicity constant. In plain English, here's what that means. The scale distance covered by the outermost 2-dB increment, 0 to −2 dB, is a particular length, approximately 1/10 the radius of the chart. The scale distance for the next 2-dB increment is slightly less, 89.0 percent of the first, to be exact. The scale distance for the third 2-dB increment is 89 percent of the second, and so on, each 2-dB increment becoming progressively smaller toward chart center. The scale is constructed so the progression ends with −100 dB at exact chart center. In amateur practice, signals of 50 or 60 dB and more below the reference level will normally be so weak as to be insignificant, so we deemed the small size of the −50 dB innermost circle as shown in Fig. 2 to be quite acceptable for our purposes. The coordinate system we've adopted may not be suitable for some laboratory work, where better definition at greater dynamic ranges may be desirable.

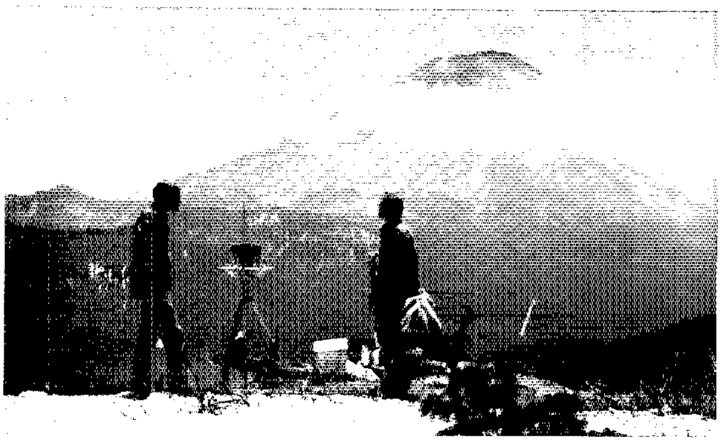
We think you'll appreciate this new look for antenna patterns. The "look" is designed for ease of pattern interpretation, in terms we're accustomed to using as amateurs. What's the front-to-side ratio of that new vertical phased array featured in *QST*? Well, if it happens to be the array patterned in Fig. 2B, you can readily determine the answer — 3 dB.

References

[1]Eggers, "An Analysis of the Balun," *QST*, April, 1980.

[2]Belrose, "The Half Sloper — Successful Deployment is an Enigma," *QST*, May 1980.

Strays



Members of the Tektronix Employees Radio Amateur Club (TERAC) helped set up this radio controlled remote camera equipment north of Mount St. Helens. This site is now under several feet of volcanic ash. *(photo by W7ADV)*

MOUNT ST. HELENS ERUPTION BURIES HAM PROJECT

☐ The May 18 eruption of the Mount St. Helens volcano in the state of Washington did more than just spread volcanic dust and ash over major portions of the United States and Canada. The major eruption took the life of at least one Amateur Radio operator and interrupted a project of the U.S. Geological Survey (USGS) and the National Geographic Society to take photographs of violent eruptive activity on the mountain.

In late April the National Geographic Society asked the Tektronix Employees Radio Amateur Club (TERAC) to provide radio equipment that would allow cameras located around Mount St. Helens to be operated by radio remote control. While commercial radio remote control equipment is available, it could not be expected to work over the distances involved.

The TERAC group designed and constructed remote control units using some pocket pager receivers and a 35-watt, 450-MHz, transmitter. Club members devoted over 300 man-hours to constructing the required encoder, decoders, antennas, battery packs and the like. They also tuned up the receivers, scrounged parts and built the high-power amplifier for the transmitter. Roger McCoy, W7DAV, and Tom Hill, WB7FHF, were the most active in this work, often staying up until 3 or 4 A.M. to finish some part of the project. Finally, all the equipment was ready and the U.S. Geological Survey had issued the necessary clearances for entry into the volcano area.

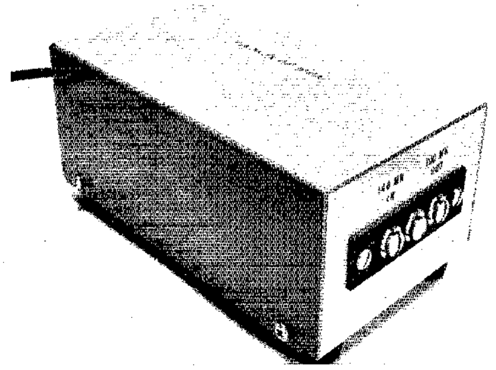
Since the major part of the eruptive activity was occurring on the north side of the mountain, the cameras were to be installed there. On May 7 Roger and Tom were flown into the area by helicopter, and assisted in installing the cameras and checking out the remote control equipment. The control transmitter was to be operated by Reid Blackburn, KA7AMF, from a USGS camp known as "Coldwater I," about 8 miles northwest of Mount St. Helens. Reid took a leave of absence from his job as photographer for the *Columbian* newspaper in Vancouver, Washington, so he could volunteer to help USGS with this project. Regular radio contact was maintained with Reid on 2 meters through the Portland area ARES repeater, WR7AOA.

On the morning of May 18 Mount St. Helens erupted with an unexpected force. The blast, which has been estimated to have had the force of a 10-megaton atomic bomb, split open the whole north side of the mountain and knocked down trees for almost 15 miles. Hot gases and great quantities of volcanic ash also erupted and covered the area north of the mountain to a depth of several feet. Reid did not meet his schedule that morning. When a helicopter crew got into the area that afternoon they found the campsite covered with ash and Reid's burning car. Reid's body was recovered on May 22. He is survived by his wife, Faye, and will be sorely missed by Portland-area amateurs and all others who knew him. — *David Lievsay, K7UUH, Portland, Oregon*

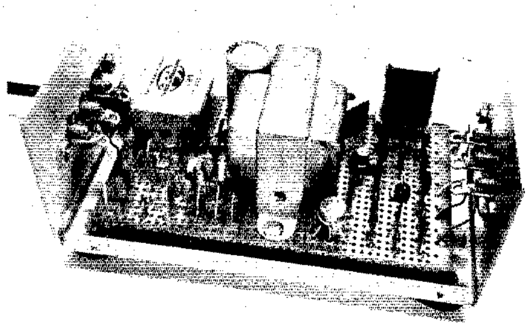
The Little Gem Mixer Box

Be sure your 2-meter fm transmitter is toeing the mark. Set the deviation precisely with this dependable instrument. It facilitates checking the frequency response and serves as a monitor, too!

By Harold E. Jones,* W6BWH



The Little Gem Mixer Box. This 2-meter test mixer is designed to help radio amateurs maintain fm transmitting equipment in accordance with the best practices. It even takes the place of an expensive deviation meter.



Use of perforated circuit board provided a convenient means for neatly arranging the components shown in this inside view of The Little Gem Mixer Box. The International Crystal Co. OE-1 crystal oscillator is visible at the upper left, while the 46-MHz third-overtone crystal is at the upper right. T1 is mounted in the center.

This simple little gadget is useful for performing at least three test and repair functions on your fm transmitter. It facilitates checking the frequency response, it monitors the output of the transmitter and it permits making a precise measurement of the deviation. Monitoring the output is a must when checking for hum, noise or intermittents. A particular benefit is that you don't need an expensive deviation meter. The Little Gem provides a means of making these important tests with equipment you probably have already.

The Little Gem may be considered a premixer. It serves somewhat in the manner of a preamplifier connected to the input of the appropriate a-m or fm receiver. The input signal to the mixer can be provided from a foot or so of wire lying on the bench next to the transmitter, the output of which is fed to a dummy load. Such a procedure will work for transmitters in the 10-watt or larger class. Lower power transmitters may require closer coupling. What the Little Gem does is to convert a sample of the output of a transmitter to another frequency where it may be received on an appropriate receiver for measurement and observation. This idea is offered in furtherance of the belief that making a few simple measurements is better than just sitting there looking at a piece of equipment and guessing what it may be doing.

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Evaluating Performance

A standard fm broadcast tuner or receiver, if in reasonably good condition, is capable of reproduction far in excess of what an amateur transmitter is capable of putting out. It is, therefore, a good instrument to have for evaluating performance of a ham rig. In using an fm tuner to make measurements, you must remember that an fm tuner has a 75-microsecond R-C roll-off filter that results in a response curve as shown by the de-emphasis graph (Fig. 2). Values from this graph must be added to any readings produced by the tuner. In other words, if the transmitter is adjusted to have a flat on-the-air response, the results measured at the output of an fm broadcast tuner should agree with the curve of the graph. The response is not down a great amount out to 5000 Hz. Besides, there are precious few commercially built amateur transmitters sold in recent years that have any kind of measurable response at 5000 Hz.

Checking the frequency response of your transmitter can be somewhat academic unless you intend to do something to improve it. In the situation where you have reports of hum, distortion, noise or an intermittent condition, listening to the results of your efforts to remedy the problem can be useful. If you have a second transceiver, fine; but most of us have only one. Therefore, letting the family fm tuner serve this purpose can be most useful.

Concerning Deviation

Setting the deviation can be a pretty

"iffy" thing unless you have some measuring equipment and you can find out what the deviation is supposed to be.

At one time, for the uhf bands at least, 15 kHz was the accepted standard. For the last four or five years, on 2 meters, the move has been to accept 5 kHz as the standard. Whatever the accepted standard may be, very few operators are able to accurately measure and adjust the deviation of their equipment.

There are two commonly accepted solutions to the deviation problem. One is to take the set to a shop that has a deviation meter. The other is to get on the air and try to find someone to guide you into making a proper adjustment. With the latter approach and a little luck, one can usually get in the ball park, but if the deviation ends up within plus or minus 1 kHz of what it should be, something of a miracle has been accomplished. The variables here include the frequency response and distortion characteristics of the transmitter and receiver, the aural evaluation abilities of the receiving operator and the voice characteristics of the transmitting operator. Some people have a heavy, full-sounding voice. They just plain sound loud no matter what. Others have weak, anemic voices that sound weak even if they are overmodulating the transmitter. Not a very exact or scientific approach to the problem!

Precise Deviation Measurements

With the Little Gem Mixer Box, a low-band ssb or cw receiver and a source of audio, a precise measurement of the deviation is possible. This procedure is based on Bessel functions. A description of this function may be found on page 13-5 in the 1980 *Radio Amateur's Handbook*. The subject is also covered in other engineering texts. Fundamentally, the theory says that for any given pure sine-wave audio modulation frequency, the fm carrier will disappear at certain mathematically predictable degrees of modulation. In practice, this point of disappearance is extremely sharp. If not, the presence of other signals (hum and distortion) is indicated.

To make this test, all that is needed is a source of audio and a method of detecting the disappearance of the carrier. The audio source can be a simple single fixed-frequency audio oscillator of the R-C phase-shift type. Information on building one of these can be found in the *Radio Amateur's Handbook*.

For the test, a frequency in the 200-Hz range is generally most satisfactory, making identification of the various beat notes easier. Also, using a frequency somewhere near that to which the transmitter is most responsive is most desirable. A frequency run will determine this response, but as a general rule, most commercially built ham rigs will peak in the 1000- to 2000-Hz range.

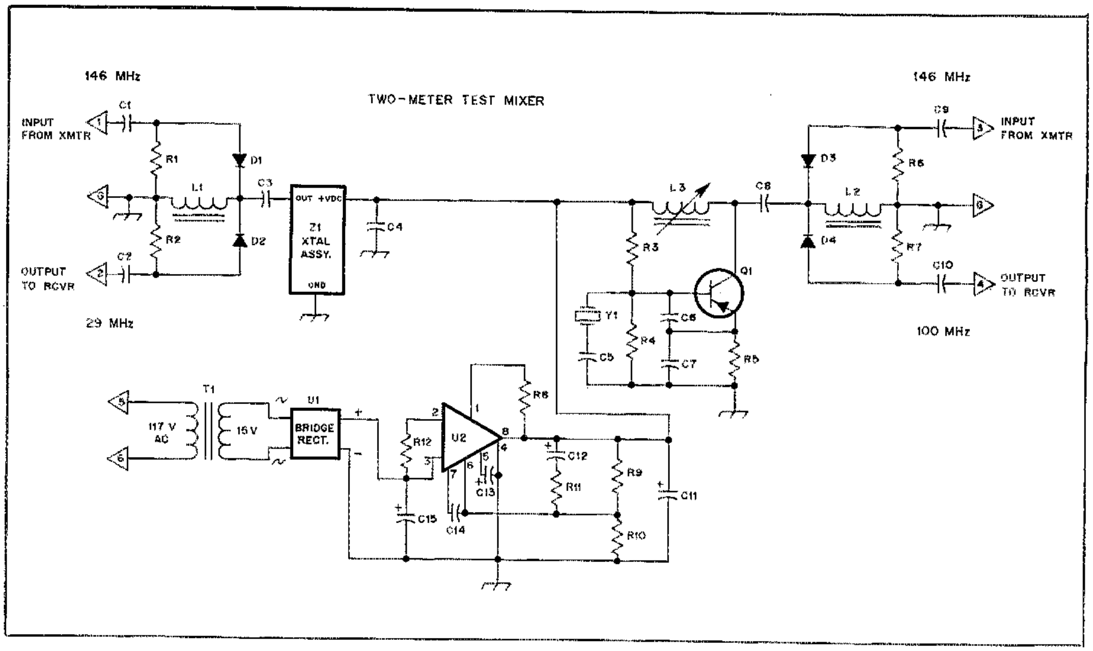


Fig. 1 — Schematic diagram for the Little Gem Mixer Box. Terminals 1 and 2, and 3 and 4, are symmetrical and interchangeable, but to avoid confusion, terminals 1 and 3 are labeled as input from the transmitter under test. Terminals 2 and 4 are therefore chosen for the output to the appropriate receiver. With a Z1 frequency of 122 MHz, as indicated below, a 146-MHz signal will appear at 24 MHz on terminal 2. If Z1 is changed to 117 MHz, the signal on terminal 2 will be 29 MHz. The 117-MHz crystal is probably the best frequency for use with a ham-band receiver. Terminal 4 can feed a standard fm broadcast receiver at 100 MHz.

C1-C3, incl., C9, C10 — 0.001 μF, 50 V.
C4 — 0.01 μF, 50 V.
C5, C14 — 20 pF, 50 V.
C6 — 10 pF, 50 V.
C7, C8 — 47 pF, 50 V.
C11 — 5 μF, 20 V tantalum.
C12, C13 — 2 μF, 20 V tantalum.
C15 — 500 μF, 30 V electrolytic.
D1-D4, incl. — 1N914.
L1, L2 — 1-mH iron-core choke.
L3 — 7 turns no. 26 enameled wire on Miller cup core no. 53A-2-2. Must tune to 46 MHz.
Q1 — Germanium pnp 300-mW high-speed switching or rf transistor, 2N706A or equiv.
R1, R2, R6, R7, R11 — 1 kΩ.
R3 — 4.7 kΩ.
R4 — 2.4 kΩ.
R5 — 470 Ω.
R8 — 5.6 Ω.
R9 — 24 kΩ, 5%.
R10 — 4.7 kΩ.
R12 — 22 Ω.
T1 — Transformer, 120-V pri., 14 or 15 V sec., 0.1 A.
U1 — Bridge Rectifier, HEP RO801, Sylvania ECG-166 or equiv.
U2 — RCA CA 3055 or CA 3085.
Y1 — International Crystal Mfg. Co., 46-MHz third-overtone crystal.
Z1 — International Crystal Mfg. Co., OE-1-122 MHz oscillator.

Table 1 taken from the *Radio Amateur's Handbook*, gives the deviation for various audio frequencies. For instance, at an audio frequency of 2079.2 Hz, the first null is at 5000-Hz deviation.

Detecting the Null

To detect the null, some form of a-m detector with a good sharp filter ahead of it is needed. The best thing to use is a low-band a-m/cw receiver with a narrow cw band-pass filter. A sideband receiver will do quite well, however, although a bit of operator concentration is required. This is a requirement that results from the great number of sidebands produced in the fm process.

In a-m, with a single audio tone and barring distortion, only a single pair of sidebands will be produced. Their amplitude will vary directly with modulation percentage. In fm, an infinite number of sidebands are produced, although only the first three or four are of any significance. The rest are of such low level as to be considered nonexistent for any practical purpose. The sidebands go through null points like the fundamental but at different frequencies and different amounts of deviation, performing independently.

The resultant sound heard from a cw or ssb receiver is not unlike several cats sitting on a fence during a warm moonlit night at mating time. To pick your cat from the mess will require a bit of concentration. This can be facilitated best if, when the fm carrier is tuned in, the receiver is adjusted to produce a beat note in the low audio range, around 200 Hz. Then if a modulation frequency in the upper audio range, around 2000 Hz, is introduced, there will be considerable difference between the 200-Hz beat note that you want to hear and the modulation beat notes that you don't care about. Advance the modulation control until the 200 Hz beat note disappears, indicating that the fm carrier has disappeared.

At this point, using Bessel function math, you can calculate the deviation, or if you have used the proper audio frequency, you can read the deviation from Table 1. The table is much easier to work with. I might add that my understanding is that all deviation meters trace their calibration accuracy back to a Bessel function series.

Table 1

Deviation for various audio frequencies, taken from the ARRL *Radio Amateur's Handbook*.

Audio Frequency (Hz)	*Deviation Produced* 1st Null (kHz)	2nd Null (kHz)	3rd Null (kHz)
905.8	2.18	5.00	7.84
1000.0	2.40	5.52	8.65
1500.0	3.61	8.28	12.98
1811.0	4.35	10.00	15.67
2000.0	4.81	11.04	17.31
2079.2	5.00	11.48	17.99
2805.0	6.75	15.48	24.27

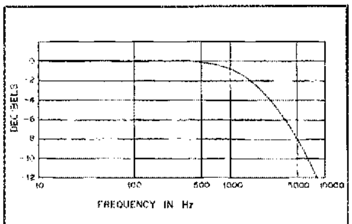


Fig. 2 — A 75-microsecond de-emphasis curve. Values from this graph are to be added to any readings produced when using an fm tuner in checking transmitter performance, as indicated in the text.

Power Supply

It will be noted that Fig. 1 illustrates a regulated power supply. Regulation is not really necessary, but pure dc is. An IC regulator gives more filtering action for the space occupied and cost than any other method I know of. Also, note that while a symmetrical diode mixer is used in this circuit, any kind of mixer can be tried. Other choices could be dual-gate FET, JFET or bipolar transistor. In some respects, one of these might be better. Sensitivity is not important in this application. Because the simplicity of the diode is appealing, I chose that for my design. Inputs and outputs are symmetrical and reversible.

Choice of Frequency for Crystals

There are some limitations and precautions in the area of the crystal frequencies to be selected. A 46-MHz crystal will convert 146 MHz to 100 MHz right in the middle of the fm broadcast band. The entire 2-meter band will fit between 98 and 102 MHz. Should there be a strong local fm broadcast station in or near this area, a search should be made to find a relatively interference-free spot on the dial and a conversion crystal frequency to convert the 2-meter band to this frequency should be used. Crystals from 40 to 56 MHz are practical. The choice of crystals for conversion to low-band receiver use may be a bit more involved. If a general-coverage a-m/cw receiver is employed, only one crystal is needed, allowing the choice of a wide range of crystal frequencies.

In my case, the International Crystal Co. OE-1-122 unit was available, having been left over from a previous project. It is a complete unit containing crystal, transistor and associated parts, all in a small package. The cost happened to be very little more than the parts. This oscillator unit converts 146 MHz to 24 MHz, where it can be received on a general-coverage receiver. Plug-in crystals are, of course, more flexible. Separate oscillators are needed because the crystals are third-overtone units and are widely separated in frequency. In the case where an amateur-band only receiver is used, a problem exists in that the 2-meter band is much wider than any of the low bands. The 10-meter band, which is the widest, is less than half as wide as the 2-meter band. This means that if the 10-meter band were used as the i-f, then three conversion crystals will be needed to cover the entire 2-meter band. For most tests, coverage of that part of the band worked most frequently is all that is necessary.

And So . . .

This simple little unit has proved most rewarding on several occasions. My hope is that it will be of value to other "homebrew artists" and "fix-it-yourselfers." Certainly it is far more economical to construct than purchasing a second transceiver. QST

Strays

MOVING? UPGRADING?

☐ When you change your address or call sign, be sure to notify the Circulation Department at ARRL hq. Enclose a recent address label from a *QST* wrapper if at all possible. Address your letter to Circulation Department, ARRL, 225 Main St., Newington, CT 06111. Please allow six weeks for the change to take effect. Once we have the information, we'll make sure your records are kept up-to-date so you'll be sure to receive *QST* without interruption. If you're writing to Hq. about something else, please use a separate piece of paper for each separate request.

AFRTS AFN-EUROPE SOCIAL AT SEANARC '80

☐ Veterans or active-duty military persons with service in AFN-Europe or AFRTS anywhere are invited to a social gathering at ARRL-SEANARC '80 in Seattle, July 25 to 27. Information from Bill Pickering, W7NZD, 9653 — 48th SW, Seattle, WA 98136.

• *Basic Amateur Radio*

IMUS Control

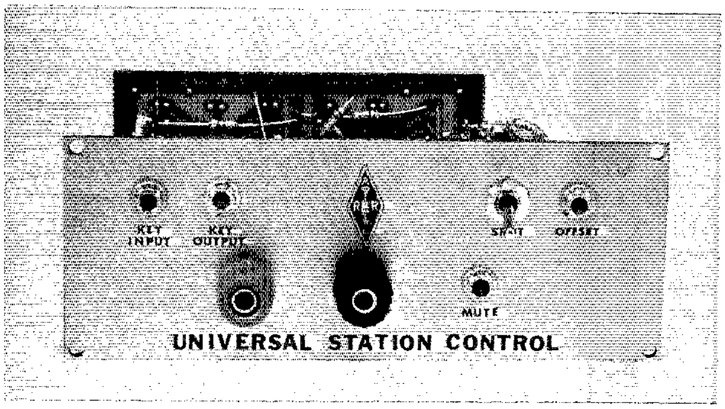
Tired of throwing 13 switches to go from transmit to receive? Want the convenience of semi-break-in? Get your soldering iron out — here we go again.

By Peter O'Dell,* AE8Q and Robert D. Shriner,** WAØUZO

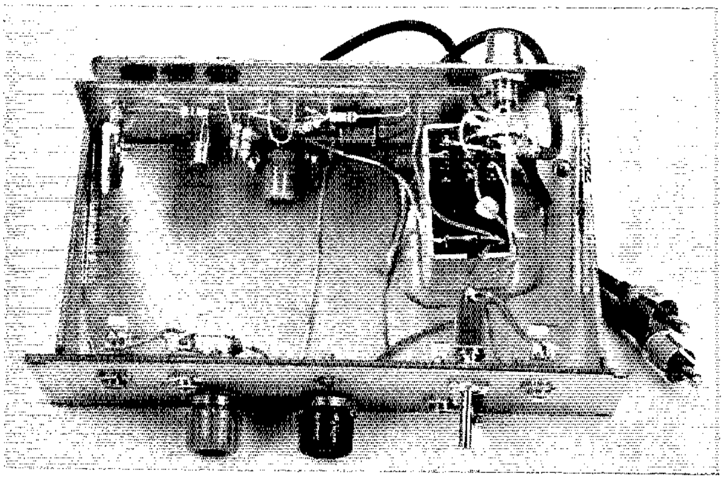
"Are you the clod who's responsible for putting these Basic Radio devices into my *QST*?" the voice screamed when I picked up the phone. Without giving me so much as a chance to respond, he went on: "Well, do you know what you've done to me? I'll tell you what you've done. Here I am enjoying getting on the air with a transmitter, receiver, keyer and those other accessories that I've built all by myself and you make me look like an idiot. How? I'll tell you how. It takes me an hour to switch from transmit to receive. I've been getting comments like 'thought you died,' and 'thought you went to sleep.' The ultimate insult came this morning when some recent convert from 11 meters asked if I had gone 10-100. Now that you bright guys have me hooked on using home-built equipment, what are you going to do to keep me from looking like a one-armed-paperhanger when I have to switch from transmit to receive?"

I told him that he was in luck because we were planning to run the IMUS Control. "IMUS Control!" he screamed, "What kind of gadget has a dumb name like that? I don't even own an IMUS and you are going to try to talk me into building something to control it. I don't have an IMUS, do I?" He was beginning to mellow a bit. Very calmly I explained to him that IMUS Control stood for Instant-Muting-Universal-Station Control and that this device, when properly connected to his Universal Transmitter[1] and Universal Receiver,[2] would allow him to switch from transmit to receive instantly by doing nothing more than keying the transmitter.

"How does this thing work? It sounds like it might just be what I am looking for." He was really calm now. I explained



Front-panel view of IMUS Control. The pc-board panel is styled to match the other units in this series.



Overhead view of IMUS. Although there are relatively few components involved, the unit does an excellent job. Some minor changes in component locations were made after this shot was taken.

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**Box 969, Pueblo, CO 81002
[1]Notes appear on page 35.

that it was an electronic switch that was wired in parallel with the keying jack of the Universal Transmitter. It uses a couple of op amps to do switching. Before I could go on to tell him that the op amps in turn drive a transistor, which in turn drives a relay, he was screaming again. "What's an op amp? Why do you keep trying to confuse me with these crazy terms?"

Rather than try to explain op amps to him, I recommended that he read George Woodward's two-part series on op amps in the Basic Amateur Radio section of *QST*.[3,4] I suggested that he pay particular attention to the section in part two dealing with op amps as switches. I went on to explain that the reason for using op amps is their capacity for high gain, which is useful when switching a relay drawing a relatively large amount of current with our keyer which is capable of sinking only a moderate amount of current. The relay can do several things for us simultaneously, because it has four sets of double-throw contacts. The obvious thing to do with it is to switch the antenna from transmit to receive. To add some further protection to the front end of the receiver, we can wire the relay such that it automatically grounds the receiver antenna input when the transmitter is switched on. It should be impossible to blow the front end that way. The other functions are for offset of the VFO and the muting function.

"What is this muting business?" he wanted to know, but he didn't seem quite so impatient as before. I suspected that the project was appealing to him. The driving force behind his questions had switched from frustration to curiosity. It would only be a matter of time until he would be digging out the soldering iron again.

Muting is simply a means of turning off the audio output of the receiver during transmit, I explained. It is particularly desirable if you are wearing headphones. We accomplish this by putting a transistor switch on the audio line ahead of the amplifier in the receiver. The switch is off during receive because the base of the transistor is grounded through the normally closed contact of the relay. When the relay is thrown, the ground is removed from the base of the transistor switch, thus allowing the transistor to go into saturation. This provides a low-impedance path for the audio signal coming out of the MPF102 audio amplifier. It is quite effective as a means of quieting an audio amplifier. I mentioned that I had noticed that some of the fm rigs on the market use a similar switch in conjunction with the squelch detector to provide squelch action.

"Don't you get some loud clicks in the headphones when you turn the transistor on and off so hard?" His question indicated that I had won him over. I explained that we did have that problem while working on the prototype. After trying several different schemes, we resorted to what might be called the brute-force method. We attached back-to-back germanium diodes parallel with the switch and parallel across the headphone jack. These diodes act as clamps and minimize any voltage swings. By using germanium diodes instead of silicon, we are able to reduce the amplitude of the spikes to 0.2 V instead of 0.7 V.

"Okay, you've sold me. Send me the schematic. Better yet, give me the parts list and I'll run over to Radio Shack and get started today." He was impatient again, but this time the source of his excitement was enthusiasm. Not wanting to dampen his enthusiasm (or rekindle his anger), I spoke slowly and softly, telling him that he was really coming along in understanding the basics of radio, which he was. I thought that he was ready for a new and bigger challenge. I bet him that based on the information I had given him and with his intense interest, he could design his own switching circuit — his own IMUS Control. Anyway, we could not mail out the schematic to him, because it was considered proprietary until it appeared in *QST*. We chatted for a few minutes more before he hung up, determined to add equipment design to his trophy case. Maybe he will drop us a note to let us know how his circuit compares with ours. There are numerous ways of doing most things; it's just a matter of playing with it until you find a good way of getting the job done — often using parts you already have on hand.

Nutshell Eye View

Simplicity is the word of the day for the circuit shown in Fig. 1. A reference voltage of 6 volts is established at the noninverting input of U1A (pin 3) by the voltage dividing network consisting of the two 100-kΩ resistors. Pin 2 is held high by the 100-kΩ pull-up resistor until the key input goes low. The key input goes low when a manual key is closed or when the output of an electronic keyer goes low, e.g., the Universal Keyer.[5] When the voltage on pin 2 crosses the reference voltage, pin 1 goes from near zero volts to near the supply voltage. The 47-µF capacitor is charged through D1. When the voltage on pin 5 passes through the

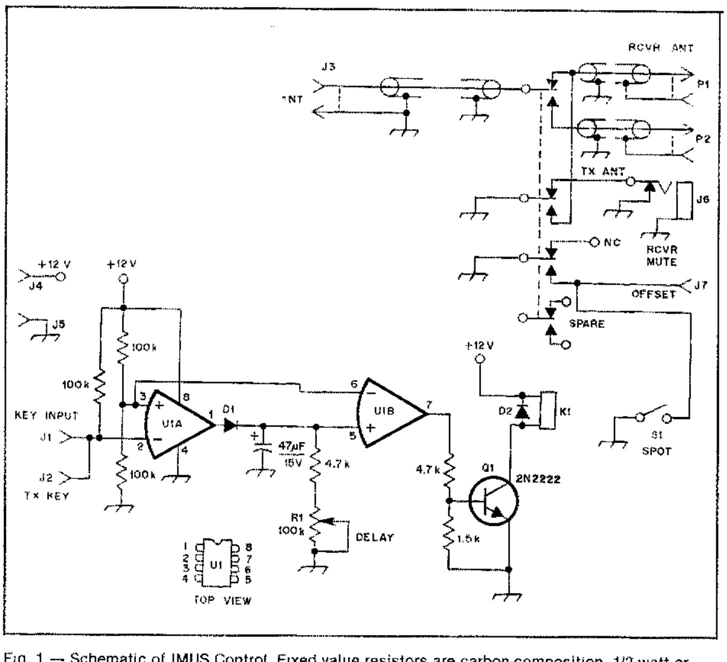


Fig. 1 — Schematic of IMUS Control. Fixed value resistors are carbon-composition, 1/2 watt or less. Resistances are in ohms; k = 1000, M = 1,000,000. Part numbers inside parentheses are Radio Shack parts suitable for use in this circuit.

D1, D2 — 1N914 or equivalent (276-1122).
J1, J2, J6, J7 — Closed circuit, 1/8-inch 2-conductor, phone jack (274-253).
J3 — Phone jack (274-346).
J4, J5 — Binding posts, one red, one black (274-662).
K1 — 12-V dc, 4-pole, double-throw relay (275-214).
P1, P2 — Phono plug (274-339).
Q1 — 2N2222 or equivalent (276-1617).
R1 — 100-k printed-circuit-board potentiometer (271-220).
S1 — Single-pole, single-throw toggle switch (275-612).
Miscellaneous — Cable, plugs, wire, epoxy cement.

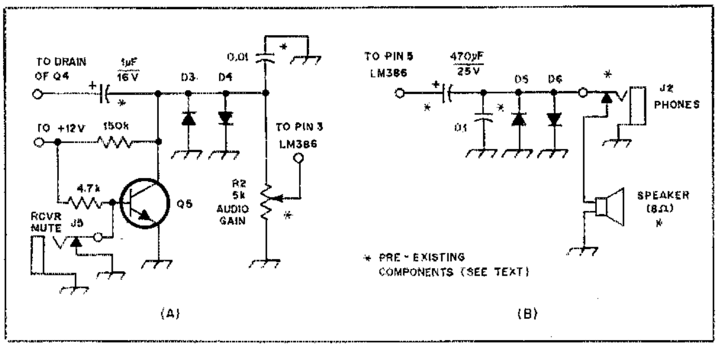


Fig. 2 — Portions of the schematic diagram of the Universal Receiver showing components that must be added for muting function. Refer to text for details of construction. Resistances are in ohms; k = 1000. Fixed-value resistors are carbon-composition, 1/2 watt or less. Part numbers inside parentheses are Radio Shack parts suitable for use in this circuit.

D3, D4, D5, D6 — 1N34, 1N270 or equivalent (276-1123).

J5 — Closed-circuit, 1/8-inch, 2-conductor phone jack (274-253).

Q5 — 2N2222 or equivalent (276-1617).

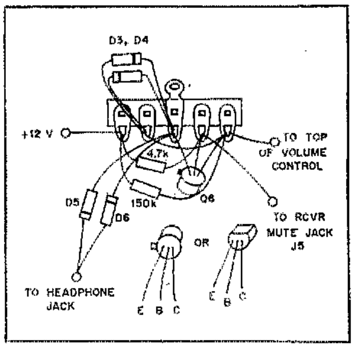


Fig. 4 — Parts placement of muting-switch circuit. Parts are mounted on a 5-lug solder terminal which is soldered to shield wall inside receiver. See Fig. 5.

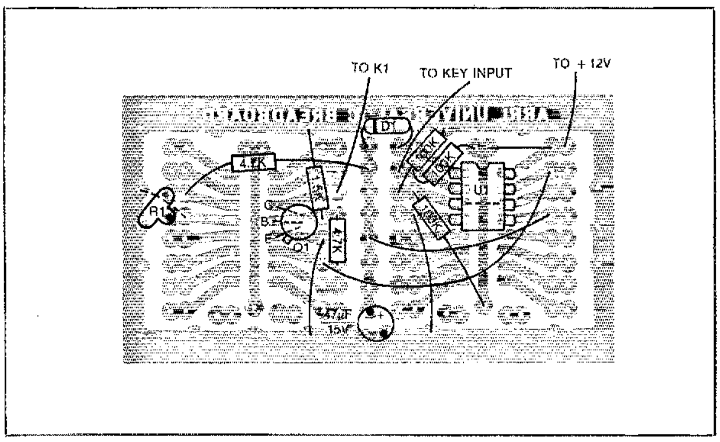


Fig. 3 — Parts-placement guide for the IMUS Control. Parts are mounted on the nonfoil side; the shaded area represents an X-ray view of the copper pattern. Resistances are in ohms; k = 1000, M = 1,000,000. Unmarked lines indicate insulated wire jumps. Broken lines indicate jumpers on foil side of board. The etching pattern of this board appears on page 42 of May 1980 *QST*.

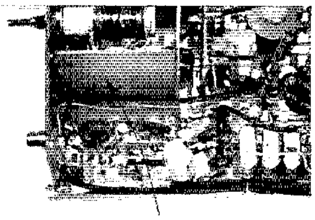


Fig. 5 — Suggested mounting position for solder lug and mute-switch components in the Universal Receiver. The mute jack is mounted on the rear panel above the antenna jack and the earphone jack.

reference voltage (pin 6 is tied to pin 3), pin 7 swings from near zero to near supply voltage. This voltage biases Q1 on, causing the relay to close.

When the key is released, pin 2 is pulled high through the 100-kΩ resistor, causing pin 1 to go low. D1 now serves to isolate the 47-µF capacitor from pin 1. The capacitor discharges through R1 and the 4.7-kΩ resistor. As long as the voltage on the capacitor is above the reference voltage, pin 7 will remain high. Thus, the capacitor and the resistors serve as a variable drop-out delay for the relay. Altering the values of the resistors and the capacitor will merely change the range of the delay; i.e., if you have a capacitor or resistor that is in the ballpark, try it, because it will probably work.

Fig. 2 shows the muting circuit that must be added to the receiver. Refer to the DeMaw and Shriner article, "The Nitty-Gritty of Simple Receivers," March 1980 *QST*, (page 26, Fig. 9). Notice that Fig. 2 here is simply selected portions of Fig. 9. In Fig. 2 those components appearing with asterisks next to them are part of the basic receiver as illustrated in Fig. 9. Components without asterisks are those to be added to enable the mute function to work. Note that the mute input jack, J5, has a shorting bar that is connected to ground. If this jack were left floating when nothing was plugged into the jack, the receiver would be permanently muted. When wired as depicted in Fig. 2, the receiver functions normally when it is disconnected from the IMUS Control.

The diodes (D3, D4, D5 and D6) serve to minimize any popping or thumping as the mute switch is turned on and off. If the prospective builder intends to use this circuit with a receiver other than the Universal Receiver, it is suggested that he experiment with positions along the audio chain for best results.

Fabrication

IMUS is constructed on the Universal IC Breadboard,* but there is nothing sacred about that. Any convenient construction system will work. A suggested parts layout is shown in Fig. 3 for those choosing to build on the Universal IC Breadboard. U1 is mounted on an IC socket to facilitate insertion and removal. The Universal IC Breadboard is mounted vertically as shown in the photograph. Relay K1 is cemented to the pc board chassis with fast-setting epoxy cement. Prepare two coaxial cables of the proper length to reach from the IMUS to the

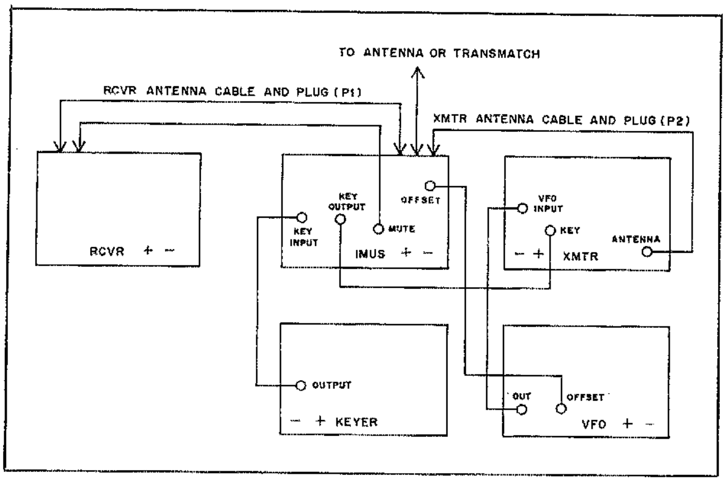


Fig. 6 — Pictorial of front panels and interconnection cables for IMUS and the other units of this series. Arrow heads indicate connections to be made on the rear of the unit. Power supply connections are indicated by + and −.

transmitter and the receiver. Solder a phono plug to one end of each and prepare the other ends for attachment to the relay. Run a short piece of coaxial cable from the antenna jack to the relay. Twist the three shield wires together and solder as close to the relay as possible. Wire the relay contacts as shown in Fig. 2 and complete the IMUS. Assembling the unit is a straightforward task that should create no problems for any one who has built any of the previous projects.

Modifying the receiver is, perhaps, slightly trickier. Using the mounting methods shown in Fig. 4 should minimize the difficulty. J5 is installed on the rear panel above the antenna jack. Check the action of the jack with an ohmmeter to make sure that the jack is grounded when nothing is plugged in. Assemble Q5 and the associated components on the five-lug solder terminal. If you happen to have a terminal that has a lug other than the center one grounded, rearrange the layout of the components so that the emitter of Q5 and the diodes are attached to the grounded lug. Attach the common ends of the two resistors to + 12 V in the receiver. Solder the terminal strip grounding mounting lug to the outer shield housing Q1 and its associated components as shown in Fig. 5. Solder a lead from the collector of Q5 and the ungrounded ends of D3 and D4 to the top of the volume control. Solder the ungrounded ends of D5 and D6 to the headphone jack. Connect the receiver mute jack to the base of Q5. At this point check the operation of the receiver. With nothing plugged into J5, the receiver should function normally. Mechanically open J5; the receiver should be muted at this time. If the muting circuit fails either of these tests, proceed no farther. Troubleshoot and correct the problem before going on.

Apply power to the IMUS; no smoke is a good sign. Short the key input to ground. You should hear the relay click; break the short and you should hear the relay click again, after some delay. Try this with R1 set at different values. If the variation in R1 does not offer a suitable delay at some point, try substituting a larger or smaller value for the 47-μF capacitor. A larger value will lengthen the delay, while a smaller one will shorten it for any given resistance.

Fast Switch

Connect the transmitter and receiver to IMUS (see Fig. 6). Attach the antenna to the antenna input of IMUS! Double check to make sure that all interconnecting cables are properly connected. Make a contact. The ease of operation should increase the enjoyment derived from using equipment that you have built yourself.

I just got another phone call — not the same fellow, though. You wouldn't believe what he insisted that we build next for this series! (Well, maybe you would.) We'll have to think about this some. There just may be a use for that spare set of contacts on the relay after all. QST

Notes

[1]DeMaw and Shriner, "Transmitter Fundamentals," *QST*, December 1979, p. 11.
[2]DeMaw and Shriner, "The Nitty-Gritty of Simple Receivers," *QST*, March 1980, p. 21.
[3]Woodward, "A Beginner's Look at Op-Amps," *QST*, April 1980, p. 15.
[4]Woodward, "A Beginner's Look at Op-Amps, Part 2," *QST*, June 1980, p. 25.
[5]O'Dell and Shriner, "The NOR-Gate Break-In," *QST*, May 1980, p. 22.
[6]The etching pattern for the Universal IC Breadboard appeared on page 42 of May 1980 *QST*.
[7]Circuit boards, negatives and complete parts kits for this project are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002.

Strays

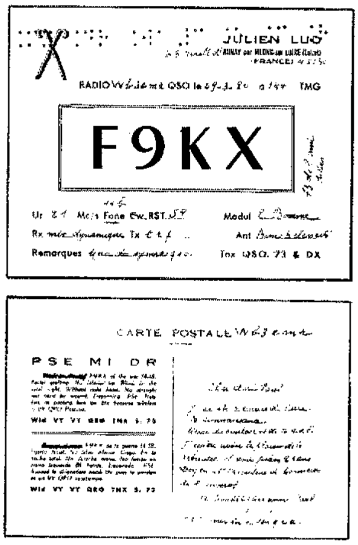
HOLY KAØW!

☐ A milestone in the history of Amateur Radio occurred recently when Dr. Tom Linde, KAØW, contacted N6AUP in Vallejo, California, using a 6-watt transceiver from his wheelchair. Linde, who has cerebral palsy, recently earned his Amateur Extra Class ticket. Dr. Linde is a psychologist at the Veterans Medical Center in Knoxville, Tennessee, and an active member of the HANDI-HAM System.

F9KX QSL

☐ Paul DeGlas, WB3EMR, of Morristown, Pennsylvania, enjoys talking to French-speaking stations. A QSL card from F9KX was the result of such a QSO.

The QSL card reveals an interesting story. Julien Luc, F9KX, is 83 years old and blind. War injuries have left Julien handicapped but, nevertheless, an active DXer. The handwritten message translates as "Dear Friend Paul, I was very happy to meet you. Thank you for the contact and your QSL. I hope to have the pleasure to meet you again. Julien is 83 years old, Doyen and President of Honor of UNESAF. Until we meet again dear friend Paul."



F9KX's QSL card sends a personal message in Braille as well as in French, English and Spanish. WB3EMR plans to frame this special card.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

MINI-MISER'S DREAM RECEIVER MODIFICATION

I constructed the Mini-Miser's Dream Receiver (September 1976 *QST*). With the few changes mentioned below, I find the performance is great. Initially I noticed that as the 12-volt supply voltage varied, so did the oscillator frequency. The fix was simple. I removed the 820-ohm mixer decoupling resistor and replaced it with a 100-ohm resistor connected to the regulated 8-volt supply. With this modification, the mixer still had the same gain with 7 volts applied. Now there is no oscillator-frequency change even though the supply voltage may vary from 10 to 16 volts.

In order to limit the audio response, I replaced the 1-μF detector bypass capacitor with one rated at 2 μF. Because of the use of a pair of crystals on the same frequency, I changed the BFO capacitor from 100 pF to 20 pF in order to obtain the correct shift.

Initially, C4 did not provide proper tuning until I added 200 pF across it. Later I learned that the diagram should have shown the turns ratio of T2 as 3:1 (9 turns and 3 turns).

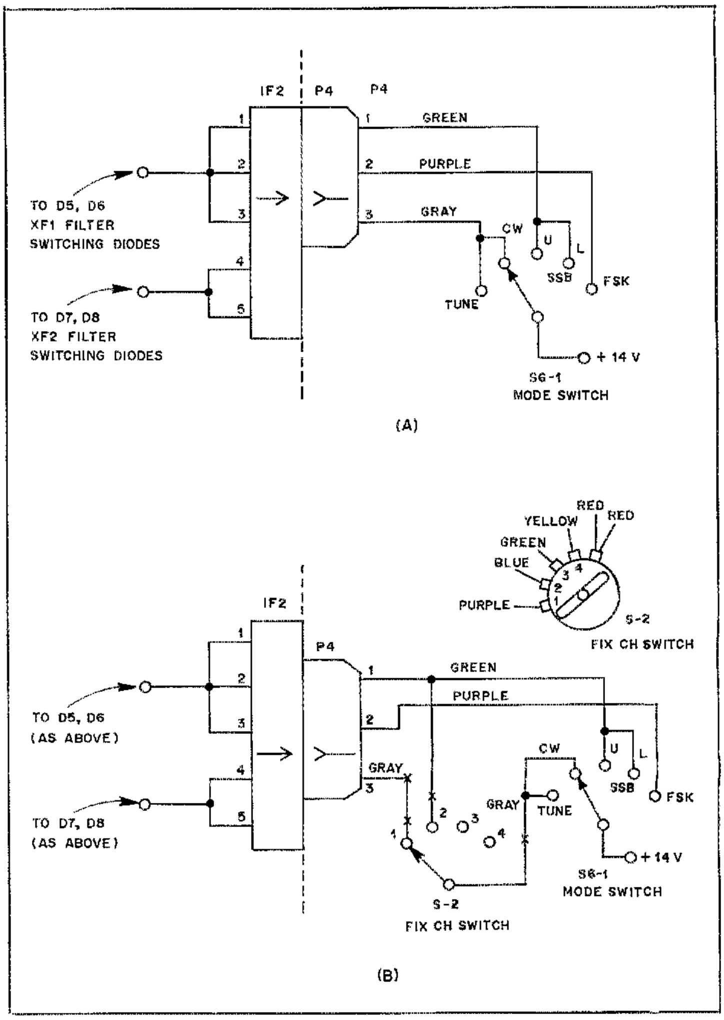
I wish to congratulate Doug DeMaw on all of the good work he has done in the field of Amateur Radio construction projects. Keep it up! — *Mike Branca, W3IRZ, Manassas, Virginia*

KENWOOD TS-820 CRYSTAL-FILTER SWITCHING

If operating your Kenwood TS-820 on cw is your pleasure, you should have the Kenwood cw filter. It separates signals marvelously. However, when the filter is plugged in, according to Kenwood instructions, a loss of "feel" for the band results. The reason for this is that the filter is in operation constantly. A solution to this problem is to make use of the FIX CH switch (common to the plate-loading control) to allow switching the filter out as desired.

You may be disenchanted with the performance of the filter if you make a common installation error. This mistake is the failure to be sure that contact is made with the common leads of the filter unit and the circuit board. The error can easily be made. The consequence is a semblance of filter action (far from what it should be) and an insertion loss that is greater than normal.

Whether or not you have the filter permanently installed and working properly, the following modifications will provide a pleasant improvement of cw operation when QRM is heavy. Carefully carry out the manufacturer's instructions for filter installation. Be especially careful in soldering the common pins to the common area of the board. The input/output pins are inserted by melting solder at the respective entry points on the board. The common pins, however, come through holes that have wide spaces around them and the common area of the board. This is where the problem lies. Be certain to spread solder from the common area of the board to each pin. Check the filter operation before going any further.



A crystal-filter switching circuit for the Kenwood TS-820. The unmodified TS-820 mode-switch circuit is shown at A. Modification of the circuit is shown at B. See text for information about faulty filter installation.

There should now be very little insertion loss and you should be able to separate signals nicely. If you have any doubts, recheck those pins!

Diode switching is used throughout the TS-820. The objective of this modification is to provide selectable switching of the +14-volt line to D5/D6 or D7/D8 on the i-f board. This will activate the ssb or cw filter.

Begin the installation by placing the TS-820 on its side. Locate the i-f board, the IF2 strip and plug P4. Move P4 over one pin to pins 2-3-4. Then proceed with the following steps to modify the Kenwood for filter switching.

1) P4 has three leads (green, purple and gray). Cut the gray lead two inches (50 mm) from the plug.

2) Strip the green lead insulation two or three inches (50 or 75 mm) from the plug.

3) Solder a length of wire to the green lead from P4 and one to each of the cut gray leads. (Three wires of different color make identification easier at the other end.)

4) Locate S2. Unsolder the two red leads from the wiper lug. Tape and tuck them away.

5) If you can't unsolder the purple and blue leads from lug positions 1 and 2 of S2, snip them a couple of inches (50 mm) away from the lug. Tape the loose ends that run back into the

*Asst. Technical Editor, *QST*

rig and tuck them away.

6) Connect the wire spliced to the green lead from P4 to the blue lead at S2. This provides the +14 volts to activate the ssb filter in position 2 of S2.

7) The wire soldered to the cut gray lead from P4 goes to the purple lead of S2. This provides +14 volts to activate the cw filter in position 1 of S2.

8) The wire soldered to the cut gray lead to S6-1 now goes to the point where you removed the two red leads from S2 (the wiper lug). This places +14 volts at S2 when S6 is in the cw position.

Combining the cw filter with an audio filter and making skilled use of the TS-820 controls, such as the IF SHIFT, AGC, RF ATTENUATOR and RF/AF gain controls, will provide a cw capability that only a zero-beat signal could upset. Credit for the modification circuit goes to Charles Hughes, K2LA. — *Vincent J. Luciani, K2VJ, Egg Harbor, New Jersey*

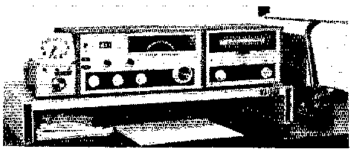
DESK-TOP EQUIPMENT SHELF

Want to organize your station, make it easier to operate and give it a new "look" all at once? If you do, build the equipment stand shown in the accompanying photograph.

The material is aluminum with 1/8- × 16- × 30-inch (3- × 400- × 760-mm) sheet stock serving as the top. Sides are 1- × 4-inch (25- × 100-mm) tubes with 1/8-inch (3-mm) thickness. Local machine shops often have this material available as scrap. Scrap dealers are an alternative source.

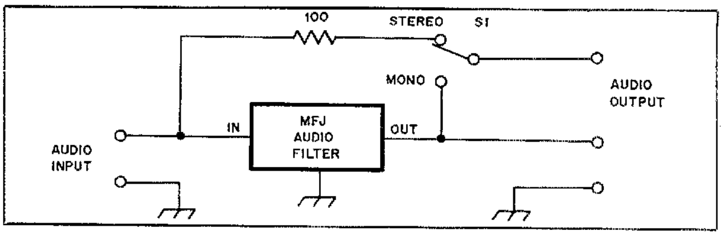
My stand is welded together. Machine screws or even self-tapping screws may be used instead. Although my stand retains a natural mill finish, paint could be applied to suit the individual's aesthetic taste. The result is a stand that is better appearing than a wooden one. Additional storage space is available beneath the stand. Equipment is placed at eye level.

One final note: I would suggest a power strip, such as manufactured by Waber Electric, be fastened to the back of the stand. This will eliminate all of the dangling cords commonly found behind Amateur Radio equipment. — *Daniel R. Shine, WA1GGN, West Haven, Connecticut*



This desk-top equipment shelf, constructed of aluminum stock, is the work of Daniel Shine, WA1GGN of West Haven, Connecticut.

MFJ CW FILTER



John Pane, AF3B, uses this arrangement to produce a simulated stereo effect when using his MFJ cw filter. With S1 in the STEREO position, one audio channel carries unfiltered audio from the receiver and the other channel carries filtered audio.

My MFJ CWF-2 cw audio filter operates quite satisfactorily on a 9-volt transistor battery until the battery voltage drops. After a few hours of use, the filter begins to ring when the voltage drops. This problem is occasionally augmented when the filter is unintentionally left on overnight.

As a solution to the battery-power/ringing problem, I first decided to connect an external power supply to the filter. According to the manufacturer, the MFJ may be operated safely with up to 18 volts applied. I chose instead to tap the 15-volt supply in my receiver. As a result of this modification, I have not experienced the former ringing problem and the filter is shut off automatically whenever the receiver is switched off.

With the arrangement I now use, the filter functions on battery power whenever the power cord is not plugged in. I've also installed a miniature phone jack on the back panel to accommodate the dc input. Another miniature jack, inserted on the back panel, replaces the inconvenient audio-input terminal post.

Next I added a simulated stereo modification as indicated in the accompanying diagram. S1, mounted on the rear panel, selects normal operation or simulated stereo. The value of R1 is not critical. I chose 100 ohms, but other operators may elect a different value to suit a particular audio taste or to accommodate a different headphone impedance.

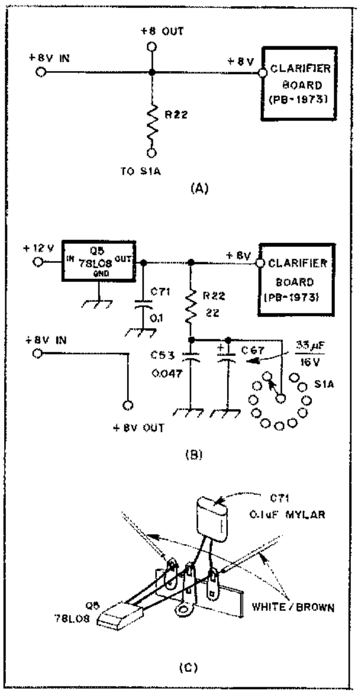
In order to use a stereo headset, I replaced the monaural phone jack (located on the front panel) with a stereo jack. The mono jack is now on the rear panel where it serves as an output for a speaker which carries the audio except when phones are used. As a concluding touch to the project, I added two LEDs to the front panel. One indicates POWER ON and the other SIMULATED STEREO.

After an operator becomes accustomed to the simulated effect, the modified MFJ filter will be found to be an invaluable aid to cw reception, especially during contests. There is ample room in the MFJ filter for these simple modifications, which should cause no difficulty for even the beginner. — *John Pane, AF3B, Baden, Pennsylvania*

FT-101ZD FREQUENCY SHIFT

Owners of early production FT-101ZDs (lots 01 through 06) may discover that operation of the DIM controls affects the VFO frequency slightly. The service manual relates a cure for this malady. Basically that change involves the addition of a terminal strip, two components and a minor wiring change. Part A of the accompanying drawing shows the original wiring of the circuitry involved. At B, the addition of a 78L08 8-V regulator (Q5) and a 0.1-µF Mylar capacitor (C71) is shown along with the wiring modification. In essence, this circuit change removes the CLARIFIER 8-V supply line from the original source and provides the board with a regulator of its own. All work is done on the underside of the transceiver.

A three-lug (center ground) terminal strip is mounted between jacks MJ1 and MJ2. Use a self-tapping sheet-metal screw to fasten the strip to the available chassis hole. Identify the white/brown 8-V lead from the CLARIFIER board to the second lug on the terminal strip immediately in front of the rectifier A board (PB 1967). Cut the lead at the terminal and relocate it to the lug immediately to the left (+12 V). This is easier than attempting to reach the 12-V lug on MJ1 as instructed by Yaesu. Cut the white/brown wire where it passes close to the newly installed terminal strip and solder the components to the strip as shown in Fig. B. Connect the ends of the previously cut white/brown wire to the proper terminals. The accompanying pictorial should be of help. When correctly installed, there should be +12 V at the input to the regulator and +8 V at the output of the regulator and at the CLARIFIER board. The frequency shift previously encountered during the DIM control operation should be absent. — *Paul K. Pagel, N1FB*



Yaesu has provided the above modification for eliminating frequency shift during DIM control operation of the FT-101ZD

Technical Correspondence

Conducted By
John C. Pelham,* W1JA

The publishers of QST assume no responsibility for statements made herein by correspondents.

A LOOK AT OSCAR-7 TELEMETRY

In October 1978, about four years after its launch, OSCAR 7 began to show signs of ailing. The battery voltages became erratic, and while in mode B, the telemetry often became garbled. The mode-B transponder would occasionally break into spurious oscillation. Reports started to come in of the satellite going dead when it passed into the earth's shadow.

These problems were symptomatic of a fault in the power systems of the satellite. A similar malfunction had apparently caused the demise of OSCAR 6, when cell after cell in its battery had shorted, resulting in an ever-decreasing battery voltage. Eventually, the battery voltage fell below the minimum necessary to operate the electronics, and the satellite went dead.

In the spring of 1979, it seemed highly likely that OSCAR 7 would end its life in much the same way. However, summer came and the satellite entered a period of continuous sunlight. This, it was hoped, would extend the satellite's life by taking some of the strain from the failing battery. We are now into 1980 and the satellite is still working, if somewhat erratically.

To try to find out what was happening up there, Pat Gowen, G3IOR, and I have been collecting telemetry data since August 1979. The Morse code telemetry system used by OSCAR 7 consists of 24 channels, each of which carries information about one spacecraft parameter. The 24 channels are transmitted sequentially in six lines of four channels. Each channel is transmitted as a three-figure number. The first digit is the line number, 1 to 6; the last two digits contain the information or data count. To convert the data count into meaningful units, there are formulas for each channel.

The first channel, called 1A, measures the total array current and has been faulty for many years. The next four channels carry information about the current from each of the four arrays of solar cells that supply the satellite with power. One panel is placed on each of the four sides of the satellite, there being no cells on the top and bottom. From their positions on the satellite, it is obviously impossible for the panels on opposite sides to receive direct sunlight simultaneously. However, on many occasions it was noted that the telemetered currents from opposing arrays were both large. This may be caused by the satellite rotating rapidly, but this seems unlikely since any rotation would tend to be damped out by the earth's magnetic field. The values for the array currents vary somewhat erratically between successive frames of telemetry.

The next channel, 2B, relates the power output of the mode-B transponder. When the satellite is in mode B, the telemetry indicates a reasonable power output of 2 to 4 W. In mode A, the telemetry indicates a full-scale output of about 8 W, which is obviously incorrect.

Channel 2C transmits the time as indicated by the internal clock of the satellite. During many passes, the time changed randomly, although on passes where the satellite was not being used, especially when in mode A, the clock appeared to function normally.

The next three channels, 2D, 3A and 3B, correspond to battery charge/discharge current, battery voltage and battery half voltage. The battery is a six-ampere-hour type. The half-battery voltage is the voltage of a point halfway up the battery string; in a normal healthy battery, it should be half the full battery voltage. In most of the recordings, the full potential is about 14 V, which is normal. The half voltage is now only about 1.8 V, however.

The charge/discharge current was typically within ±40 mA. This corresponds to a charge time of 150 hours, which is a very low rate. Charge/discharge currents of 10 times this value would be normal for this system.

Channel 3D measures the battery temperature. Typically, this remained fairly constant at 34° C over a period of several weeks, if not months. Comparing this with the telemetered temperatures for the baseplate of 31 to 38° C, and the temperatures of the + X and + Z panels of 29 to 35° C, we can see that the battery is not unduly hot. This is in direct contrast to OSCAR 6, whose battery temperature rose dramatically because of excessive power drain and overcharging.[1]

Channels 4B, 5A and 5C represent the temperature of the mode-A PA, the mode-B PA and the mode-A modulator. These temperatures depended on which mode the satellite was in. For example, channel 4B indicated a temperature of about 55° C when the mode-A transponder was active, and 35° C when it was off. It was also noted that when the mode-A transponder was being heavily used, its PA was about 6° C hotter than normal. This indicates that the telemetry was functioning normally, at least in mode A.

Channel 5B, the mode-A PA emitter current, was also shown to be dependent upon mode and the degree of loading. It varied from 0 to 35 mA in mode B and between 60 and 150 mA in mode A. Channel 6A contains information about the 10-meter power output. In mode A, the output read between 160 and 920 mW. The output did seem to be related to the observed usage of the downlink, but attempts to change the telemetered output by transmitting carriers of up to 200-W erp on the uplink passband were unsuccessful. The reason for this failure is not clear, as the passband was unused at the time. With 200-W erp, the transponder should have been well loaded. There was no indication of loading in any of the other relevant channels either. Perhaps I was just not using enough power.

Of the remaining channels, the only one of interest is 6D, the telemetry calibration channel. When the telemetry is working, this channel should read 50 ±2. However, during passes when the telemetry was relaying anomalous readings, 6D was frequently within the tolerance range. Occasionally, 6D would be way out of range, yet the rest of the telemetry would appear to be sensible. Of course when the satellite was very heavily loaded and the telemetry was sending rubbish, channel 6D was also affected.

On many occasions when the satellite is in mode B and being heavily used, the telemetry fails completely: The satellite beacon transmits the same number for each of the channels in one line. This sequence of numbers is repeated on successive frames; one of the numbers occasionally changes. It would seem that failure occurs when the battery voltage falls below about 10 to 11 V. It is also apparent that as the voltage falls the number of anomalies occurring increases dramatically. These anomalous readings become apparent by comparing successive frames of telemetry. The bad readings are not confined to any particular channel, and are characterized by a reading which is far from the normal operating range of that channel.

It would appear from these observations that the satellite is now working almost entirely from its solar cells, since when it passes into the earth's shadow, it goes dead.[2] In mode B, the power system can hardly supply enough current for the satellite to work. In mode A, where the solar cells can supply all the necessary current, the satellite functions properly.

In mode B, the telemetered battery voltage fluctuates by about 1 volt, indicating poor regulation under heavy loading. This is to be expected from the battery-charge regulator on its own. The on-board charge regulator has two functions: to limit the charge current to safe values, and to keep the battery voltage from rising above about 15 V. When the satellite is in mode B, the transponder tries to draw more than the regulator will supply, and the voltage drops. As the loading changes, the voltage varies. The poor regulation would account for the observed frequency modulation of the transponder output.

At first I thought that perhaps some of the cells in one half of the battery had shorted, the cells in the other half being overcharged to bring the full battery voltage up to 14 V. However, in view of the lack of any signs of large charging currents or an elevated battery temperature, this now seems unlikely. The second possibility is that a cell or connection has opened or developed a high resistance. This would explain the lack of regulation and the

*Assistant Technical Editor, *QST*

[1] Sweeting, "The University of Surrey AMSAT telecommand centre," *Radio Communication* (RSGB), June 1978.

[2] Roberts, "Oscar Seven Plays Elusive," *Oscar News*, Summer 1979.

absence of charging currents. If the fault occurred in the upper half of the battery, then it is feasible that the lower half would gradually discharge. This would produce the low half-battery voltage indicated by the telemetry.

As to the causes of any such battery failure, I can only speculate. Perhaps as a result of large current drains over Europe, thermal cycling has broken a connection in one of the cells. Who can say? We will probably never know the truth, unless someone takes a closer look! If my hypothesis is correct, it seems likely that OSCAR 7 will be with us for some time to come — that is until some other fault occurs. — *Nick Whyborn, G8OCJ, Kimberlin, Southwood Road, Beighton, Norwich NR13 3AB, England*

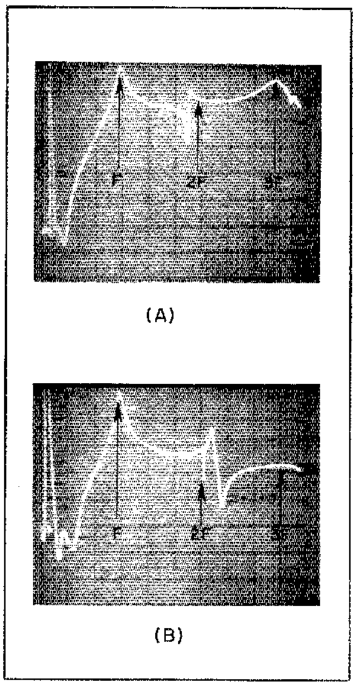


Fig. 2 — Response characteristics of an Ultimate Transmatch (A) and the SPC Transmatch (B) as viewed on a spectrum analyzer at 15 MHz. Horizontal divisions are 5 MHz, and vertical divisions are 10 dB each.

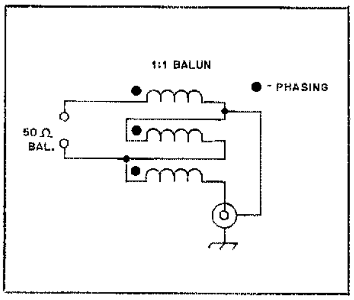


Fig. 3 — Details of a trifilar air-wound 1:1 balun for use from 3.5 to 30 MHz.

ULTIMATE TRANSMATCH IMPROVED

□ Manufacturers have been copying the "Ultimate Transmatch" circuit for many years, apparently without thought toward harmonic suppression with that network. The original circuit was developed by the James Millen Co. for use in its 50-Ohmer Transmatch. It was made more flexible in terms of matching range, and was popularized in *QST* by W1ICP as the "Ultimate Transmatch."[1] Fig. 1A shows the classical T-network represented by this circuit. The W1ICP and

[1]McCoy, "The Ultimate Transmatch," *QST*, July 1970.

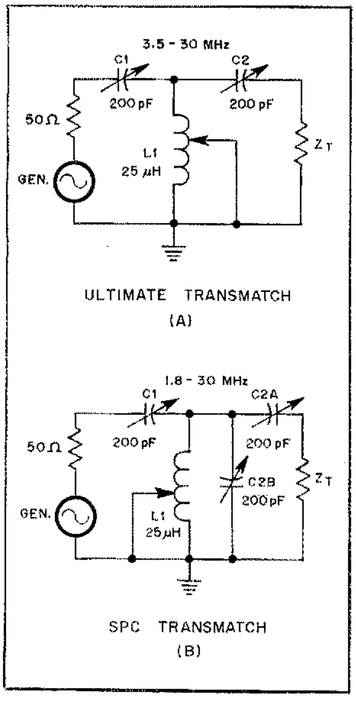


Fig. 1 — Circuit of the Ultimate Transmatch (A) and the SPC Transmatch (B).

subsequent-manufactured circuits of this type contained a dual-section variable capacitor at C1, with the half not shown being connected across the 50-ohm input terminal. The signal source was connected to the junction of the two halves of the capacitor. The lower capacitor is not necessary, as the circuit performance remains virtually unchanged with or without the extra capacitor section. Therefore, the cost of most homemade and commercial units has been higher than it needed to be.

The unfortunate aspect of the circuit in Fig. 1A is that under some transformation conditions it degenerates into a high-pass network. This is most likely to occur when Z_T is a high value and C1 is set for a low value of capacitance. As a high-pass type of network, the harmonic attenuation in a worst-case condition will be only a few dB, giving rise to possible TVI and other forms of harmonic interference if a low-pass filter is not used between the transmitter and the Transmatch. As C1 and C2 become more fully meshed, for a particular load impedance, the network exhibits a bandpass response, owing to the greater effective C in shunt with L1.

I developed the circuit of Fig. 1B in an effort to maintain a bandpass type of response under all load conditions. Since C2A and C2B are in tandem, there is always a substantial amount of capacitance in parallel with L1. This circuit was named the "SPC (series/parallel capacitance) Transmatch" because of the C1/C2 configuration.

The matching range with the improved circuit is the same as with the circuit of Fig. 1A, but the harmonic attenuation is significantly better than that obtained with the "Ultimate." Furthermore, the low-frequency limits of the original network are extended to include the 160-meter band without need for additional components of L and C, using the same coil and capacitor values in the two circuits. In fact, only 3/4 of the available L1 inductance is needed to provide matching at 1.8 MHz when the SPC circuit is employed.

Fig. 2 shows spectographs of the response of a commercial version of the Ultimate Transmatch (A) and the SPC unit (B). The operating frequency is 15 MHz, and the horizontal divisions are 5 MHz each. The vertical scale is 10 dB/div. The load at Z_T is 1000 ohms, yielding a 20:1 transformation ratio. It can be seen that the response at the frequency of the second harmonic (illustration A) is down only 11 dB, with the third harmonic response down 4 dB from the carrier frequency. The SPC response at B shows the second harmonic down 22 dB and the third is down 28 dB. Both circuits were adjusted for a best-case condition. A practical version of the SPC Transmatch will appear in the 1981 ARRL *Handbook*.

It is possible that the harmonic attenuation of the new circuit could be improved by careful isolation of the input/output leads and components, along with a shield plate between C1 and L1/C2. This was not tried.

A word about baluns in Transmatches may be in order. Broadband transformers of the type found in many of the so-called Ultimate Transmatches are not suitable for use at high impedances. Disastrous results can be had when using these transformers with loads higher than, say, 300 ohms during high-power operation. The effectiveness of the transformer is questionable as well. At high peak rf voltages (high-Z load condition such as 600-ohm feeders or an end-fed Hertz antenna) the core can saturate and the rf voltage can cause arcs between turns or between the winding and the core material. If a blanced-to-unbalanced transformation must be effected, try to keep the load impedance at 300 ohms or less. An air-wound 1:1 balun with a trifilar winding is recommended over a transformer with ferrite or powdered-iron core material. Fig. 3 shows such a balun. It contains 12 trifilar turns (close-wound) of no. 12 Formvar-insulated magnet wire on a 1-inch (25-mm) tubular form. — *Doug DeMaw, W1FB*

HAND-POWERED RADIO

☐ I enjoyed the "Stray" in February 1980 *QST* on WBNO, the solar-powered radio station in Bryan, Ohio. I am sure many hams using solid-state rigs in the 50- to 100-watt class could use solar cells with small storage batteries to power their transmitters.

I have used solar cells with my handie-talkie to extend NiCad life when I was away from the charger for extended periods. However, lack of sunshine at times limited the usefulness of the solar cells.

Recently I acquired a squeeze-generator type of flashlight, and I tried using it as an emergency source of charging current. I removed the lens and lamp, and attached leads to the empty lamp socket. When squeezed, the output was a little over 6 V ac. I connected this pair of leads to my NiCad pack in a voltage-doubler configuration, as shown in Fig. 4. A charging current of 50 to 60 mA was obtained. This extended the "on air" NiCad life by one minute when the flashlight was squeezed for 15 minutes! This is enough time to get an emergency message through.

Squeezing the generator develops the muscles in the fingers and forearm. It also reminds one of how much work old Sol does when his rays strike the silicon discs. — *Russell V. Robinson, W4UD, 1548 Valley Dr., Bristol, TN 37620.*

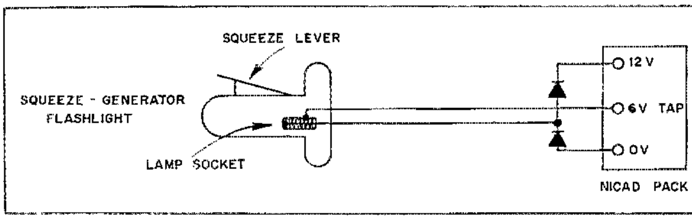


Fig. 4 — W4UD uses this voltage-doubler circuit to charge a handie-talkie NiCad pack with a squeeze-generator flashlight. The two diodes can be any small general-purpose silicon diodes. The wires between the flashlight and the battery pack should be long to allow freedom of movement while squeezing.

WALKING YOUR TOWER UP REVISITED

☐ Reference is made to the article appearing in March 1980 *QST* entitled, "Walking Your Tower Up? Can You Do It Safely?" by P. B. Mathewson, W9IR. The information contained in that article will yield reasonable results if no additional weight is concentrated at the top of the tower (from the presence of a mounted antenna system). The author states that the additional weight from an antenna system must be accounted for in the calculations if this weight is present.

The unfamiliar user might be tempted to add this additional weight to the total tower weight in the equations listed in the article. This can lead to substantial error since the tower weight is assumed to act at a distance of L/2. The concentrated antenna weight will act at the total tower length, however. The differing moment arms should be accounted for in the derivation of these equations.

Applying the same type of analysis used by the author, an equivalent weight (W = W1 + 2W2) should be used in all of the equations given in the article if an antenna system is present. W1 is the total tower weight and W2 is the total antenna system weight (both in pounds).

It should also be noted that if trigonometric reduction is used, Eq. 2 in the article can be written as

$$F = \frac{LW}{2X\,[1 + (H/X)^2]}$$

for those using a four-function calculator. — *Leigh Sedgwick, WA7BPI, 1704 June N.E., Albuquerque, NM 87112*

FREQUENCY-BLOCK PROGRAMMING OF CES 800 SCANNERS

☐ The Communications Electronics Specialties 800 series scanners are used with Clegg and other 2-meter synthesized transceivers. They are extremely versatile and convenient accessories. When programmed for repeater or simplex frequencies in your area, these scanners leave nothing to be desired in operating convenience. When they are used in areas where active repeater frequencies are unknown, however, scanning the entire 2-meter band is very time consuming.

The following program allows you to scan one or more continuous frequency blocks. No wiring changes are required. First, set all push buttons on the scanner to the outer, or released, position. Set the transceiver frequency to 144.00 MHz. Then:

1) Erase memory by pressing SCAN and DELT. Wait until the display "races" before releasing DELT. (It may be necessary to press RSME if the scanner was previously in the HOLD mode.) If you wish to retain the channels already in memory, you may skip this step.

2) Release SCAN. Set the lower limit of the desired block with the transceiver frequency controls, and press ENTR (for example, 146.00). Now set the upper limit of the block (for example, 147.00) and press ENTR.

3) Reset frequency controls to 144.00 MHz, then press SLOW and SCAN. The display will alternate between the upper and lower limits you have chosen. When the display shows the lower limit, press HOLD. Press ALL. Now hold down ENTR while pressing RSME. Continue holding ENTR while the frequency scans up from the lower limit; when it reaches the upper limit, press HOLD.

4) Release ALL and SLOW.

The unit will now scan only from the lower to the upper limits. It still may be programmed to add or delete additional frequencies in the usual manner. Additional blocks may be entered by repeating steps 2 through 4, with new upper and lower limits. — *Samuel Bases, K2IUV, 19 Standish Ave., Yonkers, NY 10710*

TEMPERATURE EFFECTS ON BYPASS CAPACITORS

☐ I'd like to share an experience I had recently with a Heathkit HW-2036 2-meter transceiver. What I found is probably not unique to this unit and may help others in similar situations.

During a recent cold spell a severe drop in receiver sensitivity occurred. The "troublemaker" was a 0.01-µF disc ceramic capacitor for a supply-decoupling resistor in a 455-kHz i-f amplifier (C227). When it was sprayed with commercial freeze spray, receiver sensitivity dropped. I replaced the capacitor, thinking it was defective. The replacement failed to correct the problem. My calculator showed why. At 455 kHz a 0.01-µF capacitor has 35 ohms of reactance. The power supply decoupling resistor is 100 ohms. The bypass capacitor would normally have a value of reactance less than or equal to 10% of the power supply decoupling resistor.

Using the calculator, I determined that the minimum value of capacitance for the bypass capacitor should be 0.035 µF. I used a 0.05-µF capacitor in the circuit. Spraying it with the cold spray resulted in little change in receiver sensitivity.

It is apparent from this exercise that disc ceramic capacitors certainly haven't the best temperature characteristics. The original bypass capacitors apparently were not temperature compensated, allowing changes in capacitance with temperature. Had compensated capacitors been used, no problems would have occurred. — *Eric Lifsey, AC7K, 5733 South 2050 West, Roy, UT 84067*

Feedback

☐ In Fig. 1 of "Increasing Receiver Dynamic Range," May 1980 *QST*, page 17, L5 is a ferrite bead, not a 10-µH inductor as shown. In the lower right corner of Fig. 6, a wire connects the right side of a 1000-pF capacitor and a 1-kΩ resistor to the +5-V bus. This wire should be replaced with a 1-kΩ resistor. In the text above Fig. 6, the references to a BF246 and a BF246C should refer to a U311 transistor. The reference to a BC177 should refer to a 2N2907.

☐ A mail delay prevented the author's script changes from being inserted in the article, "Simple, Accurate Resistance Measurements," appearing in January 1980 *QST*. The following corrections are to be made in the text.

On page 30, col. 3, line 11, change to "The ratio $R2_A/R2_B$ then is X/(1000 − X) . . ." and in the same paragraph change 1.286 to 0.7778, and 12,860 to 7778.

On page 31 in the middle of column 2, the words, "maximum" and "minimum" should be interchanged. In the same paragraph, 10,100/9286.2 should be 9473.8/9990. Also change 1.0876 to 0.95695. The sentence that follows should show 9286.2/10,100 or 0.91943 instead of 1.0450. And add "(R_U in Fig. 3)" to the words ". . . that the comparison resistors . . ." in the next-to-last paragraph.

Product Review

Conducted By Paul K. Pagel,* N1FB

The Swan Astro-150 Transceiver

The Swan Astro-150 Transceiver

Claimed Specifications

Frequency coverage: 3.0-4.5, 6.0-8.3, 13.8-16.0, 20.8-23.0 and 28.0-30.0 MHz.
Power requirement: 12-14 V dc at 20 A peak.
Dimensions (HWD): 3.75 × 9.75 × 11.75 inches (953 × 248 × 299 mm).
Receiver sensitivity: 0.35 µV for 10 dB S + N/N typical.
Transmitter power output: 100 W PEP.
Price class: Astro-150, $925. PSU-5, $180.

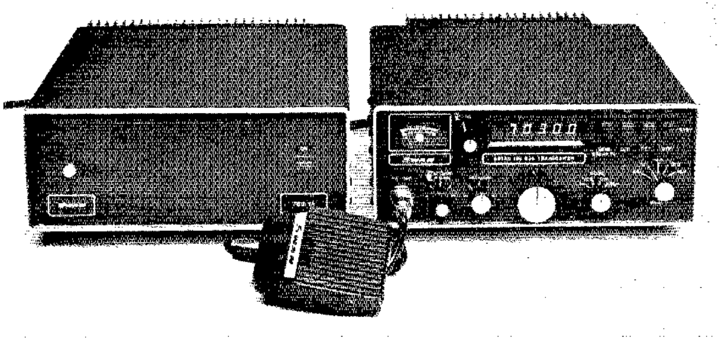


Fig. 1 — The Swan Astro-150 and matching power supply/speaker unit. The "Variable Rate Scanning" knob is the large one in the center of the panel. The microphone shown is included in the price of the Astro-150. Frequency tuning can also be accomplished by using two buttons (not visible) on the top surface of the microphone.

Mention of the name "Swan" calls to mind radios such as the well-known Swan 350 or Swan 500C, along with a particular period in the evolution of Amateur Radio equipment. But the Swan brand name hasn't been heard from much since those days of a decade ago, so it was with particular interest that this offering from Swan was unpacked.

The Swan Astro-150 is an extremely compact, solid-state, 80- through 10-meter ssb and cw transceiver. A matching power supply/speaker combination of equal size is also available. The PEP input of this little Goliath is 235 watts, with a 100-watt output. No receiver peaking or transmitter tuning is necessary. Band-pass filter techniques are used throughout. Also included in the small package are a noise blanker, VOX, RIT (receiver incremental tuning), full break-in cw operation and an easy-to-read digital frequency display (no analog readout is provided).

The quality of construction found upon examining the innards of this unit is second to none. In fact, the reviewer was reminded of a well-executed piece of expensive commercial or industrial test gear. Nine double-sided, glass-epoxy boards are used, and while they don't all plug into a neat row of sockets, the boards can be freed for component replacement relatively easily. Each board is held in place by screws and standoffs (they're captive, so don't worry about them falling into the rig), and all the connections to the board unplug without desoldering. Point-to-point wiring is minimized inside the unit; instead of a mass of wires leading to the front panel controls, a single large circuit board is used. The terminals on the back of all the controls are soldered directly to this board! All in all, looking inside gives the impression of extreme reliability and ruggedness.

*Asst. Technical Editor, *QST*

The Circuit

Single-conversion, as is usual for Swan, is used. The receive signal is filtered first by the transmit low-pass filters, then a three-section band-pass filter before being amplified by a dual-gate MOSFET. The amplified signal is fed to a doubly balanced, diode-ring passive mixer. It is this design choice that is probably responsible for the excellent dynamic range of the receiver. The reviewer's location (1/2 mile from W1AW) is a good dynamic-range test bed. At no time on any band was any "buckshot" or IMD product heard when W1AW was transmitting. No receiver desensing was ever evident either, even 3 kHz away from W1AW's transmitting frequency. Receiver dynamic-range measurements were made on 80 and 20 meters. On 80 meters, the receiver noise floor measured −127 dBm, blocking occurred at greater than 114 dB and the IMD dynamic range measured 84 dB. This data equates to an input intercept figure of −1 dBm. On 20 meters, the noise floor was −131 dBm, blocking occurred at greater than 118 dB, IMD dynamic range was 86 dB and the input intercept was calculated to be −2 dBm.

Six "birdies" were found in the receiver tuning range. Three of these (at 21.280, 28.010 and 29.010 MHz) were quite strong, reading S5 on the S meter. They were bothersome when operating in their vicinities.

Audio-derived fast-attack, slow-decay agc is used, and in my opinion the attack isn't fast enough. Also, some agc "pumping" on strong signals is evident. Plenty of audio output power is available from the single integrated-circuit audio amplifier, a good feature for mobile use.

The only relay used in the transceiver is an spst reed relay which disconnects the receiver from the transmitter low-pass filters during transmit periods. All other T-R switching is solid-state. This facilitates the incorporation of true cw break-in, with the reed relay following each transmitted dit and dah. The reed relay is extremely quiet, and QSK operation is a joy! If band conditions are such that QSK is not desired, the operator may revert to semi-break-in with a front-panel switch.

A frequency synthesizer in the Astro-150 generates both the variable LO frequency and the usb/lsb carrier oscillator frequencies. The heart of the synthesizer is a Signetics microprocessor LSI chip, nestled deep in the center of the transceiver. It takes input data from the bandswitch, mode-switch and tuning knob and determines the required number for a programmable divider in the phase-locked loop. When this number varies, the LO output frequency varies, tuning the transceiver. Each frequency thus generated is as stable and as accurate as the crystal oscillator used for a reference. Digital outputs are also provided to drive the LED readout. This micro-computer chip also has a memory. As long as power is continuously applied, it will remember the last frequency tuned on each band and return to that frequency when the band is selected again. A third position is provided on the power switch that removes power from all the circuitry except the memory. Thus, the unit can be turned "off" without losing the stored frequencies.

The synthesizer covers a significant range of frequencies outside of each amateur band, which should be a delight to MARS operators. Reception of 15-MHz shortwave broadcasting (and 15-MHz WWV) is provided, perhaps inadvertently, because on 20 meters the synthesizer will tune all the way up to 16 MHz! (Note to hf-ers: Tuning below 28.0 MHz is *not* possible!) When the bandswitch position is changed, the synthesizer is unlocked for a few seconds until all of the new frequency information is sorted out. This is indicated by the muting of the receiver audio and the illumination of all the decimal points in the frequency display. However, when the synthesizer is unlocked, keying the transmitter still produces rf output! The rf output sweeps up and down the band as the synthesizer hunts for a locked condition. These sweeps can be as much as several hundred kHz in width, so an out-of-band emission is a possibility, especially if the frequency is set near a band edge. Don't transmit while the synthesizer is unlocked! It's too bad Swan didn't see fit to mute the transmitter as well as the receiver.

Operating Characteristics

Perhaps the most notable operating feature of the Astro-150 is what Swan calls "variable rate scanning." The scanning rate is determined by the position of the large knob in the center of the front panel. This "tuning knob" is not really a tuning knob at all; it is a potentiometer with a center detent. With the knob in the detent, no scanning occurs. A slight clockwise rotation of the knob starts a scan upward in frequency, and counterclockwise rotation initiates downward scan. The scan rate depends on how far the knob is rotated from the center detent: The rate is variable from approximately 200 Hz to 100 kHz per second.

It is also possible to change frequency with the hand-held microphone supplied with the unit. Two buttons are located on the top surface of the mic., one to scan up in frequency, the other, down. A single push on a button will jog the frequency by one 100-Hz increment. If the button is held, the synthesizer will scan at about 1 kHz per second. It is worth noting that when the synthesizer is scanning, the frequency does not change in discrete 100-Hz steps (as in the ICOM IC-701). Instead, it sweeps smoothly across the band, coming gently to rest on the selected 100-Hz increment. In case these fixed 100-Hz steps do not allow ssb tuning as precise as the operator would desire, a fine-tuning control is provided which can vary the transmit *and* receive frequencies ±75 Hz from the synthesizer-determined frequency. RIT is also provided, but its range is a paltry ±300 Hz. A much wider range (say ±5 kHz) would be desirable for limited split-frequency cw or DX work. Also, the RIT is always active with no defeat switch included. Not even a center detent has been provided. Thus the operator is always unsure that he is transmitting and receiving on *exactly* the same frequency. In all fairness, it must be mentioned that the circuit was perfectly calibrated: True transceive occurred with the knob precisely at 12 o'clock.

Even after several weeks of use, I never quite got used to the variable-rate scanning. I felt constrained and frustrated. Its somewhat like telling another person to do your tuning for you, following your verbal commands: "Tune higher. There's a signal — stop! Now tune a little lower. Oops, you overshot, tune a little higher." Since the frequency and many other functions are microprocessor controlled, it's a pity that a few user-programmable memories weren't included. This couldn't have been too difficult to do, and would have ameliorated the disadvantages of the tuning system somewhat.

As received from the factory, the built-in, peak-reading wattmeter was slightly generous when compared to an accurate in-line wattmeter. An internal wattmeter reading of 100 watts corresponded to 80 watts of actual rf output. A quick adjustment of the internal calibration control dispatched this problem!

An alc circuit in the '150 works in combination with the forward- and reverse-power outputs of the wattmeter. It acts on a low-level transmitter stage and reduces the drive if either forward or reverse power exceeds preset levels. This circuit was initially responsible for a rather poorly shaped cw keying envelope and moderate on-air key clicks. After a slight adjustment of R103 (FWD alc sensitivity), the cw envelope became near perfect. And as an added bonus, the maximum power output level increased slightly to about 110 watts.

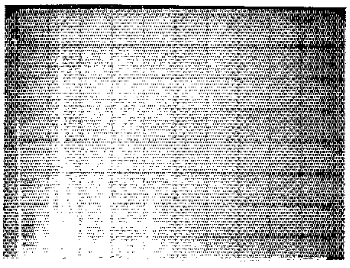


Fig. 2 — Spectral display of the Astro-150 rf output on 40 meters (worst case). Vertical divisions are each 10 dB. Horizontal divisions are each 5 MHz. The response at the far left is the zero-frequency reference of the analyzer. The full scale pip is the 7-MHz carrier. Note the spurious signals (probably synthesizer byproducts) clustered about the carrier. The second harmonic is down 44 dB from the fundamental, and the third harmonic is suppressed 57 dB. The '150 is in compliance with current FCC regulations regarding spectral purity. All measurements were made in the ARRL lab.

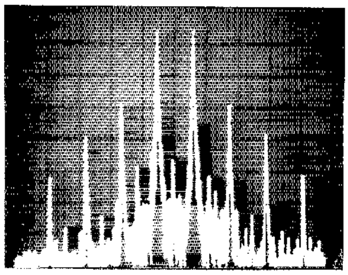


Fig. 3 — Spectral display of the transmitter IMD characteristics at rated power. Vertical divisions are each 10 dB; horizontal divisions are each 1 kHz. Third-order IMD products are down 29 dB from the PEP level while fifth-order products are down 39 dB.

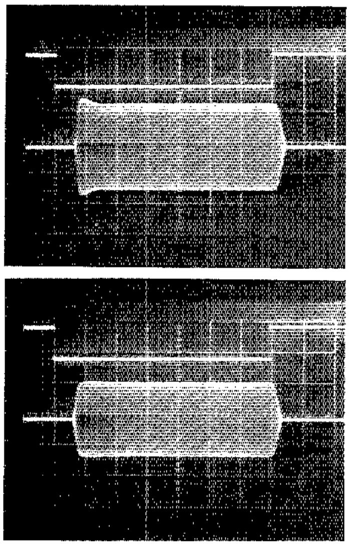


Fig. 4 — Two pairs of keying waveforms are shown. The upper waveform in each pair is the actual key-down time, while the lower is the resultant rf output. The upper rf output waveform is typical of that obtained when the carrier level is advanced just to the clipping point. This waveform did not sound bad on the air. When the drive was reduced slightly, the more ideal lower-output waveform resulted.

An omission on the part of the manufacturer is the absence of a front-panel headphone jack. An audio output jack *is* provided on the rear panel which mutes the built-in speaker, but it is usually stuffed with the external speaker plug if the matching power supply/speaker is used. No headphone jack is provided on the power supply either, although it would be very easy for the owner to add one.

The Astro-150 appears to have been designed with cw operation as a primary concern, not an afterthought. In addition to the full break-in mentioned earlier, two VOX delay potentiometers are provided — one for cw when using semi break-in and the other for 'phone. Also, two degrees of selectivity, 2.7 kHz normal and "narrow," are selectable from the front panel while in the cw mode. The characteristics of the narrow cw filter are not specified in the owner's manual, but appear to be approximately a 500-Hz bandwidth with reasonably sharp skirts; suitable for all but the most demanding cw operating. These are nice touches — other manufacturers please *take note!* The sidetone used for cw monitoring has very heavy weighting. This is not evident in the transmitted signal, but is annoying at first and takes some getting used to.

The features of the Astro-150 add up to make it a nifty little mobile rig as well. Its diminutive size will allow it to squeeze into spots where no ordinary hf rig would fit. Its hefty audio output and microphone tuning buttons are also well suited to mobile use.

On ssb, the performance of this transceiver left little to be desired. Both receive and transmit audio quality were good. The action of the alc circuit on ssb was excellent. The Astro-150 was very difficult to overdrive. A clean-sounding signal was maintained even when the mic gain control was advanced far beyond the correct setting.

The owner's manual supplied with the unit is very well written and informative, especially the theory of operation section. It includes a brief alignment routine consisting of only those adjustments which Swan feels are within the owner's capabilities. These include VOX, S-meter sensitivity and carrier-oscillator frequency. Not included are the more complex synthesizer, reference generator, alc circuit or bandpass filter adjustments. Further information on the Swan Astro-150 is available from Swan Electronics, 305 Airport Rd., Oceanside, CA 92054. — *John C. Pelham, W1JA*

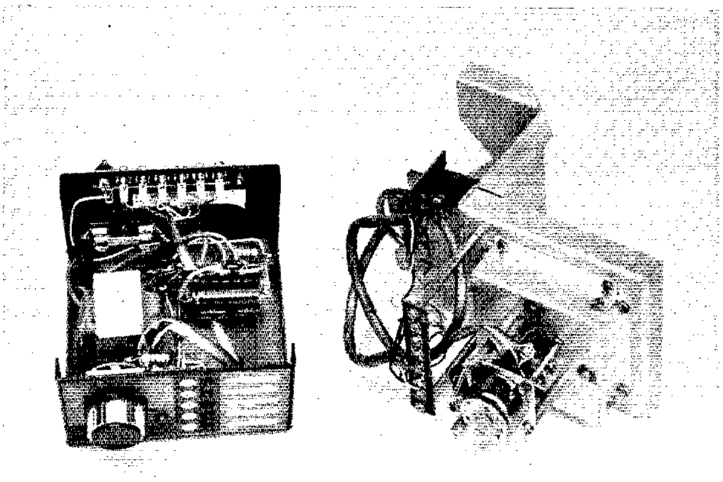


Fig. 5 — The Heath SA-1480 Remote Coax Switch. The actual coaxial switch is within the shielded portion of the right-hand assembly. LED indicators and an erasable front panel are featured on the station control unit.

HEATHKIT SA-1480 REMOTE ANTENNA SWITCH

After replacing my tribander with monobanders last summer and noting the high price of separate runs of coaxial cable, I decided a remote antenna switch was the best way to go. A look at the commercial antenna switches available told me that none of them satisfied my requirements for price and number of positions, so I built my own. During a storm, my homebuilt remote antenna switch filled up with water. As I was lamenting its loss, the annoucement of the new Heathkit SA-1480 remote antenna switch caught my eye. The advertisement indicated that the remote switch required an eight-conductor control cable and that it would switch up to five different antennas. It couldn't have fit my needs more closely.[1]

Construction of the remote antenna switch required approximately five hours and was relatively straightforward: Just make sure the polarities of the diodes and LEDs are observed. The complete unit consists of two basic pieces, the remote switch that mounts on your tower or mast, and the control box which is placed at the operating position. The control box is a compact unit using LEDs to indicate which antenna is in use. The switch can be set so that all antennas are grounded and the feed line left open.

The remote switch box is solidly built, with silver-plated switch contacts on a ceramic switch wafer, and good shielding of the rf compartment. A one-piece cover protects the entire unit from the weather. An ample supply of sealant is provided to assure a watertight seal. When assembling the remote unit, be certain to wire the switch and switch motor carefully. Though the instructions are adequate, the wiring is tricky and a mistake can be made. Two little capsules of locking compound are provided to ensure that all hardware remains tight. This compound is particularly nasty stuff when it gets onto your workbench, so read the warnings carefully.

After everything was soldered and assembled, a short piece of cable was used to test the operation of both units. The first attempt resulted in the loss of the 3/16-A slow-blow fuse in the control box. Thorough checking found no errors in wiring, and after an afternoon of searching for a replacement fuse, the second test went perfectly. Possibly the remote unit switch motor (pulse switching) required an extra amount of current to start the first time. In any case, no further difficulties have occurred.

Mounting the remote unit on the tower proved to be very easy. Clamps were provided which accept a mast or tower leg of up to 1-1/2 inches in diameter. It took only about 15 minutes to mount the remote unit and attach the cables from the three antennas. Only three of the five positions available were originally used. Caps are provided to weatherproof the unused connections (all are type SO-239). A multidirectional sloper array for 40 or 80 meters could be switched from this remote antenna switch quite easily. The switch has been in use for several months now with no problems encountered. Less than a second is required to go between any of the switch positions, and the pulse switching generates no noise in the local receiver.

Heath has again come out with the right product at the right time. I would have spent more money for coax than for the remote antenna switch. See if your calculations tell you the same thing! — *Tom Frenaye, K1KI*

[1] One comment: The description Heathkit gives of the remote antenna switch in their general catalog wasn't exactly clear. According to the manufacturer's specifications, the use of the SA-1480 will introduce no more than a 1.05:1 VSWR under 30 MHz and less than 1.2:1 under 150 MHz. The catalog description could be read by inexperienced amateurs to mean that the *switch* would reduce VSWR, which isn't correct.

THE BIRD 4381 RF POWER ANALYST

Microwave ovens, keyers, sewing machines and rf power meters — what do they have in common? A few years ago, that would have been a most puzzling question, but today the answer is easy — microcomputers! By utilizing a single-chip microcomputer, A/D converter and a dual-element THRULINE, Bird Electronic Corp. has produced a convenient and versatile rf power-measuring instrument, the model 4381 RF Power Analyst.

The 4381 will measure forward and reflected power in watts; it will also display power in dBm, measure PEP in watts or dBm, and calculate SWR, percent of modulation and return loss. It records the minimum and maximum value of any of the above quantities and has a peaking-aid mode.

The THRULINE used in the 4381 is similar to that used in the Bird model 43 wattmeter, using the same plug-in elements, but the 4381 has two elements in the THRULINE. This allows the microcomputer to completely control measurement of both the forward and reflected wave. Two "range" slide switches, located just above the display, are used to tell the microcomputer which plug-ins are being used, thus enabling it to correctly interpret the voltage levels received from the THRULINE. The range switches must be set to correspond to the full-scale power rating of the forward plug-in. When both the forward and reflected elements are used for a measurement, as in the case of SWR or return loss, it is assumed that their power ratings are in a 10 to 1 ratio. Readout is by means of a four-digit LED display, and the power for the unit is provided by self-contained, rechargeable NiCad batteries. The NiCads will power the 4381 for about eight hours of continuous operation without recharging.

While most of the functions of the 4381 are straightforward, certain features deserve mention, namely the minimum and maximum reading memories and the peaking-aid mode. By pressing the maximum key, the highest reading obtained since the last clearing of the memories can be displayed. I found this very useful while measuring PEP output of an ssb transmitter when using voice-waveform inputs. Under such conditions, it is difficult to follow the rapidly changing digital display and it is easy to miss the highest value measured. By using the memory, the maximum PEP obtained is easily read.

Bird 4381 RF Power Analyst

Manufacturer's Claimed Specifications

Power range[1]: 100 mW to 10 kW full scale using Bird plug-in elements. Accuracy not guaranteed with components not supplied by Bird.
Usable over-range: To 120% of scale on cw, PEP, SWR and return loss functions. To 400% of scale (PEP) on dBm and % modulation.
Frequency range[1]: 450 kHz to 2.3 GHz.
Sampling rate: 2-3 readings per second.
Accuracy
Power readings: ± 5% of full scale.
SWR: ± 10% of reading.
% modulation: ± 5%[1]
Return loss: ± 0.3 dB to corresponding SWR value.
Modulation frequency: 50-10,000 Hz.
Impedance: 50 ohms.
Insertion SWR: 1.05 max. to 1000 MHz.
Weight: 4.0 lb (1.8 kg).
Battery life: (Rechargeable) 8 hours approx.
Ac power: (Using adaptor) 115 V, 50-60 Hz 6 W 230 V, 50-60 Hz 6 W.

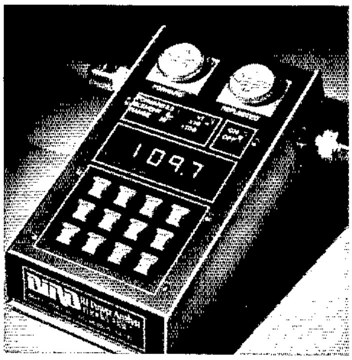


Fig. 6 — The Bird Model 4381 RF Power Analyst. A collapsible bail permits positioning the unit for easy readability.

When using a constant two-tone input, the 4381 reads PEP directly. The minimum memory can be used in this same manner to adjust matching networks for minimum SWR. For those familiar with making such adjustments using an analog meter, the transition to digital readout may be difficult. To help in this respect, the 4381 has a peaking mode. In this mode, the selected quantity is monitored. If successive readings show increasing values, a right-facing arrow is displayed, decreasing values produce a left-facing arrow, and a blank digit is displayed if the values are constant. This reviewer, being accustomed to analog meters, found it very difficult to peak a transmitter output rapidly, but had little trouble quickly adjusting a matching network. The difficulty no doubt arises from differences in smoothness and rate of tuning. In any event, I found myself opting for the analog meter to make such adjustments and then going to the 4381 for precise measurement of the resulting value. While measurement of forward and reflected power (using a conventional meter) and some calculations will produce parameters such as SWR and return loss, I found the 4381's direct readout a nice convenience.

The 4381 is normally supplied with two female N-type connectors; these are easily interchanged with a variety of connector types. The construction of the unit is excellent, and the instruction manual is complete and well written. While the 4381 is without doubt a "professional" instrument and perhaps somewhat expensive for many amateurs, it definitely represents an outstanding measurement instrument. The 4381 is available from the Bird Electronic Corp., 30303 Aurora Rd., Solon, OH 44139. The unit measures 3-21/32 × 6-7/32 × 8-29/32 in. (93 × 158 × 226 mm), HWD. Price class: $590, including connectors and either 117- or 235-V ac adapter. Element prices are $47 each for the 2- to 30-MHz range and $39 each for the 25- to 1000-MHz range. — *George Collins, AD0W*

[1]Frequency band and power range is determined by plug-in element selected. See Bird catalog for availability. Some modes require two elements in a 10:1 power ratio.
[2]For cw power levels greater than one-third of full scale, accuracy of the % modulation mode is ±5% from 0 to 90% and ±10% from 90 to 100%.
[3]For pulse modulation the minimum parameters are: 50 μs pulse width, 100 pps repetition rate and 1% duty cycle.

AUTEK QF-1A ACTIVE AUDIO FILTER

We gave a hefty rundown of the Autek QF-1 audio filter in March 1977 *QST*. Since there are many similarities between that model and the QF-1A, we will ignore the "sameness" and dwell on updates of the original circuit. Outwardly, the QF-1A resides in a new low-profile cabinet of rectangular format. A new control has appeared on the front panel — the AUXILIARY NOTCH FREQUENCY. The color scheme has been changed from black to gray, with noticeably better quality in the cabinetry and the silk screening on the panel.

We were pleased to note that the power on-off switch has been changed to include bypassing the filter when the switch is in the OFF position. The earlier model was awkward to use, because the operator had to disconnect it from the receiver (PL-55 plug) when filtering was not desired.

Autek Research has made another improvement: The previous model used a pair of small-signal bipolar transistors in the audio-output section. Distortion was apt to occur at medium-to-high audio output levels from the receiver, but the QF-1A has an audio IC at the output, and its output is substantially cleaner than that of the QF-1 amplifier. It is worth saying, however, that the new unit can still be saturated at high receiver-output levels.

Auxiliary Notch Frequency

This feature needs to be described in some detail, as it represents the most important change in the circuit. What it gives the operator is the ability to null out annoying heterodynes during cw or ssb reception, irrespective of the filter operating mode (BANDPASS, HIGH PASS, LOW PASS or NOTCH). The null depth is not as great (approximately 40 dB) as is the depth in the NOTCH position of the filter (up to −70 dB), but it is entirely adequate for most forms of steady-tone and cw QRM from 80 to 11,000 Hz. The null frequency is adjustable from the front panel. To disable the circuit, one simply turns the control to one or the other extreme of its range. Although this circuit is not specified as a "notcher" for some forms of ssb splatter, chatter or whatever, the writer has found that it does help in reducing the annoyance of adjacent-frequency ssb QRM.

Other Features

The innards of the QF-1A are more organized and professional than those of the QF-1. Susceptance to RFI has been greatly reduced through the shortening and bypassing of critical leads. No RFI effects could be detected at W1FB when running 1 kW from 3.5 to 29 MHz. The antennas used during this test were 50-ohm types, fed with coaxial cable, and well removed from the station equipment. Different results might be had while using an end-fed horizontal type of antenna, or if there is a high VSWR on the coaxial transmission line.

The new model of filter has SELECTIVITY and FREQUENCY controls which operate more smoothly than those of the old model. Furthermore, the selectivity is reduced automatically when the filter is switched to the LOW-PASS and HIGH-PASS modes. This prevents "blasting" at high settings of the SELECTIVITY control — a definite improvement!

Autek Research QF-1A Active Audio Filter

Claimed Specifications

Size (HWD): 2-1/2 × 6-1/2 × 5 inches (63 × 165 × 127 mm).
Color: Two-tone gray.
Audio output: 1 watt.
Center-frequency range: 250 to 2500 Hz, all modes.
Power requirements: 117 V ac, 50/60 Hz or external +12 V.
Installation: Connects externally to receiver output. Requires external speaker or phones.
Bandwidth: Variable from 20 Hz to flat response.
Price class: $65.
Manufacturer: Autek Research, Box 5127E, Sherman Oaks, CA 91403. Tel. 800-854-2003, ext. 842.

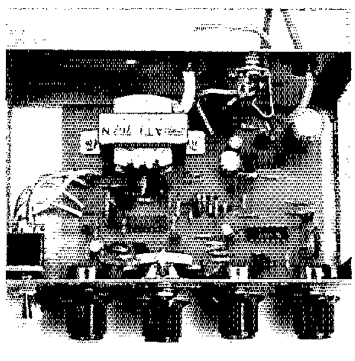
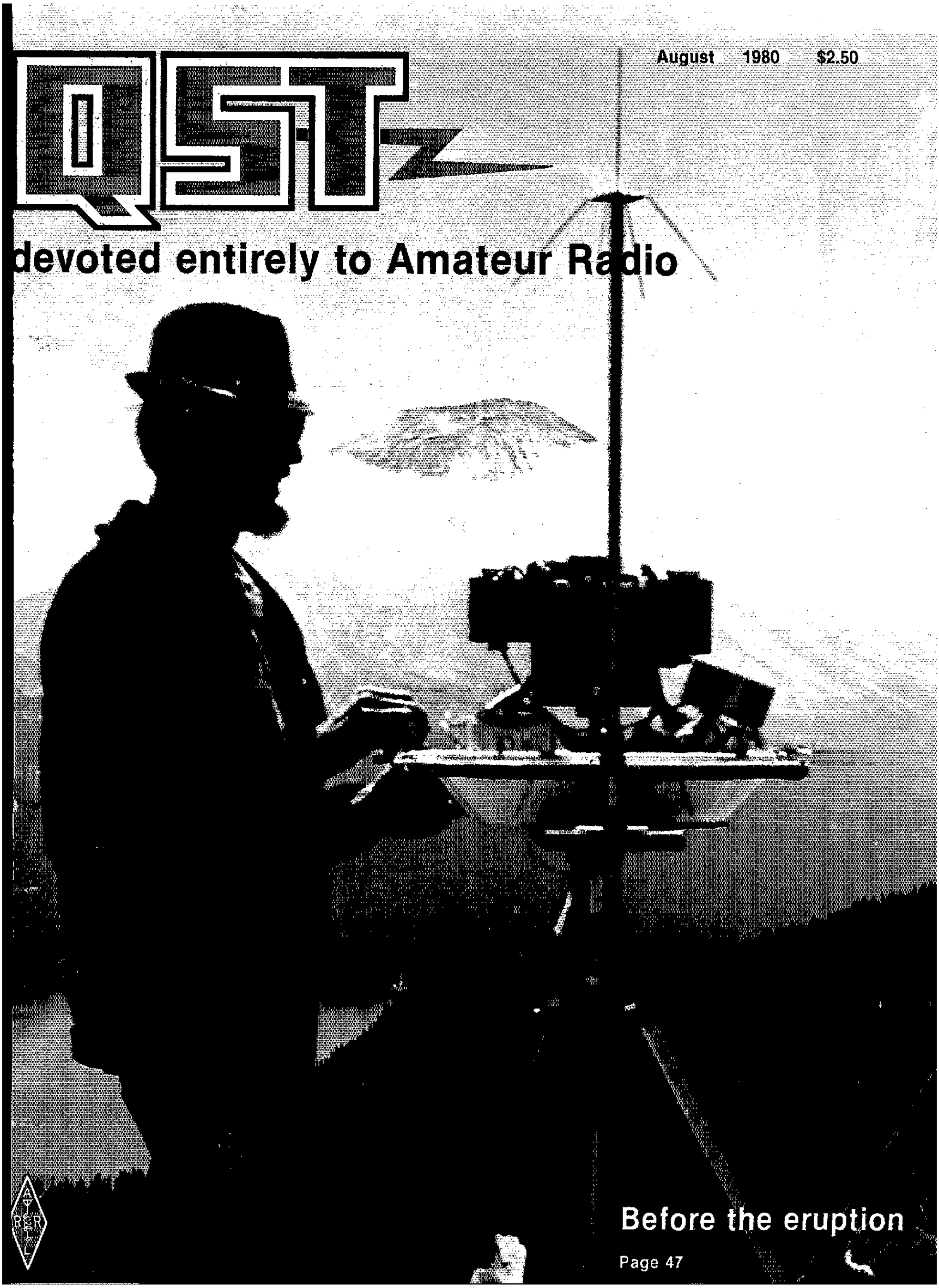


Fig. 7 — A neat, uncluttered layout greets the eye inside the Autek QF-1A audio filter.

Summary Remarks

If there really is such a person as a "serious DXer" (an oft-heard expression), then that person probably knows what can be gained from using a good R-C active audio filter. The uninitiated can learn more on this subject by reading the QF-1 product review, referenced earlier. A good example of how the QF-1 filter "saved the day" (actually, two weeks) for the reviewer was seen during a DXpedition to Montserrat late in 1979, where W1FB/VP2MFW was unable to pull signals out of the noise on 160-meter cw without the audio filter. Signals that were unreadable without the QF-1 became "solid copy" when it was used in the high-selectivity mode. The same filter was used early in 1980 by K1ZZ during his operations on 160 meters from Montserrat.

A good R-C active audio filter can provide the same benefits as a second i-f filter (tail-end filter) in a receiver: It greatly diminishes receiver wide-band noise, thereby improving the overall signal-to-noise ratio. The owner of this type of unit may find himself addicted to its use, even when copying strong signals! — *Doug DeMaw, W1FB*


August 1980 $2.50
QST
devoted entirely to Amateur Radio
Before the eruption
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QST

August 1980 *Volume LXIV Number 8*

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THE COVER

Roger McCoy, W7ADV, was just one of the amateurs active before, during and after the Mt. St. Helens eruptions. The remote-camera site and the lake are now buried under volcanic ash and mud. See p. 47. *(photo courtesy K7UUH)*

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Solar Powering a Ham Station

Double your hamming pleasure by reducing your electric bill! W5PIZ reveals how a small investment and a few hours of time have produced rewards far in excess of his expectations.

By John R. Halliday,* W5PIZ

Several months ago, I was in contact with Ted Handel, WB5REA, in Los Alamos, New Mexico, through the Redondo solar powered repeater. Ted is one of the engineers who installed the repeater on Redondo Peak, nearly 11,000 feet above sea level; it has delivered 20 watts of trouble-free power for several years. He suggested I build a solar-powered ham station and show how reasonable the cost can be. That made me think about the possibility of using solar power. Perhaps it would cut the power bill each month.

Well, with about $150 from the ham-radio savings kitty and the junk-box material on hand, I made the dream come true. I asked Ted to buy me three used panels (solar batteries) with his next order. They arrived in first-class condition.

These solar panels are very sensitive; even on a very cloudy day, they have good voltage output. On a clear night with a full moon I can get 6 to 7 volts from the system. One evening very low clouds passing over brightly lit Albuquerque produced 2 to 4 volts peak depending on the density and reflection characteristics of the clouds. Certainly, solar panels could be effective for almost any location.

This modest installation atop W5PIZ's home provides the electricity for his entire amateur station.

*4808 McKnight, N.E., Albuquerque, NM 87110

Inexpensive Accessories

The panels are mounted on a wooden rack made of surplus wood. I built the rack so the panels would be at a 45-degree angle to the roof, which is a flat surface. (Our home is a pueblo-style structure typical of the Southwest.) The panels face due south to catch the greatest amount of sunlight. Also, the panels are mounted about 12 inches above the bottom of the rack, so if it snows or rains, they will have some protection from any accumulation. The wooden rack has been treated with weatherproofing paint to stand the seasonal weathering. If I'd had metal

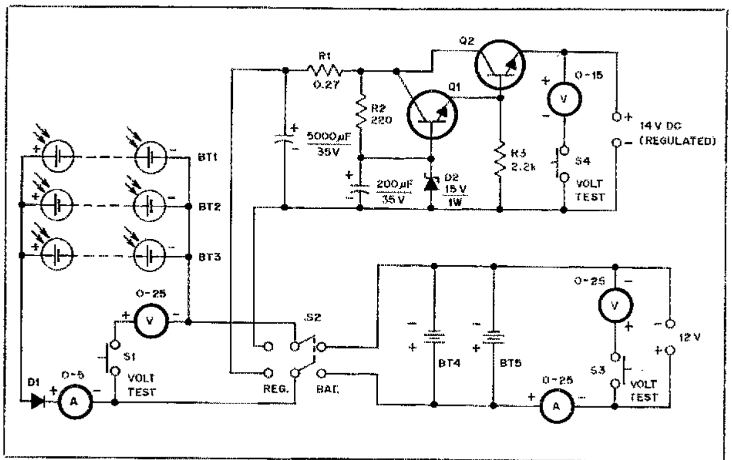


Fig. 1 — Schematic diagram of solar power supply. Note that battery charging circuit does *not* employ a regulator or switch to shut off charging current once the storage battery reaches full charge state. Because the output of the solar panels is, at most, 1-1/2 amperes and the storage batteries are full-size automobile batteries, the danger of damage from overcharging is not great. Anyone contemplating higher current solar batteries or smaller storage batteries should give serious consideration to a regulator and/or an automatic cutoff switch for the charging circuit. (See page 12 of this issue.)

BT1, BT2, BT3 — 20-V, 1/2-ampere solar panels by Spectrolab.
BT4, BT5 — 12-V, lead-acid automobile batteries.
D1 — Motorola MR 752/7414 or any diode with at least 2-ampere capacity and with at least 50 PIV.
Q1 — Npn silicon 90-W transistor, power switching, TIP31, Radio Shack 276-2020 or equiv.
Q2 — Npn silicon 115-W transistor, power switching, 2N3055, Radio Shack 276-2041 or equiv.
S1, S2, S3 — Spst, momentary contact switch.
S2 — Dpdt knife switch.
R1 — 0.27 Ω, 1 watt.
R2 — 220 Ω, 1 watt, carbon composition.
R3 — 2.2 k-Ω, 1 watt, carbon composition.

(such as aluminum) available, I would have used that instead of wood. Toward the rear of the wooden rack I mounted a terminal strip with the blocking diode (D1 of Fig. 1) and the connections from the solar panels.

I used large, stranded hook-up wire on the panels. From the terminal strip I used no. 10 wire (color coded; red is positive and black is negative). It is a 15-foot run from the terminal strip to the battery bank at the operating position.

I like to keep track of both the voltage and the amperage with meters. The ammeters are left in circuit at all times; however, to minimize current drain from all sources, I have put switches in series with the voltmeters. Every little bit helps! S2 switches the solar panels directly to the equipment through a regulator circuit or to the battery-storage system. Make sure the solar panels have sufficient current output to supply the equipment you are using when connected directly through the regulator.

My Argonaut 509 requires 12 to 14 V dc at 1 ampere. I have three solar panels with a total of 1-1/2 amperes output. This can supply the needed current when the equipment is connected to the solar panels through the regulator. Each panel produces 20 volts dc under a no-load condition. Under load the panels provide enough voltage to yield 13 to 14 volts dc from the regulator.

The equipment I am using with my solar-powered station is an Argonaut 509 (2 watts PEP), Atlas 210X (180 watts PEP), ICOM-245 (10 watts PEP) and FT-901-D (180 watts PEP). The FT-901-D draws between 18 and 21 amperes; short transmissions are very desirable. I have ordered more solar panels so I can increase the capacity of the charger. W6PQZ designed the transistor regulator circuit that is connected directly to my solar panels when using the Argonaut 509. The circuit is shown in Fig. 1. My plans are to keep up to date on solar energy for powering electronic equipment and to find out who else is using solar power. How about you? Wouldn't you like to have fun on the air without straining the family budget? I'll look for you on the bands. QST

Table 1

Some Solar Battery Manufacturers and Distributors

Solar Power Corporation
c/o Lindberg Company
4163 Montgomery, N.E.
Albuquerque, NM 87109
Tel. 505-881-1006

Solarex Corporation
1335 Piccard Dr.
Rockville, MD 20850
Tel. 301-948-0202

Applied Solar Energy
15251 E. Don Julian Rd.
City of Industry, CA 91746
Tel. 213-968-6581

Solec International
12533 Chadron Ave.
Hawthorne, CA 90250
Tel. 910-325-6215

An Electronic Switch for a Solar Panel

Do you waste time constantly checking the condition of your batteries as you recharge them with solar cells? Here is a set-it-and-forget-it switch that will protect your batteries, eliminate worry and make solar-powered hamming more fun.

By Douglas A. Blakeslee,* N1RM

Because I live in an area where power failures are common, DeMaw's article about using solar power was of interest.[1] Here is a way to power both an hf transceiver and a 2-meter fm rig during those lights-out periods. In fact, I can run my radios via solar power all the time!

A "lifetime" 12-volt automobile battery and solar panels were acquired. The missing element was a method of turning off power from the solar panel when the battery was fully charged.

Circuit Description

The circuit which evolved for the electronic switch is based on an idea published by Millard.[2] The unit described was too complex for my application and called for components which I didn't have. After some work with a pencil, I settled on the circuit shown in Fig. 1.

The electronic switch consists of a voltage reference (U1), a comparator (U2) and a pass-transistor switch (Q2). The reference is a 3-terminal regulator, the 7805. This unit normally puts out 5 volts, which is raised to 6.2 volts by including two silicon diodes in its ground lead. This reference voltage is compared to the voltage across the battery divided approximately by two. An op amp — the ever popular 741 — is employed as the comparator. R7 is included to allow adjustment of the point at which power from the solar panel is turned off.

A lead-acid storage battery is fully charged at 13.5 V. Whenever the battery is less than fully charged, Q1 will be on,

*4 Maple Lane, Brookfield, CT 06804

[1]Notes appear on page 13.

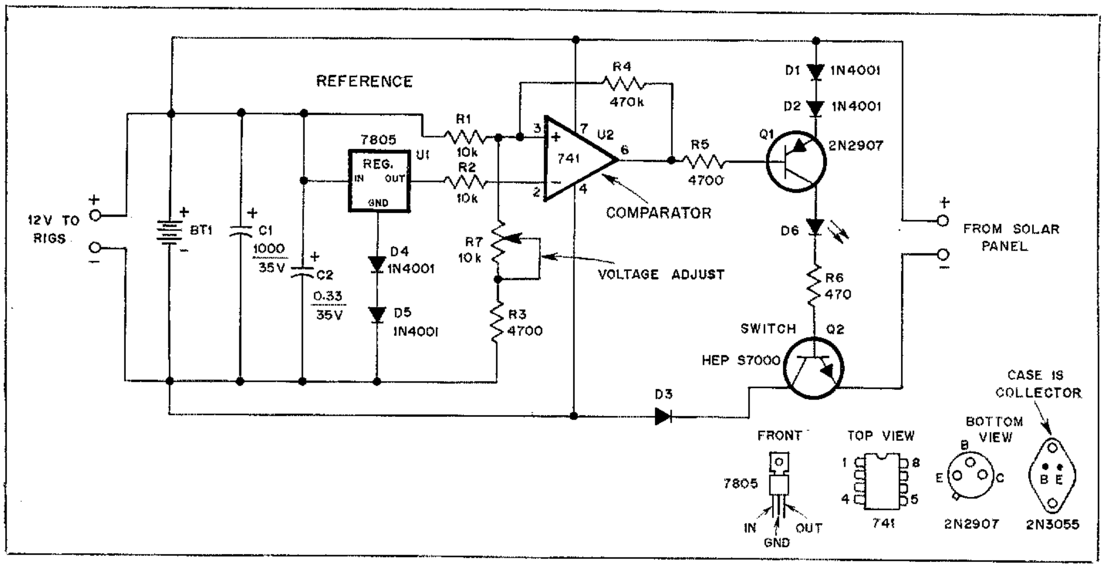


Fig. 1 — Schematic diagram of the electronic switch. Resistances are in ohms; k = 1000; capacitance values are in microfarads (µF).

BT1 — Automotive storage battery, lead-acid type.
C1 — 1000-µF, 35-V electrolytic.
C2 — 0.33-µF, 35-V, Solid-tantalum type
D3 — Silicon diode. PIV of 50 or more, current rating sufficient to pass full output of the solar panel.
D6 — Light-emitting diode, any type.
Q2 — Low-frequency power transistor; 2N3055, HEP S7000, or equivalent. Use heat sink of 9 square in. (52,258 square mm) or more.
R7 — 10 kΩ, 1/2 watt, carbon control, linear taper, pc mount.
U1 — 3-terminal, 5-volt regulator.
U2 — Op amp, any of the 741 family usable.

which will inject sufficient base current into Q2 so that it also will be on, allowing current from the solar panel to be passed to the battery. D3 isolates the panel from the battery. A light-emitting diode is used in the base lead of Q2 to indicate when the battery is being charged.

Q2 can be any member of the 2N3055 power-transistor family. It requires a heat sink, which can be fabricated from a 1- by 3-in. (25- by 75-mm) piece of aluminum, or, the Radio Shack 276-1364 heat sink is suitable. For solar panels with current output above 2 amperes, a larger heat sink or a second, parallel-connected pass transistor will be needed.

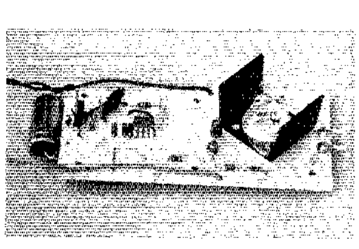
Suitable components for the electronic switch are available from Radio Shack outlets. My unit is assembled on a Radio Shack no. 276-151 experimenter's pc board. The small components are mounted via holes drilled in the block pattern using a no. 60 bit. The op amp is mounted in the holes provided in the circuit board for an IC. Holes for the pc-mount control and the pins of the power transistor are made with a 1/16-in. (1.6-mm) diameter drill bit.

Once the unit is assembled, it can be checked by using a 100-ohm resistor in place of the battery. With a voltmeter connected across the 100-ohm resistor, adjust R7 until the trip point which turns the LED on and off is between 13.2 and 13.5 volts. Then the unit is ready for installation. In my station the electronic switch is mounted atop the battery. No enclosure or rf decoupling was used. Running a kilowatt amplifier within a few feet of the unit produced no adverse effect.

When my solar-power system was first installed, I was left to wonder what was happening. The LED came on, indicating that the battery was being charged. Somehow, it wasn't enough, so an ammeter was added, *temporarily*. It was fun to "see" what was coming out of the solar panel under varying amounts of sunlight.

I found that the solar-power system produced more than enough stored energy to run my hf and 2-meter rigs. Even spates of contest operation haven't run down the battery sufficiently to require using an ac-line-operated power supply. After several years of turning out lights and adjusting thermostats to save energy, I've become cavalier about the ham shack. I leave the rig on for hours while wandering in and out to check a band. After all, except for the original investment, this energy is free.

Let's hope the government forecast of a 20-fold decrease in the cost of solar energy by 1986 comes true. If so, my roof will be solid silicon! QST



Author's compact, neatly laid-out version of the solar switch. All components including the breadboard-style pc board should be available locally.

Notes

[1]DeMaw, "Solar-Electric Power and the Amateur," *QST*, August 1977, p. 24.
[2]Millard, "Solar-Powered Regulator Charges Batteries Efficiently," *Electronics*, September 13, 1979.

Strays

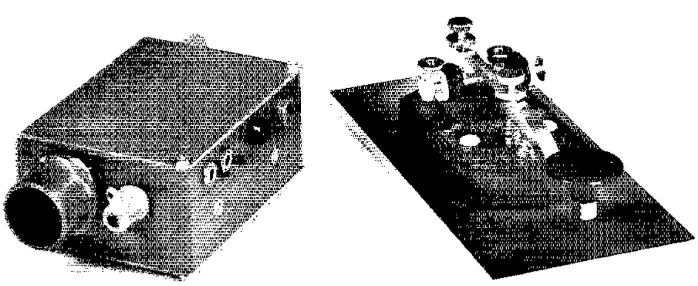
Jim Decker, WB9UQT (left), and Jim Romelfanger, K9ZZ, operated K9DOK, Yellow Thunder ARC's club call, at the Winter Special Olympics. Held February 20 to 22 at Devils Head Lodge, near Merrimac, Wisconsin, the event was staged for retarded athletes of Wisconsin. The event featured two-and-a-half days of instruction and competition in skiing and ice skating. *(photo by Carl Dvorak, KA9EYJ)*

An Optimized QRP Transceiver

A rig doesn't need to be complex to work well. This 40-meter cw transceiver, designed for performance, ease of operation and low power consumption, is a case in point.

By Roy W. Lewallen,* W7EL

Many QRP rigs have been described in Amateur Radio publications over the years. The distinguishing characteristic of *this* transceiver is that it was designed and then optimized for high performance. It's relatively easy to build something that works, but it usually requires a great deal more effort to produce something that works really well. That effort has gone into this rig, and the result is a 40-meter cw transceiver with the following characteristics: full electronic break-in; clean keying and smooth, quiet transceive operation; *stable* VFO coverage from 7.0 to 7.15 MHz; receiver incremental tuning (RIT); single 12-volt supply operation; two-watt power input, 1.5-watt output into a 50-ohm load; receive current drain less than 20 mA; reasonable transmitter efficiency; high-performance direct-conversion receiver; and small size (1-1/2 × 2-1/2 × 3-1/2 in. [40 × 70 × 90 mm]).



This diminutive QRP transceiver is a joy to operate. It features a high-dynamic-range receiver, smooth break-in operation, RIT and a host of other high-performance features.

This is *not* a step-by-step construction article. Rather, the purpose of this article is to share some of the many things I learned from designing, building and perfecting the transceiver. Very little of the article is devoted to mechanical packaging and, since there are no printed circuit boards in my rig, none are available from the author. I hope that this article will help potential designers of such gear to avoid some of the pitfalls I've encountered, in addition to provoking thoughts about how to make *good-quality*, simple rigs.

Some Underlying Philosophy

"High-performance direct-conversion receiver" may seem to be self-contradictory. After all, direct-conversion (DC) receivers are so simple they can't possibly compete with a good superhet, right? Wrong! DC receivers have only *one* significant disadvantage when compared to superhets: the presence of an audio image which doubles the amount of noise and interference heard.

The only other inherent disadvantage is the inability to generate other than audio-derived agc. The same careful attention to detail and potential problems is required in designing the DC receiver as is required for a top-quality superhet, if comparable performance is to be realized. This last point is frequently overlooked, and that may be one reason why the DC receiver is often looked upon as a mediocre performer.

All other problems can be overcome with careful design, and even the two inherent disadvantages can be overcome to some extent. On cw, narrow af filters may be used, reducing the image bandwidth along with the desired signal bandwidth. RIT helps also: When an image signal produces the same beat note as the desired signal, adjusting the RIT will move one up in pitch and the other down, thus separating them.

As for agc, this rig does without, and I've hardly missed it. This receiver is on a par with all but the best superhets for any type of operation, except perhaps during contests in conjunction with a high-power transmitter, but at a fraction of the complexity. Note also that to use a superhet in a transceiver, an additional oscillator and mixer must be added to the *transmitter* to convert the VFO to the transmit frequency. In a transceiver using a DC receiver, the required shift is only a few hundred hertz, and can easily be accomplished by pulling the VFO.

Since the rig was designed for portable use, current drain was a major consideration. My experience indicates that many solid contacts may be had using simple antennas and operating during the night with 2 watts on 40 meters. This power level is also more than adequate for short-range daytime operation. Power drain is low enough that the rig will run for about a week of evening operation from one charge on ten NiCad "A" cells (660 mA-h).

The small size precludes wide-range antenna impedance matching — a necessity for field use — so a Transmatch was built in a separate box. The circuit for the Transmatch was taken directly from the reference (page 167).[1]

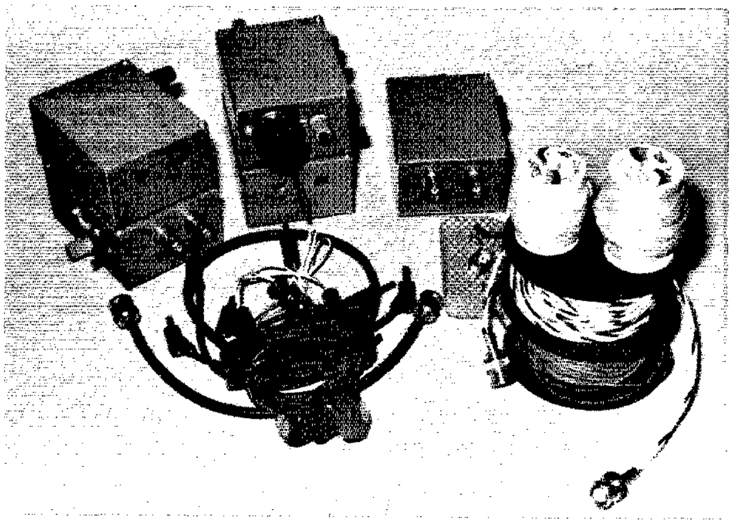
While crystal oscillators have

*5470 SW 152 Ave., Beaverton, OR 97007

[1]Hayward and DeMaw, *Solid State Design for the Radio Amateur*, ARRL, 1977.

advantages for certain types of operation, a VFO is preferred in a rig which is intended primarily for ragchewing (and, I can't resist, a miniscule amount of DXing) and Field Day. Full electronic break-in was taken on as a challenge, and the convenience it offers is well worth the effort. RIT was originally left out of the design for the sake of simplicity. I later decided that RIT is a necessity in a transceiver, no matter how simple it may be, so an RIT circuit was added.

Many of the circuits and concepts used here were taken directly, or with some modification, from the reference. The following discussion concentrates on the unique features of the circuits used, rather than on basic principles or those well covered in the reference.



Here's the complete W7EL QRP station, ready to pack for portable use. At the left, the box on top contains 10 "A" NiCad cells. Below it is a Transmatch. Below the transceiver itself in the center is a keyer and, at the right, for when the going gets rough and batteries are plentiful, is a 10-watt amplifier "brick."

The VFO

The oscillator, Fig. 1, is a good example of the principle that a circuit doesn't necessarily need to be complex to work well, if properly designed. This simple Hartley circuit exhibits less than 200-Hz warm-up drift, with about half of that occurring within one minute after turn-on. This drift performance is completely repeatable, as the building of many such oscillators has shown. The circuit used here is the result of a considerable amount of experimentation directed toward identifying the sources of drift in such VFOs. Without giving the details of the experiments, I'll summarize the results.

1) No part of the VFO circuit except the FET drain should be connected to a pc-board pad that is over a ground plane or near other pads. It's best to avoid pc construction (including ARRL "universal breadboard") of the VFO altogether, because the capacitances formed with the board material as a dielectric have extremely poor temperature and humidity characteristics. I prefer building VFOs using point-to-point wiring on standoffs above a ground plane of copper-clad board (copper side up).

2) Use NP0 ceramic capacitors. Commonly used polystyrene units are predictable, but have too strong a temperature coefficient to compensate a decent inductor. If a rather poor inductor is built, one might get lucky and have the considerable drifts cancel, as they are in opposite directions. But I don't consider that to be a good approach. I prefer to first reduce the temperature dependence as much as possible, then if necessary, compensate what's left. The NP0 ceramic capacitors have a much lower temperature coefficient than polystyrene or silver-mica types. "Dogbone" NP0 units have a black-painted end, and some NP0 disc capacitors are marked "NP0."

3) The gate diode is essential to minimize drift, for reasons put forth in the reference. A 1-megohm gate resistor provides better drift performance than the sometimes recommended 100-kilohm value, possibly because of reduced tank loading.

4) The temperature of the FET itself has a negligible effect on this circuit. Therefore, circuits which more loosely couple the active device don't have any significant advantage over this one.

5) After the above recommendations have been followed, the only remaining significant source of drift is the inductor. Of the inductors I've tried, the best are those wound tightly on type-6 powdered-iron toroidal cores, with core size being relatively unimportant. A technique suggested by W7ZOI is to anneal the coil after winding, which I do by boiling it in water a short while, then letting it cool in air. This noticeably reduces drift, and this method was used to obtain the quoted drift.

If extreme environments with rapid temperature changes are to be encountered, you may want to compensate the VFO. This can be done by replacing part of the fixed capacitance with negative temperature coefficient (TC) capacitors, such as polystyrene or negative TC ceramic units.

It should be possible to make other oscillator types perform as well as, or better than, this one, as long as the above guidelines are followed. The secret, however, lies in the choice, rather than the number, of parts.

The rig had been used for a year without voltage regulation for the oscillator, and with no difficulty with chirp or hum. Supplies used have been a NiCad battery, an ac supply using a 3-terminal regulator, and fresh lantern batteries. This was possible because the sensitivity of the unregulated oscillator is only 50 to 80 Hz/volt from 9 to 15 volts. A regulator was added when experiments showed noticeable modulation of received audio (and, presumably, transmitted rf) when a small amount of ac was purposefully introduced to the supply. It can now be used with poorer ac supplies or an automobile power system with the engine running.

The buffer, although designed for low current drain, is the major power consumer in the receiver, requiring 10 mA. The key to efficiency in this sort of buffer is to choose the transformer turns ratio to sustain as large a voltage swing at the output stage collector (or drain) as possible. Another potentially efficient approach is to use a complementary-symmetry stage. One was used for some time, but its temperature-stable, low-distortion design consumed as much power as the present buffer, and was more complex. Buffer voltage gain is approximately one half, providing about 2.5 volts pk-pk output.

The RIT circuit uses a Zener diode as a voltage-variable capacitor. While Zener diodes are inexpensive and readily available, their nominal capacitances may vary a great deal with different manufacturers. An empirical procedure to adapt the circuit to an individual diode is to select a series capacitor (here 15 pF) to obtain a tuning range of about 1300 Hz with a diode reverse bias variation of about 9 to 4 volts. When the control is adjusted to the center of its range, the frequency shift should equal the center frequency of the receiver audio filter (about 650 Hz). During transmit, or when the ZERO button is depressed, the shift is removed, causing the transmit frequency to be the same as that of a received signal peaked at the audio-filter center and tuned to the correct side of zero beat.

The Transmitter

The transmitter is a fairly efficient (75%) Class C design. The Zener diode was added after twice blowing the output transistor by inadvertently transmitting with the antenna disconnected. The diode protects the output transistor from this hazard. Some caution is necessary when using a Zener diode at the output-stage collector, as many Zener diodes have a large amount of shunt capacitance. When adding the diode, the collector capacitance must be reduced by an amount approximately equal to the capacitance of the diode when it is reverse biased by the collector supply voltage. In this transmitter, the total capacitance at the collector should equal approximately 450 pF, including the fixed capacitor, the 51-pF receiver-pickoff capacitor, the Zener diode and the transistor (about 10 pF for this type). If the capacitance of the diode can't be measured, the 385-pF fixed capacitor should be made variable and adjusted for best transmitter efficiency.

The value of L2 is not critical, as long as it's not much smaller than the 10 μH shown. Conventional solenoidal rf chokes will work fine also, but toroids are required in a tightly packed rig such as mine to keep mutual coupling acceptably low.

The Receiver

More time has been spent improving the receiver than any other part of the rig. The end result is no more complex than the first version, but the improvement has been great, again showing that complexity and performance don't equate. In the following discussion I'll relate why some types of circuits were chosen and others rejected.

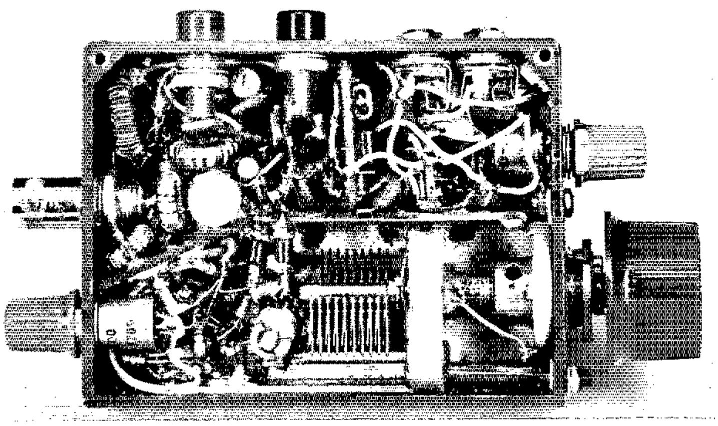
Receiver signal pickoff is through the 51-pF capacitor from the transmitter output filter. When transmitting, the diodes protect the receiver and cause the 51-pF capacitor to become part of the transmitter output network. When receiving, the capacitor and L5 make up a fairly low-Q series resonant network to reduce signal attenuation by maintaining an approximately 50-ohm source impedance to the mixer. The additional filtering it provides is helpful also.

The mixer is a conventional doubly balanced type. Unfortunately, I didn't choose this by accident — it was selected after a good deal of frustration trying to use other kinds!

I'll digress here a moment to explain about a-m demodulation, a problem which is common in "simple" direct-conversion receivers (but not because they're simple!). Direct-conversion receivers have most or all of their gain at audio frequencies. Thus, if any device near the receiver input is nonlinear — such as forward- or reverse-biased diode junctions — audio from strong shortwave broadcast and a-m broadcast stations or ssb stations is detected. If passed through the mixer, this audio is amplified and appears as an annoying "din" in the background — or foreground, if severe enough! Leakage of the local-oscillator signal into the circuitry preceding the mixer definitely aggravates the problem, but I haven't attempted to isolate the (apparently) several phenomena involved. An often-overlooked point is that the audio amplifier itself will usually happily rectify any rf which reaches its input, amplifying the resulting detected audio.

A common solution is to use very selective tuned circuits at the receiver input, a solution not practical in this case. Another is simply to avoid using nonlinear elements ahead of the mixer — and following the mixer, if rf can get through it. This is difficult when using electronic T-R switching — this rig has the T-R diodes, Zener diode and PA transistor as potential culprits. Yet another solution is to use a balanced mixer which will, in theory, prevent detected audio from getting through the mixer. I took this last approach, first trying an MC1496 IC mixer. Try as I did, I was never able to obtain good rejection of a-m signals originating over a wide frequency band. The balance seemed to depend on the source impedance which, of course, changes with frequency when an antenna is the source — to say nothing of the transmitter output network and series-resonant network in the path. My attempts included different biasing and signal levels, and driving the inputs through baluns.

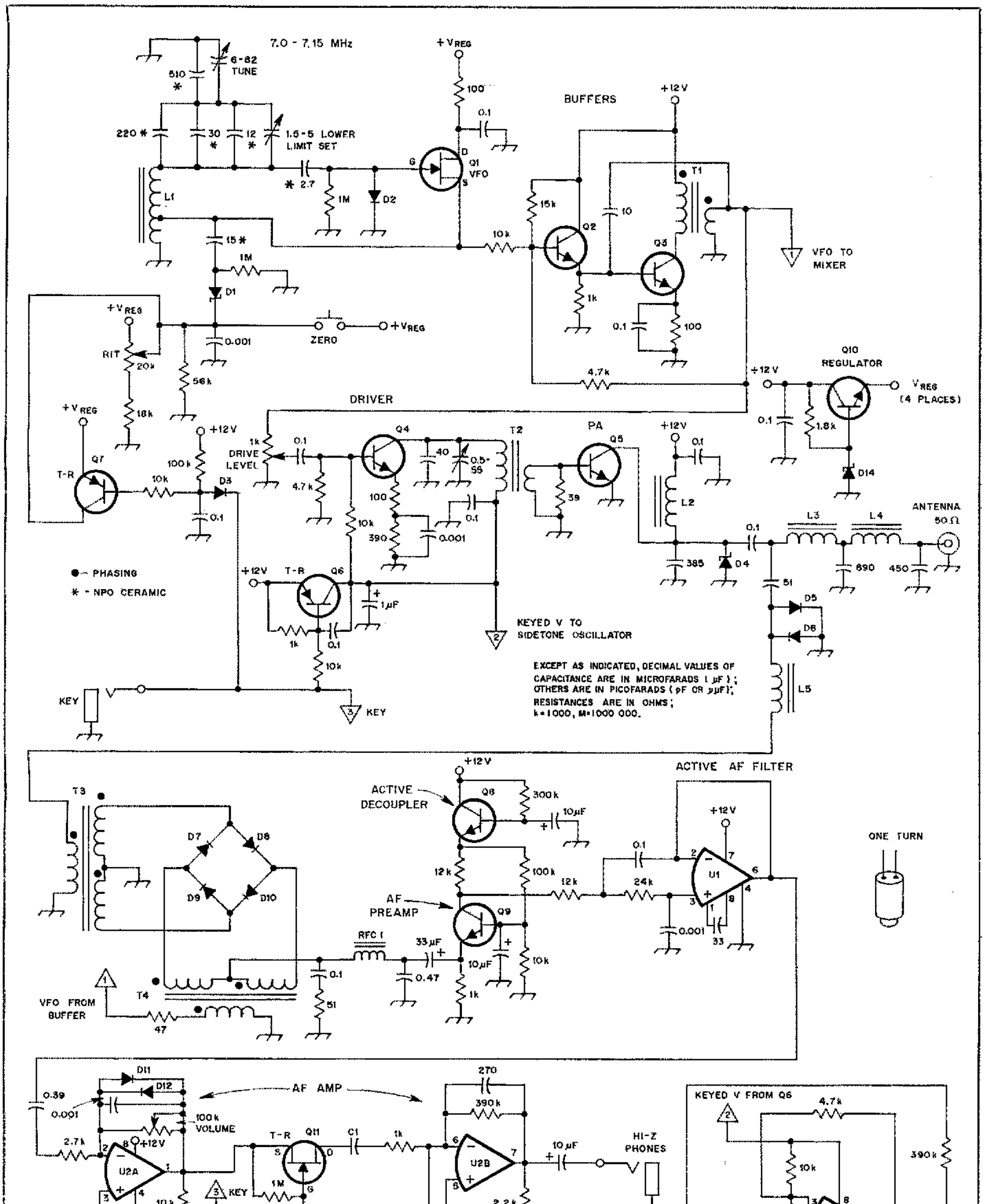
I next tried a singly balanced diode mixer, with and without two extra diodes for improved balance. I used this for quite a while, and it was quite satisfactory after I replaced the T-R diodes with an MOS transistor switch. The noise figure was marginal, however, and there was still some background a-m interference when propagation was good. While trying to improve that situation, I performed quite a few experiments using the mixer with and without the extra diodes, with the input ports exchanged, with Schottky and



High component density is necessary to allow the author to squeeze all the circuitry of the transceiver into such a small package. Point-to-point wiring is also used. The transmitter circuitry is at the upper left in the photo above. The output transistor, which is bolted to the case, is hidden below the top layer of components.

Fig. 1 — The circuit of the W7EL 40-meter QRP transceiver. Resistors are 1/4 or 1/8 watt, 5%. All ferrite cores are available from Amidon Associates. When winding the inductors that use BLN-43-2402 cores, the wire should be passed once through both holes of the core for each "turn" specified. See the illustration at far right.

C1 — 1-μF, 3-V non polarized ceramic.
D2, D3, D5-D13, incl. — Silicon general-purpose/switching diode; 1N914, 1N4152 or equiv.
D4 — Zener, 33-V, 400-mW; 1N973 or equiv.
D14 — Zener, 10-V, 400-mW; 1N961 or equiv.
L1 — Approx. 3 μH; 26 turns on a T-44-6 core. Tap at seven turns from ground end.
L2 — Approx. 10 μH, 43 turns on a T-50-2 core.
L3, L4 — 1 μH; 19 turns on a T-37-6 core.
L5 — 9.4 μH; 58 turns on a T-37-6 core.
Q1, Q11 — Silicon n-channel JFET, 300 mW, 2N4416.
Q2, Q3, Q10 — General purpose, silicon npn, 310 mW, 2N3904.
Q4 — General purpose, silicon npn, 1.8 W, 2N2222.
Q5 — Rf power, silicon npn, 7 W, 2N3553 or 2N5859.
Q6, Q7 — General purpose, silicon pnp, 310 mW, 2N3906.
Q8 — General purpose, silicon npn, 310 mW, 2N4124 or 2N3565.
Q9 — General purpose, silicon npn, 310 mW, 2N3565.
RFC1 — 100-μH subminiature choke, wound on a 1/4-watt-resistor-sized ferrite form. Dc resistance is approx. 8 Ω.
T1 — Primary 15 turns, secondary 3 turns. Wound on a BLN-43-2402 core.
T2 — Primary 39 turns (approx. 6.7 μH), secondary 5 turns. Wound on a T-44-6 core.
T3, T4 — Five trifilar turns on a BLN-43-2402 core.
U1 — Op amp, LM301.
U2, U3 — Dual op amp, LM358N (one section of U3 unused).



7.0 - 7.15 MHz
6-82 TUNE
1.5-5 LOWER LIMIT SET
Q1 VFO
BUFFERS
VFO TO MIXER
ZERO
RIT
T-R
Q7
Q10 REGULATOR
VREG (4 PLACES)
DRIVER
DRIVE LEVEL
Q4
PA
Q5
ANTENNA 50 Ω
●- PHASING
* - NPO CERAMIC
Q6
KEYED V TO SIDETONE OSCILLATOR
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k=1000, M=1000 000.
KEY
ACTIVE DECOUPLER
Q8
ACTIVE AF FILTER
ONE TURN
AF PREAMP
Q9
U1
VFO FROM BUFFER
RFC 1
AF AMP
100 k VOLUME
U2A
Q11
U2B
HI-Z PHONES
KEYED V FROM Q6
U3
SIDETONE OSCILLATOR

conventional diodes, and with various VFO source impedances. None were satisfactory with respect to both a-m demodulation and noise figure.

These problems virtually disappeared when I replaced the mixer with a doubly balanced type. Additional improvements were significant when I designed the present preamplifier and input diplexer. Now, a huge am-signal is required to cause interference, and none has been heard since it was implemented. The noise figure is very good, with a minimum-discernable signal level of less than 0.1 μV. Other balanced mixers, such as CA3028 IC or discrete balanced JFET mixer, might match the a-m demodulation characteristics of this receiver, but they probably won't match its signal-handling capability. A signal 50 kHz away must be greater than 100 mV in amplitude (120 dB above the minimum discernable signal) to have any noticeable effect on a medium-amplitude (30-μV) received signal. Try that test with *your* station receiver!

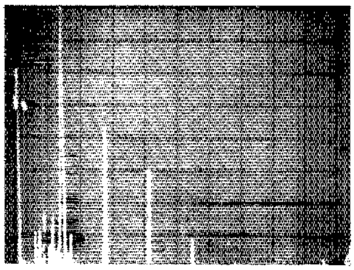
Following the mixer is a diplexer. Its purpose is to provide a wide-band 50-ohm termination for both rf and af, while preventing rf energy from getting into the af amplifier and preventing af energy from being wasted in the rf termination. The rf termination consists of the 0.1-μF capacitor and 51-ohm resistor; RFC1 and the 0.47-μF capacitor form a low-pass filter which prevents any residual rf from reaching Q10, thus greatly enhancing immunity to a-m. Q10 presents an input impedance of approximately 50 ohms for maximum power transfer.

Receiver Audio

Because the receiver audio gain exceeds 100 dB, great care must be taken to prevent feedback or amplification of power supply hum. This receiver uses an active decoupling circuit consisting of Q9 and associated parts to avoid these problems in the input stage, where the sensitivity is greatest.

Following the preamp is the active audio filter. This one is a peaked low-pass type with a Q of five — low enough to keep ringing unnoticeable. It is simple, noncritical and adquate for general operating. The peak frequency is about 650 Hz, which corresponds to the transmit-receive frequency difference with the RIT control centered. An LM301 is used because of its low noise and relatively low current drain. A TL071 or TL072 should give comparable performance, and one section of an LM358 may be used with a 2-dB increase in noise figure, an amount I feel is quite acceptable.

The last two stages are conventional amplifier stages, with frequency response rolled off outside the range of about 150 to 1500 Hz. The gain distribution (31 dB in the first stage, 52 dB in the second) is unusual, but not for any special reason — it just evolved that way.



The output spectrum of the Optimized QRP Transceiver. Vertical divisions are each 10 dB; horizontal divisions are each 5 MHz. For a transmitter of this power level, FCC rules require that spurious outputs be suppressed at least 30 dB. The 14-MHz second harmonic can be seen at about −37 dB. The pip at the extreme left is the zero-frequency reference, generated within the spectrum analyzer.

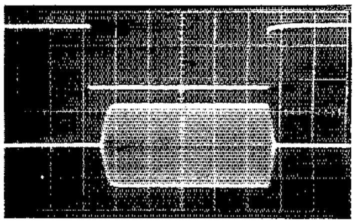
U3 is a sidetone oscillator. The reference suggests keying just the bias resistor, but this doesn't work with the LM358, as the negative supply voltage (ground) is an acceptable input. It will still oscillate (at a very low frequency) with both 10-kΩ resistors grounded! Therefore the IC supply line is keyed also. Sidetone injection level is set by the 100-kΩ resistor at pin 6 of U2B; this may be varied to suit individual taste.

Keying and T-R

Three events must occur when this type of transceiver is keyed, and they must occur in the proper sequence if operation is to be clean. They are, in order: (a) receiver mutes, (b) VFO shifts frequency, and (c) transmitter keys. These events must occur in reverse sequence when switching back from transmit to receive. The sidetone oscillator must also be keyed, but its timing isn't as critical.

Attention to this sequence and proper transmitter waveform shaping makes the difference between a poor-sounding rig and a really clean one. Many people have been surprised to learn my power input — because "it doesn't *sound* like a QRP rig." Only a few parts are required to accomplish this. In addition, it's easier to copy a clean weak signal than a poor one, so good keying and freedom from chirp, clicks and roughness are particularly important for QRP transmitters.

The receiver is muted by Q11 which acts as a series gate. Q10, U1 and U2A are all driven to saturation for a while when the transmitter is keyed, and again when the key is released. This is caused by the relatively large rf signal appearing across the T-R diodes, as well as stray rf pickup by the receiver. Such a disturbance is impractical to eliminate, as it would require a T-R switch with very high attenuation, and extensive shielding. I solved the problem by other means: Q11 is turned off immediately when the transmitter is keyed, then turned back on after the disturbance is over, about 60 ms after the key is released. The diodes around U2A prevent the output of U2A from swinging to ground during the disturbance, a condition which turns Q11 on when it should be off. I find the 60-ms delay to be ideal, as it removes distractions between dits and dahs at medium speeds while being short enough to provide essentially instantaneous break-in. The disturbance (hence, required delay) could possibly be reduced further by limiting the swing of either or both Q10 and U1, or biasing U1 and U2A outputs closer to the positive supply voltage.



The keyed cw waveform of the Optimized QRP Transceiver. The horizontal divisions are each 5 ms. The upper waveform indicates the actual key-down time. The rise and fall times of approximately 2 ms result in a crisp sounding but clickless signal.

Oscillator frequency shift is obtained by changing the bias on the Zener diode (used as a voltage-variable capacitor) in the VFO circuit when going from transmit to receive or vice versa. The timing is provided by Q8, which comes on fast when the key is closed, but goes off some five milliseconds after the transmitter output drops to zero following the release of the key. Shaped transmitter keying is provided by Q7 and associated components. I found that simultaneous keying of the base and collector circuits of the driver stage was required to give the desired rise and fall times of a few ms at the transmitter output. The sidetone oscillator is keyed from the same line.

Construction

I discourage others from attempting to duplicate the construction of my unit. To do so requires access to subminiature parts and several no-longer-available items, a good understanding of potential crosstalk, shielding and ground problems, and a large amount of patience. There are, however, a few points which may be of interest to those wishing to build similar gear.

A great deal of information is available regarding bypassing, decoupling and layout techniques. If the potential builder isn't familiar with these basics, construction of a similar unit may cause a great deal of frustration indeed. I would suggest, as a minimum, that construction be over a ground plane, as shown in many

QST articles and in publications such as the reference, or *The Radio Amateur's Handbook*.

I am certainly no expert on miniaturization, and this rig doesn't by any means approach the ultimate in that regard. My only general advice is to begin with the box and build the rig into it, rather than the other way around, and get a good idea of the placement of controls, connectors and large components before you begin. Since it's difficult to troubleshoot or modify such a rig once built, ideally a larger breadboard version should first be constructed, perfected and operated. When I got really pressed for space, I found that building the circuitry on small pieces of perfboard and mounting the boards vertically allowed very dense packing. It helps a great deal to mount components on both sides of the board, and to ignore the usual conventions of placing parts in neat rows. The use of 1/8-watt resistors saves a surprising amount of space compared to 1/4-watt units. Another great space-saver is the use of tantalum, rather than aluminum, electrolytic capacitors. Small parts are nearly always more expensive and less available than their larger counterparts, so each builder must decide if the trade-off is a good one.

Adjustment and Operation

The only adjustments required are the VFO trimmer, used to set the VFO frequency at the lower band edge; the drive level pot, used to set power input at 2 watts (although no major problem will arise if driven at higher or lower levels, efficiency may drop slightly); and the transmitter rf-amplifier tank circuit, which is peaked at the center of the frequency range. None should require readjustment once set.

Operation is, by design, simple. The only point worth noting is that, as with any direct-conversion receiver, signals must be tuned on the correct side of zero beat so that the transmitter will be on the same frequency as the received signals. Guest operators have picked this up in a few minutes, so the SPOT button is seldom used. When the rig is new, however, it's nice to have the assurance of knowing just where the transmitter will be when the key is pressed.

I do want to emphasize that this isn't just a "paper design," but a rig which has undergone a good deal of operation at W7EL and, on many occasions, from portable locations, including Field Day operation. The first version was built about two years ago. Nearly all states, as well as a few DX stations, have been contacted using simple antennas. I enjoy ragchewing, and countless enjoyable QSOs have been had with this rig. It's a pleasant experience anytime to operate a stable, clean, full-QSK, essentially crush-proof rig. And, to my taste, to do this from a backpacking tent or cabin at the beach enchances the pleasure even more. The very best part, however, was best stated in the closing paragraph of the reference: *That* is "where it's at."

Closing Remarks

I hope that this article has illustrated a few important points: that simplicity and performance aren't mutually exclusive, that a well-designed direct-conversion receiver is a good receiver indeed, and that really good designs don't generally just happen. I also hope that some readers are moved to question the statements I've made, and those which have been made elsewhere, so that more of the subtleties of simple solid-state gear can be widely understood. Most of all, I hope that this will be of help to people who were puzzled, as I have been, by some of these phenomena.

To the extent that time permits, I will be glad to answer questions. An s.a.s.e. would be appreciated for inquiries. No circuit boards, board layouts, parts kits or parts availability information are available from the author. I'm too busy working on my *next* rig! I wish to thank Wes Hayward, W7ZOI, for his comments, criticism and encouragement during the design and testing of this rig, and the writing of this article.

Strays

OPERATION HELL AND PARADISE

☐ Few amateurs can say they have worked either hell or paradise. On August 23 and 24 the Adrian (Michigan) ARC will be operating from both Hell and Paradise, Michigan. They offer a QSO and a colorful QSL certificate to prove your QSO with two of the rarest spots (on earth?). QSL W8TQE/Hell and W8TQE/Paradise via P. O. Box 26, Adrian MI 49221, with a legal size s.a.s.e. Frequencies to be used are: cw — 3710, 7110 and 21,110 kHz; ssb — 3900, 7235, 14,285, 21,360 and 28,625 kHz from Hell; and cw — 3720, 7120 and 21,120 kHz; ssb — 3910, 7245, 14,295, 21,370 and 28,635 kHz from Paradise. Two-meter fm operation will be on 146.52 MHz from both locations.

QST congratulates . . .

☐ Charles Dorian, W3JPT, of Washington, DC, 1980 recipient of the National Marine Electronics Association (NMEA) Reginald A. Fessenden Award for his career devoted to the improvement of marine communications. Chuck is a Life Member, ARRL, and a member of the ARRL Long Range Planning Committee.

LOW-FREQUENCY EXPERIMENTERS' NET

☐ Ken Cornell, W2IMB, reports the formation of a 160-meter ssb net for persons interested in operation in the so-called "experimenters' band," which is from 160 to 190 kHz. The conclave, called the "Soldering Iron Net," meets every Monday evening at 0100 UTC on 1818 kHz. Ken says that the participants are LOWFERS (low-frequency experimenters) and that the discussions are semi-technical in nature.

The low-frequency band is one set aside by the FCC for signalling and control purposes at a power level of 1-watt maximum dc input to the last stage of the transmitter. The antenna cannot exceed 50 feet (15.24 m) in length, including the feed line, for transmitting. A number of amateurs and nonamateurs in the USA have been operating beacon transmitters in the 160- to 190-kHz range, and cw contacts are claimed for distances in excess of 100 miles. No operator's license is required for activities in that part of the spectrum, provided the FCC regulations are complied with. The primary difficulty the experimentes report is impaired reception after dark, at which time neighborhood SCR light dimmers pollute the airways with severe hash. — *Doug DeMaw, W1FB*

ENERGY CONSERVATION QSL EXCHANGE

☐ Armond, K6EA, and Gladys, WØMFW, Brattland of Long Beach, California and Bemidji, Minnesota, observed an insulated wire descending past their fourth floor Las Vegas hotel room at the January 80 SAROC. They used a rubber band to tie their QSL card to the wire. They've just received a return QSL from Ken Grabenauer, WA6BJW, of Napa, California, marked "SAROC 1980 carrier pigeon Atlas 210X with long wire vertical from 14th floor of Dunes Hotel."

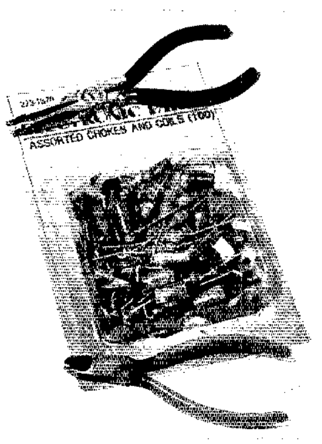
A Radio Parts Eldorado!

Buy 'em by the blister pack and save your "bucks" for bigger things! How about 100 new coils, chokes and capacitors for only $1.98?

By Doug DeMaw,* W1FB

How long has it been since you browsed the small-parts rack at your nearby Radio Shack store? If you're anything like me, you probably drop in every now and then, just to see what's new and tempting — within the constrictions of your ham-radio budget, that is. This article deals with a bargain package on which the tag reads "Coil Assortment." I spotted this cornucopia of small parts during a recent visit to a local Radio Shack outlet. The cost of the blister pack of goods was $1.98 at the time of this writing. The only catch — although it's not a bad one — is that there are capacitors included in the assortment of parts. But, they're choice capacitors for amateur work (more on that later).

The intent of this article is not to encourage you to focus your attention entirely on the Radio Shack no. 273-1570 coil kit. Rather, I'd like to stimulate your thinking about all facets of bargain hunting for small parts.



An unopened coil pack that contains the same part number as the one discussed in this article, but contains a different group of components.

How to Find Parts

A popular outcry today among those who build equipment or like to experiment is, "Parts are impossible to get!" This is anything *but* a fundamental truth. Components are difficult to find only if the hunter is unfamiliar with typical amateur "scrounging" techniques, or if he or she is suffering from a terminal case of chronic lassitude! Admittedly, there are a few electronic devices that elude even the most experienced "hunter." But that is only because he or she lacks the purchasing power to buy 1000 or more pieces of a given component at one time. This restriction is imposed (unfortunately) by a number of major manufacturers — notably the ones who produce semiconductors. If they do have appointed distributors who will sell you a single part "over the counter," chances are that the distributor won't have the item you need. He may even tell you that he's never heard of it! If the parts vendor does acknowledge that the item of interest actually exists, you might find yourself facing a frustrating back-order situation — for weeks or even months! It's a sad matter of fact and none of us knows the answer to this problem.

Parts Sources

There are a number of useful methods we amateurs can apply in obtaining small parts for our home-built gear. Here are six basic rules:

1) Read the surplus ads in the various amateur magazines.

2) Order catalogs from as many new parts and surplus outlets as possible. Keep this file current by updating it every 12 months.

3) Take money and your shopping bag to as many hamfest flea markets as you can.

4) Check the parts-supplier listing (extensive) in the construction-practices chapter of *The Radio Amateur's Handbook*. It shows who sells parts, what kinds of parts are sold, if a catalog is available and if a minimum order is imposed.

5) Tell your friends what you're searching for — in person or while on the air. If they have the part, they may be happy to let you swap something for it. In other words, "make lots of noise!"

6) Check the Ham Ads in *QST* for the material you need. Don't overlook the classified ads in other amateur magazines.

Bargain Assortments

Do you avoid buying bargain packs of small parts because you're afraid you won't be able to identify the components or their values? If such things prevent you from making an investment, then you're not a high-spirited typical ham

*Senior Technical Editor, ARRL

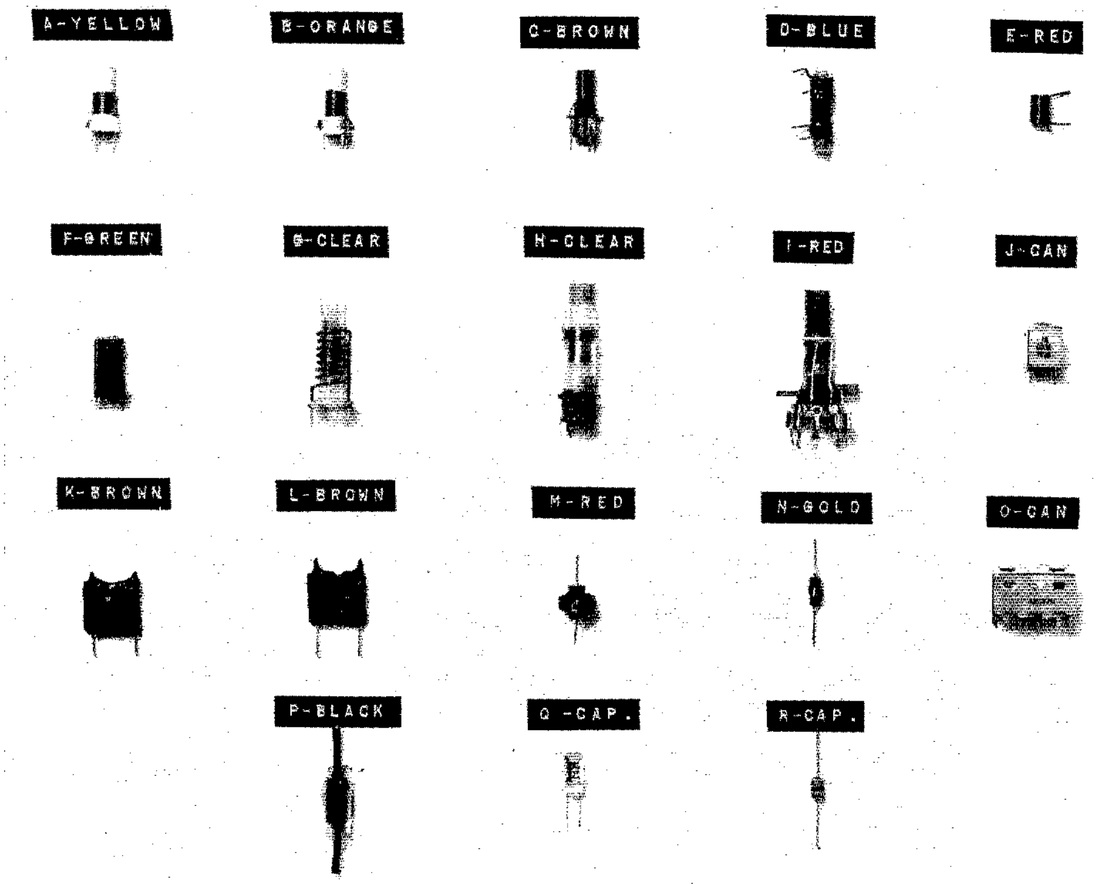


Fig. 1 — A layout photograph showing each type of component found in one coil kit. Other assortments bearing the same kit number may contain completely different components. The label above each part gives it a designator that is keyed to Table 1. The color code of most items is included in the label above it.

experimenter, and the key word here is *experimenter*. You must be willing to dabble with unknown components as well as with the circuit you plan to build! Otherwise, your veins don't contain the blue blood of your amateur forefathers!

It's unlikely that everything we find in a bargain assortment can be identified properly. Furthermore, some of the parts will be of no immediate use to us. But the initial investment is so small that a 100% return should not be a criterion when garnering a new bag of goodies.

The RS 273-1570 Coil Pack

I was unable to resist buying the Radio Shack no. 273-1570 kit. It was filled with beautiful printed-circuit types of miniature and larger slug-tuned coils. A small number of rf chokes were also visible through the plastic window of the pack. Since the coils had very few turns of wire on them, it was reasonable to conclude that they were made for use at hf and vhf. Similarly, the rf chokes had small

Table 1

Part	*Value*	*Type*	*Q (unloaded)*	*Quantity*	*Remarks*
A	0.4-0.8 µH	slug tuned	90 @ 9 MHz	5	single winding
B	2.7-6.0 µH	slug tuned	70 @ 9 MHz	5	single winding
C	0.5 µH min.	slug tuned	100 @ 9 MHz	4	slug stuck
D	0.18-0.26 µH				
	0.36-0.56 µH	slug tuned	100 @ 9 MHz	3	two coils, two slugs
E	0.45 µH	air	80 @ 9 MHz	5	no core
F	0.1-0.5 µH	slug tuned	100 @ 9 MHz	2	sealed winding
G	0.3-0.6 µH	slug tuned	20 @ 9 MHz	1	low Q
H	not tested	slug tuned	----	2	two windings
I	not tested	slug tuned	----	1	three windings
J	0.8-1.8 mH	slug tuned	90 @ 250 kHz	3	shield can, built-in capacitor
K	750 µH	rf choke	35 @ 800 kHz	28	vio/grn/brn
L	100 µH	rf choke	30 @ 800 kHz	5	brn/blk/brn
M	1 mH	rf choke	45 @ 800 kHz	5	single-pi choke
N	3.5 µH	rf choke	70 @ 9 MHz	9	single layer
O	not tested	transformer	----	1	ratio detector or discriminator
P	not tested	ferrite choke	----	1	ferrite sleeve type
Q	470 pF	polystyrene capacitor	----	10	temperature-stable capacitor
R	2 pF	ceramic capacitor	----	14	5% tolerance

Refer to Fig. 1 for the above part designators. Parts K and L are encapsulated. The actual parts count was 104. The slugs in item C appear to be cemented in position at the minimum-inductance position. All slug-tuned coils are pc-mount types.

windings, suggesting their usefulness in amateur work. The entire collection appeared to be taken from some TV-set manufacturer's inventory overrun. All of the parts looked brand new.

I found some polystyrene capacitors (great for use in stable circuits such as VFOs and RC active audio filters) and a collection of 2-pF, 5% ceramic capacitors. How often have you searched for or tried to buy a low-value capacitor like a 2-pF unit? If your luck is similar to mine, the answer is "many times." There were also some shielded inductors (in metal cans) and what appeared to be an fm receiver ratio-detector or discriminator transformer.

Fig. 1 shows one each of the parts that were in the packet. The labels provide a key for use with Table 1, which gives the approximate component values and additional data about each of the parts shown.

Certainly there is no guarantee that every 273-1570 blister pack will contain exactly the same type and number of parts that were found in mine. But you can be sure that there will be plenty of components you can use in your projects. In fact, the packet shown in the photograph on the first page of this article contains many parts that aren't shown in Fig. 1. It was bought at a Radio Shack store some five miles from the branch store where the pack in Fig. 1 was obtained. The irony here is that I paid \$1.98 for 100 parts, whereas I would have paid \$1.92 for a single brand-new slug-tuned coil of similar characteristics, as listed in the current catalog of a leading U.S. coil manufacturer! So in general terms, we might extrapolate this to an equivalent cost of \$192 for the bargain pack if we were to pay the single-lot price for each of the 100 units!

I realize that few amateurs have access to laboratory test equipment. Therefore, it may not be easy for you to determine the inductance values of unknown coils and chokes. But if you have access to a dip meter (most hams do) you can come pretty close to learning what the unknown values are. Component evaluation involves placing a capacitor of known value in parallel with the inductor to be checked. A dip meter is used to find the resonant frequency of the coil or choke. Once you know the value of capacitance and the resonant frequency, you can determine what the inductance is from

$$L_{\mu H} = \frac{X_c}{2\pi f}$$

where f is the frequency in MHz at the dip and X_c is the reactance in ohms of the capacitor used in the test. Therefore, if we had a 50-pF capacitor in parallel with an unknown inductor, and the dip meter indicated resonance at 12 MHz we would find the inductance from

$$L = \frac{265}{6.28 \times 12} = 3.51\ \mu H$$

The value of X_c is obtained from

$$X_c = \frac{1}{2\pi f C}$$

where X is in ohms, f is in MHz and C is in μF. Since X_c and X_L are equal at resonance, either term can be used to find the coil inductance. The *ARRL L/C/F Calculator*, type A, can be used to find the unknown inductance if you'd rather not massage the keys of your pocket calculator.

It should be said also that you can find the capacitance of an unknown low-value capacitor by means of a dip meter when you connect the capacitor in parallel with an inductor of known value. If this were done, you would determine the capacitance from

$$C_{\mu F} = \frac{1}{2\pi \times f \times X_L}$$

where f is in MHz and X_L is in ohms. X_L can be determined from $X_L = 2\pi \times f \times \mu H$. The mathematics is all of grade-school level, so none of us should be afraid to use the equations.

The relative Q (figure of merit) for an inductor can be gauged by the depth of the dip-meter indication when checking a resonant circuit. The deeper the "null," the higher the tuned-circuit Q. Also, the higher the Q, the farther from the tuned circuit we can place the dip-meter coil and still obtain a dip. An accurate home-workshop technique for finding the Q of a tuned circuit is shown in Fig. 1 on page 54 of the *ARRL Electronics Data Book*. If a coil shows very low Q at the test frequency, don't use it for circuits near that frequency. However, the core properties might be ideal for some lower frequency. Checks with a dip meter and a higher-value capacitor should prove this. Pi-wound rf chokes seldom exhibit high Qs. Typically, they yield Q values between 30 and 60. In most applications we don't want an rf choke with high Q. The lower Qs provide a wider frequency response, and that is desirable for rf chokes.

Closing Comments

The rectangular encapsulated rf chokes (probably video peaking coils) in the 273-1570 kit are color coded to indicate their values, so no need to check them for other than open circuits. The 1980 Radio Shack catalog (no. 315, page 108) lists this kit as a standard item, so I presume an ample supply exists. Some other tempting assortments are shown in the same catalog.[1]

This article cites only one example of how you can save money while building up your parts stock for experimenting. Lots of good parts can be found: All we need do is look for them! QST

[1] Experimenters may want to check the Poly Paks no. 92CU6283 coil/transformer assortment which contains 200 pieces and sells for \$2.99. See *QST* ads for the address.

Strays

HOW YOUNG IS THAT AMATEUR EXTRA CLASS LICENSEE?

□ Bernard Weinstock, K2MU, of Queens, New York, earned his Amateur Extra Class license when he was 13 years, 5 months and 17 days of age; Greg McIntosh, AFØE, of Springfield, Missouri, became an Extra when he was 13 years, 4 months and 16 days old; and Timothy Wettach, of Heneoye, New York, was a youngster of 13 years, 3 months and 10 days when he reached Extra Class. The young people of today are really amazing. There are probably other young amateurs with equally amazing accomplishments to their credit. Do you know any young hams whose feats match those of Bernard, Greg and Timothy? If so, we'd like to hear about them. Send details to KA2BNV at ARRL hq. [Editor's Note: Thanks to AF2K for providing information on these fine young hams.]

PROJECT MOCH: MORSE COMMUNICATION FOR THE HANDICAPPED

□ Sharon Williams, KA6BJB, is involved with a very special program with a group of students in Fremont, California's Glanker School. The students, ranging in age from 12 to 20, cannot speak or "sign," owing to physical handicaps. The new instructional program, the brainchild of Stu Langs, AA6SL, provides for classroom instruction in sending and receiving Morse code by the handicapped students, their parents and teachers.

For the first time the students will be able to "speak" in group conversations or tell their parents about the events of the day. The wheelchair-bound child will be able to use a keyer to activate an alphanumeric converter to communicate with the outside world. If the project works as well as expected, a massive effort will be made to locate qualified instructors. — *Jane Bell, WD6GKN, South Bay ARA, Fremont, California*

Sharon Williams, KA6BJB (left), instructs Paul Boyce in sending and receiving Morse code. *(photo by Jeff Pinto)*

Modulation Systems and Their Noise Performance

When can ssb have a better signal-to-noise ratio than fm? When can fm have an even better signal-to-noise ratio than a baseband system? This article answers these questions and unravels some of the mysteries of modulation.

By Wayne Greaves,* WØZW

At first glance, the concept of modulation seems simple enough. Modulation is the process of varying a parameter of a carrier wave — either its amplitude, frequency or phase — in proportion to an information-bearing signal. The wide variety of modulation types which are in use yield an almost equally wide variety of performance characteristics. Let's begin our exploration into modulation systems and discover what makes some methods superior to others for a given application.

Why Modulate?

Now that we have defined modulation, of what use is it? By translating a message to a different frequency band via modulation, we can take advantage of the shorter wavelengths of that band to build a smaller antenna. An antenna system assembled for the audio frequency range, for instance, would be enormous, although such systems have been constructed.[1,2] For the radio amateur with an average-sized lot, this is reason enough for using modulation! Another use is that one can take advantage of propagation characteristics by translating the message to a particular frequency. As an example, conventional, long-haul communication is typically done in the hf bands rather than uhf. In this respect we gain some control over the propagation of our message. Last, by moving message signals to unique spectral locations, or channels, interference from other messages may be avoided.

At this point it is hoped that the use of modulation is well justified. Indeed, it is fundamental to radio communications. As will be shown, there can be significant performance differences between modulation types. Even the casual observer can recognize the noise performance advantage of fm over a-m. In an effort to quantify such observations, the remainder of this article is devoted to introducing the relations which mathematically describe the noise performance of various modulation systems. The relations given are simple and understandable, yet provide considerable insight into modulation characteristics. The section that follows

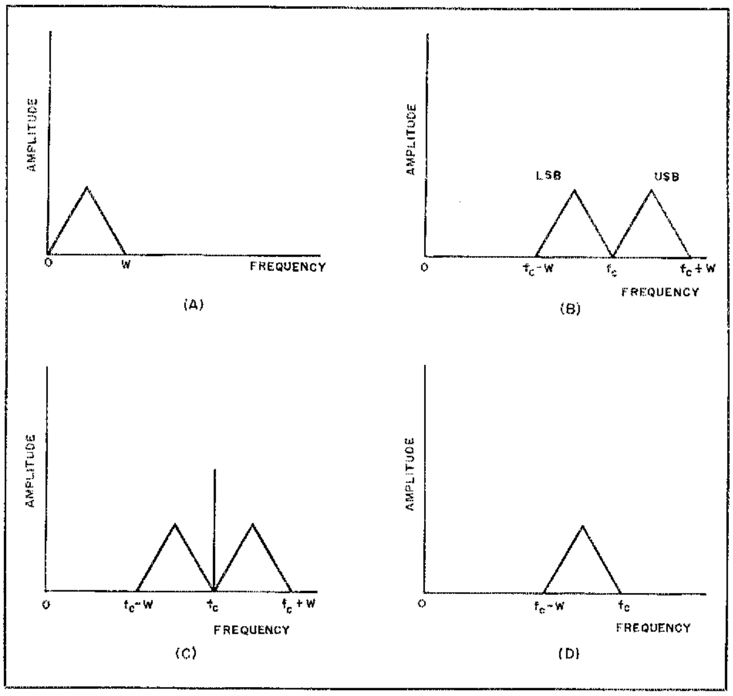


Fig. 1 — At A, the spectrum of the modulating, or message, signal is shown. A double-sideband spectrum is shown at B. At C is the spectrum of an a-m signal, while the spectrum of a single-sideband signal is shown at D.

*2009 Via Corona, Carrollton, TX 75006

[1]Notes appear on page 25.

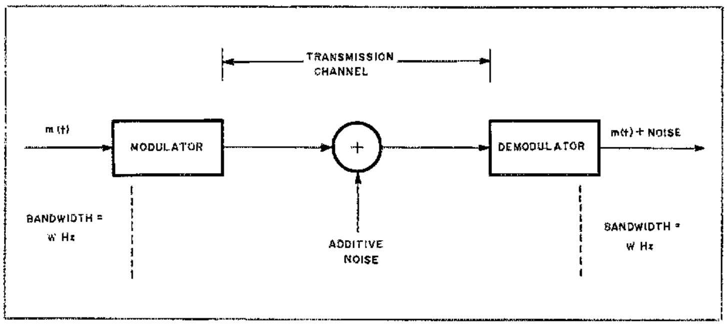


Fig. 2 — Block diagram of a basic communication system.

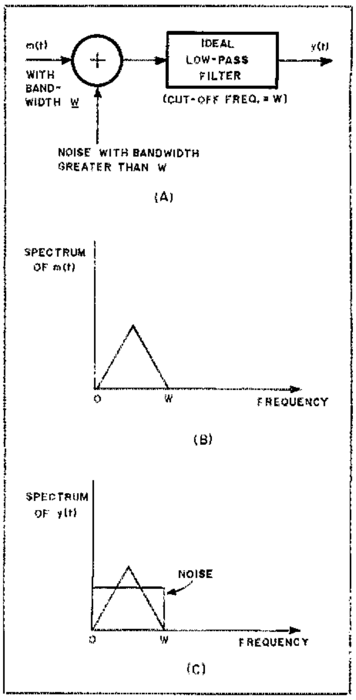


Fig. 3 — A baseband communication system. At A is the block diagram. At B is the spectrum of the message signal, and C shows the message signal after the addition of system noise and low-pass filtering.

reviews some modulation basics and introduces notation which will be used in the discussion on noise.

Basics of Analog Modulation

The output of an analog modulation system is a continuously variable signal which is proportional to the message signal in some manner. Double-sideband (dsb) modulation is the result of a simple multiplication of a carrier by the message signal, m(t). The output of a dsb modulator is

$$s(t) = m(t)\cos 2\pi f_c t \qquad \text{(Eq. 1)}$$

where f_c is the carrier frequency. The frequency domain representation of a dsb signal is shown in Fig. 1B. Note that the message-signal spectrum appears on either side of the carrier frequency, resulting in an upper sideband and a lower sideband. A message-signal bandwidth of W Hz yields a dsb signal bandwidth of 2W Hz. An inherent disadvantage in the use of dsb modulation is that a cw signal of the same frequency as f_c is needed for demodulation. This increases the complexity of the receiver. A demodulator using a cw signal of the same frequency and phase synchronism as the carrier, called a coherent demodulator, is desirable. In general, it is the most complex type to implement but yields the best linearity and noise performance.

When a dc bias (K) is added to the message signal prior to the modulation process described above, amplitude modulation (a-m) results. This is described by

$$s(t) = [K + m(t)]\cos 2\pi f_c t$$
$$= K[1 + i\, m_n(t)]\cos 2\pi f_c t \qquad \text{(Eq. 2)}$$

where $m_n(t)$ is constrained between 1 and −1, and $i = |\text{max amplitude of } m(t)|/K$. The parameter i, known as the modulation index, is an indication of the degree to which the a-m carrier is modulated. As shown in Fig. 1C, the spectrum of an a-m signal is identical to dsb except that a carrier component is present in a-m. Although this carrier component transmits no information and thus is wasted power, it does allow for a simpler receiver than that used for dsb. The bandwidth of a-m is identical to dsb for the same message signal.

Transmission of both an upper sideband and a lower sideband is not really necessary because each by itself contains all the information needed for reconstructing the message signal. Eliminating one of the sidebands of a dsb signal yields a single-sideband (ssb) signal. The resulting bandwidth is W, the same as the message signal bandwidth. Single-sideband transmission requires a relatively complex transmitter and receiver.

Dsb, a-m and ssb are all examples of amplitude modulation. Phase modulation (pm) and frequency modulation (fm) are examples of angle modulation. A pm signal is described as

$$s(t) = \cos[2\pi f_c t + k_p m(t)] \qquad \text{(Eq. 3)}$$

where k_p is the phase deviation constant.

A description of the spectrum of an fm or pm signal is a complex task and in fact would reveal a signal of infinite bandwidth. Fortunately, the power is negligible in sidebands far from the carrier frequency. This fact permits an expression for the bandwidth (B) of an angle-modulated signal which is known as Carson's Rule:

$$B = 2(D + 1)W \qquad \text{(Eq. 4)}$$

where D (deviation ratio) is the ratio of the peak carrier-frequency deviation to the corresponding maximum-frequency component of the message. For D much less than one, the resulting signal is a narrowband angle-modulated signal. D much greater than one yields a wideband angle-modulated signal.

Noise

We are now at a point where the effects of noise in modulation systems can be considered. Noise is present everywhere. In communication systems, it causes random degradation of signals in their journey from transmitter to receiver. The effects of noise in communication systems depend on the type of modulation being used. In fact, modulation can actually reduce noise, but not without a trade-off, as will be shown.

There are many ways of comparing the relative merits of communication systems. In this discussion, the signal-to-noise ratio (SNR) following detection shall be the basis for comparing the noise performance of modulation systems. Fig. 2 illustrates the basic system under study in block diagram form.

Although this article concerns noise in modulation systems, the first noise analysis will be of a system which involves no modulation or demodulation. Such a configuration, called a baseband system, is shown in Fig. 3. Assume the message signal, m(t), has bandwidth W Hz and a power of P watts. The noise has a spectral power density of N watts/Hz. Low-pass filtering improves the SNR by not passing noise above W Hz. The amount of noise present in the system output is

$$(N \text{ watts/Hz})(W \text{ Hz}) = NW \text{ watts} \qquad \text{(Eq. 5)}$$

and the baseband system SNR at the filter output is therefore

$$\mathrm{SNR} = \frac{P}{NW} \qquad \text{(Eq. 6)}$$

(the ratio of signal power P to noise power NW).

The SNR of the baseband system is presented as a reference for comparison to the SNR of other systems. Except for this purpose, the baseband communication system is of limited use to the radio amateur. For the remaining, more complex communication systems, the SNR will simply be given without derivation. Analysis of these systems is beyond the intent of this article, but excellent texts are available for those interested.[3,4]

We will now consider the noise performance of several practical amplitude modulation systems. Interestingly, the SNR of both dsb and ssb following coherent detection is P/NW, which is identical to the baseband system. Therefore, if signal-to-noise ratio is the sole basis of system performance comparison, dsb and ssb would be equal candidates. Trade-offs enter the picture when the wider bandwidth of dsb versus the added complexity of ssb is considered.

The discussion of the basics of analog modulation mentioned that the carrier component of an a-m signal is wasted power. Once can therefore surmise that the noise performance of a-m is inferior to dsb or ssb. The SNR for a-m after coherent detection is

$$\mathrm{SNR} = \frac{i^2\,\overline{m_n^2}}{1 + i^2\,\overline{m_n^2}}\left(\frac{P}{NW}\right) \qquad \text{(Eq. 7)}$$

where $\overline{m_n^2}$ is the mean squared value of the normalized message signal and i is the modulation index. As an example, for $\overline{m_n^2} = 1$, as is the case for a square wave message signal, and a modulation index of one, a-m SNR is P/2NW, which indeed is 3 dB worse than dsb and ssb. Substituting a sine-wave message ($\overline{m_n^2} = 0.5$), SNR = P/3NW. The fact that typically $\overline{m_n^2}$ is about 0.1 and i is less than one reveals further the poorer noise performance of a-m over dsb and ssb. As if that isn't bad enough, we have only considered coherent demodulation of an a-m signal. An advantage of a-m is that simpler, noncoherent demodulation techniques such as envelope detection can be used. Such techniques trade simple implementation for noise performance inferior to the coherent system described above. Therefore, the a-m SNR given earlier is the best that one can hope to achieve with ideal conditions. In spite of the relatively poor performance of a-m, it is popular in broadcast applications because of the simple detectors which can be used.

Thus far, this investigation has not revealed a modulation system with better noise characteristics than the baseband system. As we turn now to angle modulation systems, just such an improvement is evident. Exactly how much better is angle modulation over amplitude modulation? The expression for the signal-to-noise ratio of a pm system is

$$\mathrm{SNR} = K_p^2\,\overline{m_n^2}\left(\frac{P}{NW}\right) \qquad \text{(Eq. 8)}$$

In that $k_p\,\overline{m_n}$ is constrained to a maximum value of π to allow unique demodulation, $K_p^2\,\overline{m_n^2}$ cannot exceed π^2. Therefore, the noise performance of a pm system is at best about 10 dB better than the baseband system. Of even greater significance, in an fm system

$$\mathrm{SNR} = 3\,D^2\,\overline{m_n^2}\left(\frac{P}{NW}\right) \qquad \text{(Eq. 9)}$$

This relation reveals a noteworthy property of fm. By increasing the deviation ratio, D, one can realize ever-increasing signal-to-noise ratios! Unlike pm, there is no theoretical upper SNR boundary. As long as the received fm signal is above the operating threshold of the demodulator, one can achieve any SNR at the expense of increased transmission bandwidth. Significant noise improvement begins when the carrier-frequency deviation is large compared to the message-signal bandwidth. Note that for a narrowband fm signal, where D is much less than one, the SNR falls below that of baseband. In the early days of radio, fm experiments proved disappointing for this reason because the fm signals were limited to a relatively narrow bandwidth, mimicking that of an a-m signal. Not until 1933, when Edwin Armstrong used an fm signal which swung over a very wide bandwidth, was the advantage of fm realized. One can see this benefit in the following example: For the case of a wideband fm signal, assume D = 10 and a sine-wave message ($\overline{m_n^2} = 0.5$). This yields an SNR which is a factor of 150 or 21.8 dB better than baseband. Examining the bandwidth penalty by applying Carson's Rule (Eq. 4), one finds that such a signal has a bandwith of 22W Hz as opposed to W Hz for baseband.

Summary

Having established the purpose and need for modulation and having developed the basics of analog modulation, we have explored the noise performance of some systems in common use by radio amateurs. With the equations provided, the performance of these modulation systems in the presence of noise can be quantitatively compared. Indeed, we have discovered that the various signals which carry our communications are not all equal performers. Angle modulation techniques can yield much-improved performance over amplitude modulation, but the superior performance of pm and fm systems is gained at the expense of wide transmission bandwidths. Table 1 condenses modulation-system trade-offs. Given the often demanding communications environment amateurs experience, it is hoped that the preceding brief treatise sheds some light on the effects of noise in radio communication. QST

Table 1

Modulation-System Trade-offs

Modulation System	*Postdetection SNR*	*Required Bandwidth*	*System Complexity*
Baseband	$\frac{P}{NW}$	W	minor
Dsb with coherent demodulation	$\frac{P}{NW}$	2W	moderate
Ssb with coherent demodulation	$\frac{P}{NW}$	W	major
A-m with coherent demodulation	$\left(\frac{i^2\overline{m_n^2}}{1 + i^2\overline{m_n^2}}\right)\left(\frac{P}{NW}\right)$	2W	moderate
Pm above threshold	$K_p^2\,\overline{m_n^2}\left(\frac{P}{NW}\right)$	2(D + 1)W	moderate
Fm above threshold	$3\,D^2\,\overline{m_n^2}\left(\frac{P}{NW}\right)$	2(D + 1)W	moderate

Notes

[1]Ruhe, "ELF In Warfare," *Signal*, January 1979.
[2]Black & Lindstrom, "TACAMO," *Signal*, September 1978.
[3]Ziemer and Tranter, *Principles of Communications*, Houghton Mifflin Co., Boston, 1976.
[4]Schwartz, Bennett and Stein, *Communication Systems and Techniques*, McGraw-Hill, New York, 1966.

Verti-Beam III — A Multidirection 20-Meter Antenna

Radiation patterns of this array, covering 360 degrees, are selected with a simple relay circuit. No "tricks of the trade" are needed for matching or tuning. It's a fun antenna!

By James A. Turner,* W9LI

Trees are gifts of nature offering aesthetic appeal to nearly everyone. To the radio amateur they have a special value, for almost intuitively the amateur sees trees as a practical means of supporting wire antennas. Where trees are well spaced, installation of horizontal antennas generally is a task accomplished without tribulation. But when there is an abundance of arboreal growth, putting up such an antenna may often be nearly impossible. That is the way it is here at W9LI.

Being blessed with such a situation, one could say my choice was either to demolish much of my "forest" or seek a simpler solution. Nature seemed to dictate the simpler approach. The W9LI antennas would be vertical.

A Practical Antenna That Seems Best

Although the advantages of vertical antennas were known to radio engineers in the earliest days of radio, relatively few amateurs took advantage of the low-angle radiation and DX capabilities of this type of antenna until after World War II. Today the vertical is favored not only by DXers, but also by those amateurs who are not fortunate enough to have sufficient land available for stretching out a large horizontal antenna.

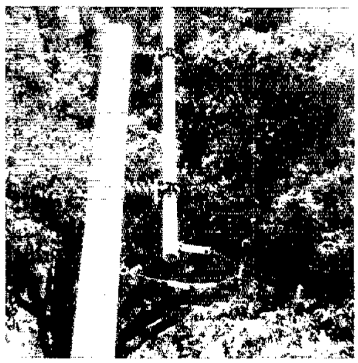
Over the years, I have tried numerous vertical antennas in a variety of configurations. My latest, which I am about to describe, seems to be the most practical and, in my opinion, the best of the lot.

A Three-Element Vertical Array

The W9LI antenna is designed to provide not only additional gain, but also to provide a choice of directional patterns. As you can see by examining Fig. 1, two relays serve to switch the elements from one pattern to another with the result that there is 360-degree coverage. The system consists of three half-wave, self-supporting 20-meter elements set in an equilateral triangle. Each side of the triangle is 17 feet or approximately 1/4 wavelength.

*[Editor's Note: After accepting Mr. Turner's article for publication, we were saddened to learn of his passing.]

The W9LI 20-meter array. Vertical elements are mounted on self-supporting posts. The relay control box containing the matching network is mounted on the center post. Open-wire line feeds the individual radiators.



The author mounted the vertical elements as illustrated by this photograph. One wire of the transmission line can be seen terminated at the bottom of the radiator. The other wire is supported by an insulator.

Open wire (Zepp) feeders voltage feed the bottom of each vertical radiator. Two elements are fed in phase and the other out of phase. The signal is beamed through the two in-phase elements and in the direction of the out-of-phase element. Relays switch the elements so that 360-degree coverage is obtained. Curves in *The ARRL Antenna Book* show 1-dB gain for the in-phase elements at the indicated spacing and 4-dB gain for out-of-phase elements. We could estimate the gain, therefore, to be about 5 dB.

How the Array is Made

Each vertical element is mounted on an 18-foot (5.5-m), 4 × 4 in. (100 × 100-mm) redwood post set four feet (1.2 m) in the ground. This places the bottom of the elements 11-1/2 feet (3.5 m) above ground. There is nothing sacred about this height except that it puts the fairly high rf voltage points out of the reach of neighborhood youngsters.

I chose 61ST aluminum tubing with 0.058-inch (1.47-mm) wall thickness for the elements. This choice allows the elements to telescope with a 0.009-inch (0.23-mm) clearance. The first segment of each element has a 1-1/2-inch (38.1-mm) OD with a 1-3/8-inch (34.9-mm) OD piece inserted in the full 12-foot (3.7-m) length. There is a very practical reason for this, namely to stiffen the first segment and allow it to bend in a long arc during high winds. Previous experience has shown that a sharp bend results in permanent damage to aluminum tubing. So far, the antenna has weathered 80 mi/h winds with no resulting harm to the array.

The next section is formed with 1-1/4-inch (31.8-mm) OD tubing, 12 feet (3.7 m) long. Then follow three 4-foot (1.2-m) sections, 1-1/8-inch (28.6 mm) OD, 1 inch (25.4 mm) OD and finally 7/8 inch (22.2 mm) OD. Each section is telescoped 9 inches (229 mm) into the next larger section. A self-tapping screw is placed in each larger section before assembly to act as a stop. Each joint is secured with three self-tapping screws. It would have been better to slot the sections, use some anticorrosion compound and a hose clamp. As it is, the thing will probably never come apart. The overall length of each element is 33 feet (10.1 m). All three elements are mounted on the poles with some old power-line insulators. Stainless-steel strapping provides the electrical connection at the bottom of each element.

The Feed System

As indicated in Fig. 1, 450-ohm ladder line connects the elements to the central tuning box containing the relays and matching network. Each of these feed-line segments is 10 feet (3.0 m) long. All must be exactly the same length. As with the familiar Zepp antenna, the transmission line is connected to one end of the radiating element in the manner shown in Fig. 1. One wire of the 450-ohm line is attached to the radiator, and the other wire is dead-ended at an insulator on the pole.

The directivity switching relays inside the tuning box must be fairly rugged if they are to withstand normal use under medium or higher power conditions. Those at W9LI are Advance products. A few years back, when 500-ohm transmission lines were popular, Advance relays were commonly used in antenna-changeover units. At the present time, they are rather expensive. Mine were acquired through the generosity of W9NEX and by the fortune of purchasing one at low cost at a hamfest.

As the Zepp feeders are less than 1/4-wavelength long, a simple series tuner is sufficient for matching purposes. L1 is wound with no. 12 tinned copper wire placed on a grooved 2-1/2-in. (64-mm) diameter ceramic form. Spacing between turns is equal to the diameter of the wire. There are four turns on either side of the three-turn center link, L2, as indicated by Fig. 1.

C1 and C2 are also "scroungees" from a hamfest. High-voltage, wide-spaced capacitors are not necessary because the voltage is low at this point. The tuner is fed by buried RG-8/U cable extended from the shack. Regular rotator control cable, also buried, carries the relay control voltage.

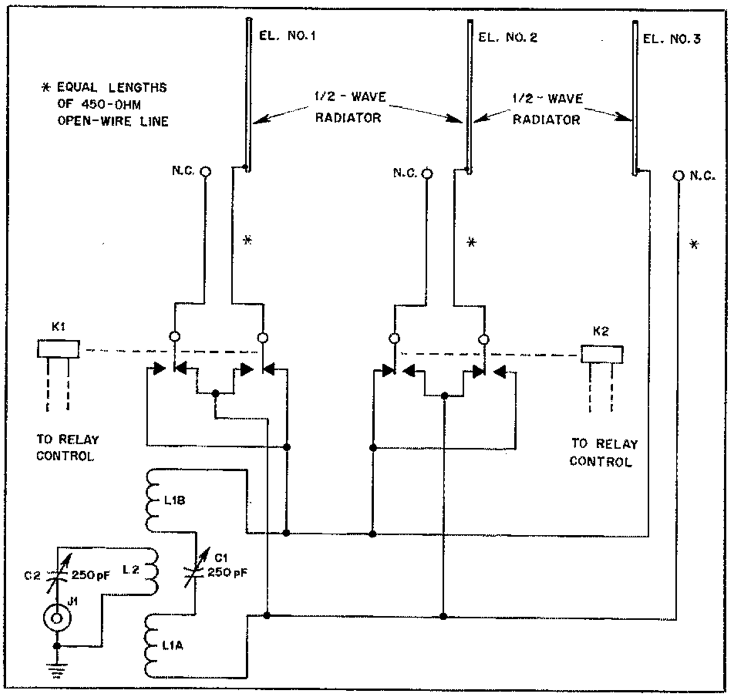


Fig. 1 — Circuit diagram for the W9LI vertical antenna array. Relays enable the operator to switch radiation patterns covering a full 360 degrees. Lengths of the 450-ohm ladder line must be equal (see text). A simple network provides proper matching between the coaxial line from the transmitter and the antenna-system load. Relay contacts should be rugged enough to handle the anticipated rf current flow to the open-wire lines. A variable link (not essential), placed between the two sections of L1, will permit adjustment for maximum coupling. Pattern directivity switching is obtained by energizing K1 only, or K1 and K2 together.

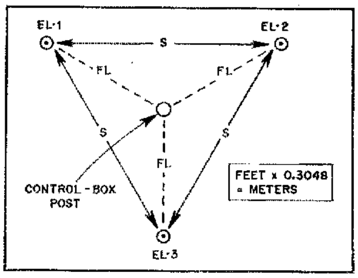


Fig. 2 — A top view of the W9LI antenna array. Spacing (S) between each pair of elements is 17 feet. Feed-line length (FL) from the control box to each element is 10 feet.

Two knife switches control the relays during tune-up. A third switch keys the transmitter. All control wires are bypassed to ground with 0.001-μF mica capacitors.

Ground radials, either buried or otherwise, are not needed for the sake of good radiation. This is helpful where space is at a premium. Nevertheless, a ground for lightning protection is desirable. Also, in the case here at W9LI, a ground connected to the braid of the coaxial cable at the antenna end of the line cleared up a case of fundamental-overload TVI.

Tuning the array is simple. Insert an SWR meter in the coaxial line at the antenna tuner and adjust C1 for minimum SWR. C2 primarily compensates for reactance of the link. Touch-up of C2 may be required but once that is accomplished, the job is done.

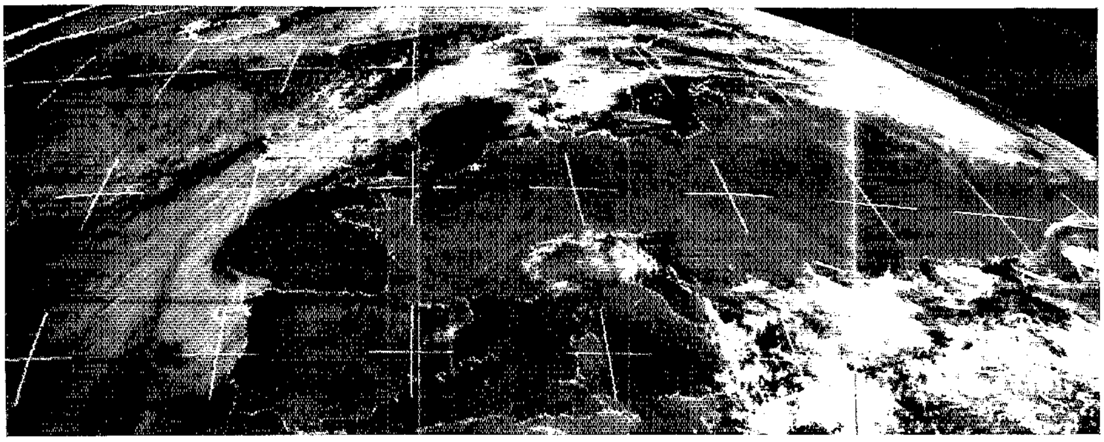
No vertical is an ideal receiving antenna under most circumstances. This one, however, does show good directivity and gain on low-angle DX signals as compared with a 5/8-wave antenna. Side discrimination is good. On short skip such as high-angle stateside signals, the discrimination leaves something to be desired.

Transmitting performance, on the other hand, is good both from the standpoint of directivity and gain. Of course, it has caused no frustration among those amateurs who have high Yagis and four-element quads, but I am pleased by the results. The first morning I tried the antenna, I contacted two VUs with little effort. Since that time, the array has held its own in pileups during DXpeditions, special prefix races and the like. I think it would be fair to say, though, that some of those 599 push-button reports should be discounted a bit!

An S-band Receiving System for Weather Satellites†

How's the weather? Be ahead of any backyard weather forecasters in your neighborhood by building this satellite receiving system. With it and some surplus facsimile equipment you can receive weather pictures from space!

By Guido Emilani,* I4GU, and Marciano Righini,** I4MY



Europe as seen by Meteostat. This is a composite of three images received by I4GU/I4MY on May 15, 1979.

Have a look at Fig. 1. In all probability your location lies within one or even two of the areas enclosed in the dotted lines (telecom coverage). This means that you are in a position to receive the signals from one or two of the five geostationary weather satellites which are positioned over the equator at intervals of about 70 degrees of longitude. Before deciding that the reception of a geostationary weather satellite is a feasible project, let's examine the pros and cons of the matter.

Advantages:

1) A geostationary satellite is at a "fixed" position in the sky and need not be tracked. The antenna is aligned only once.

2) The antenna need not be tower-mounted. Installation at ground level is fine, as long as the "view" of the satellite

*Via Fratelli Bandiera 18, I-48018 Faenza, Italy
**Via Colombo Lolli 8, I-48100 Ravenna, Italy

†Adapted from a similar article which appeared in *Radio Rivista* (ARI), July 1979.

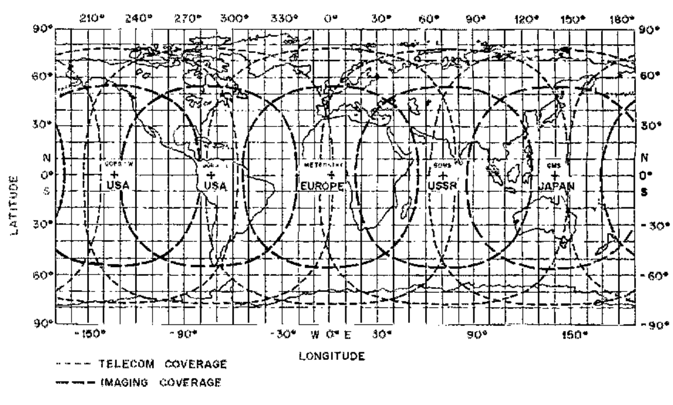


Fig. 1 — Coverage areas of the five geostationary weather satellites.

is not blocked by trees or buildings.

3) The frequency used by the weather satellites is free from man-made electrical noise and not subject to Faraday rotation.[1]

4) The satellites operate 24 hours a day.

5) They have a common downlink frequency. In a suitable location, two satellites can be received with the same equipment simply by re-aiming the antenna.

[1]Notes appear on page 33.

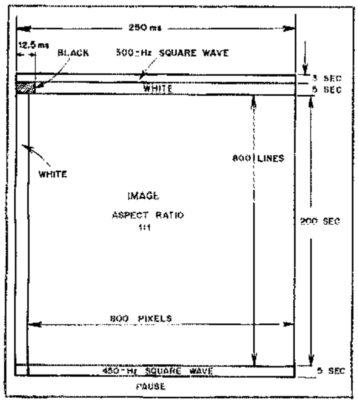


Fig. 2 — The WEFAX image format.

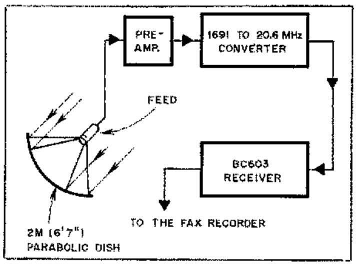


Fig. 3 — Block diagram of the 1691-MHz receiving system.

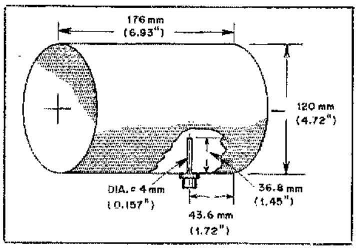


Fig. 4 — The tubular radiator for 1691 MHz consists of a metal cylinder with one end open. This end faces the dish. The rod element should be soldered directly to the type-N connector. The connector should have a provision to slide 5 mm (0.197 in.) forward and backward to find the best position.

6) The format of their APT-WEFAX images is the same all over the world and no changes in the format are planned.

Disadvantage:

The satellites transmit at 1691 MHz. Construction of receiving equipment for this frequency can be difficult even for the experienced amateur.

Reproducibility of the Receiving System

We have been receiving weather pictures from all the USA and USSR polar-orbit satellites for 10 years. Last year, after Meteostat, the first European geostationary weather satellite, was launched, we decided the advantages far exceeded the disadvantage! We

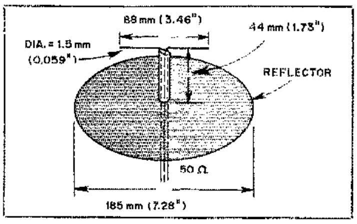


Fig. 5 — Dipole and reflector for 1691 MHz. The two branches of the dipole are soldered to the inner and outer conductors of a 50-ohm coaxial cable. The cable is held in position by a metal tube.

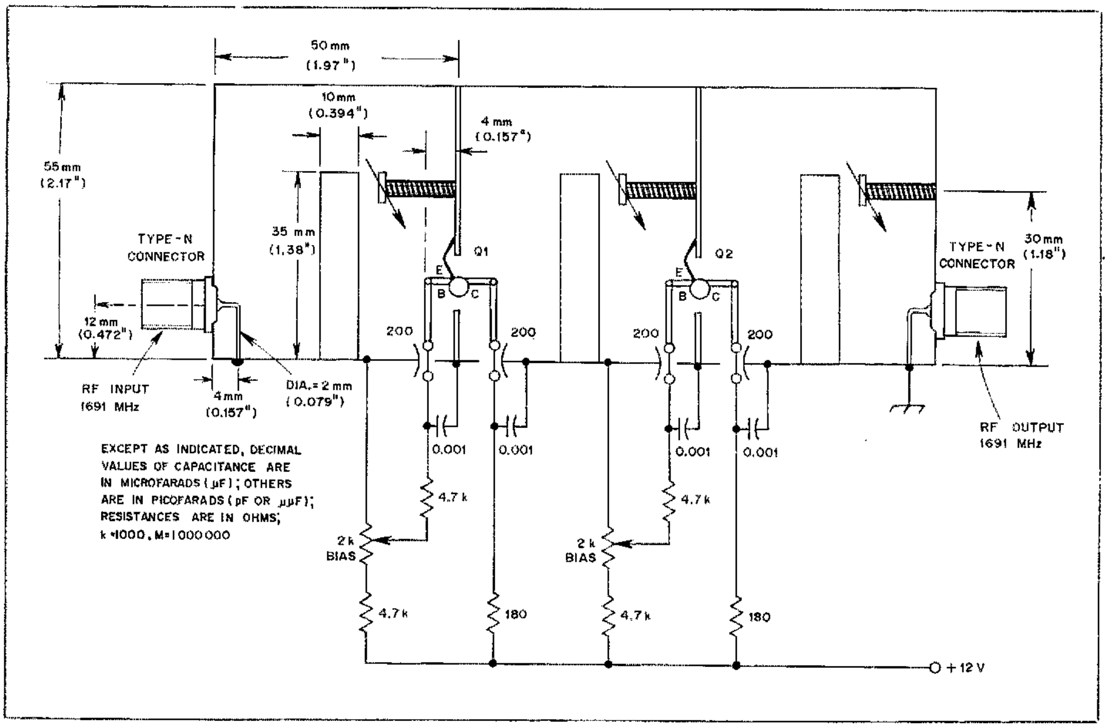


Fig. 6 — The 1691-MHz preamplifier. Q1 and Q2 are BFR-91 transistors. All three cavities are identical; dimensions shown for the left-most cavity also apply to the two cavities on its right.

experimented for several months and succeeded in developing a receiving system that can be duplicated without too much difficulty. Indeed, it has been constructed tens of times by amateurs here, always with good results.

The International Global System

The system of satellites is designed to contribute to the Global Atmospheric Research Program (GARP) and to the World Weather Watch (WWW) of the World Meteorological Organization.[2] An international group for Coordination of Geostationary Meteorological Satellites (CGMS) has been able to relate many aspects of the system, so that in many cases the modes of operation are quite similar even though the satellites themselves were constructed in different countries.

Table 1

Status of the International Satellite System

Operator	*Satellite Name*	*Location*	*Status*
ESA (Europe)	Meteosat	0° E	in operation
Japan	GMS	140° E	in operation
USA	GOES-E	75° W	in operation
USA	GOES-W	135° W	in operation
USSR	GOMS	70° E	not yet launched

The status of the system is shown in Table 1. The GOMS spacecraft has not been launched as of this writing; it is expected to have similar functions to the other four. As a special effort on the part of the USA and the European Space Agency (ESA), a third GOES spacecraft

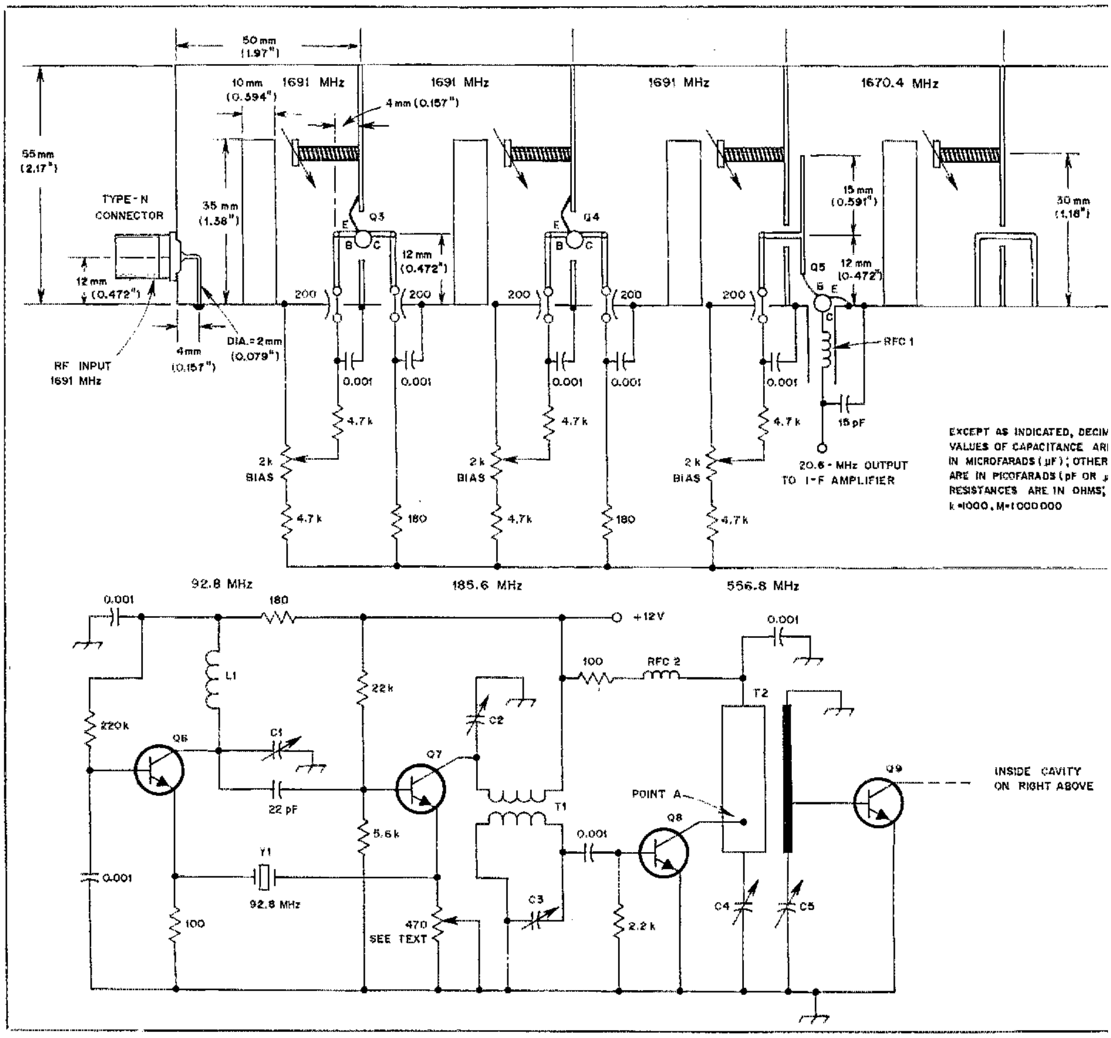


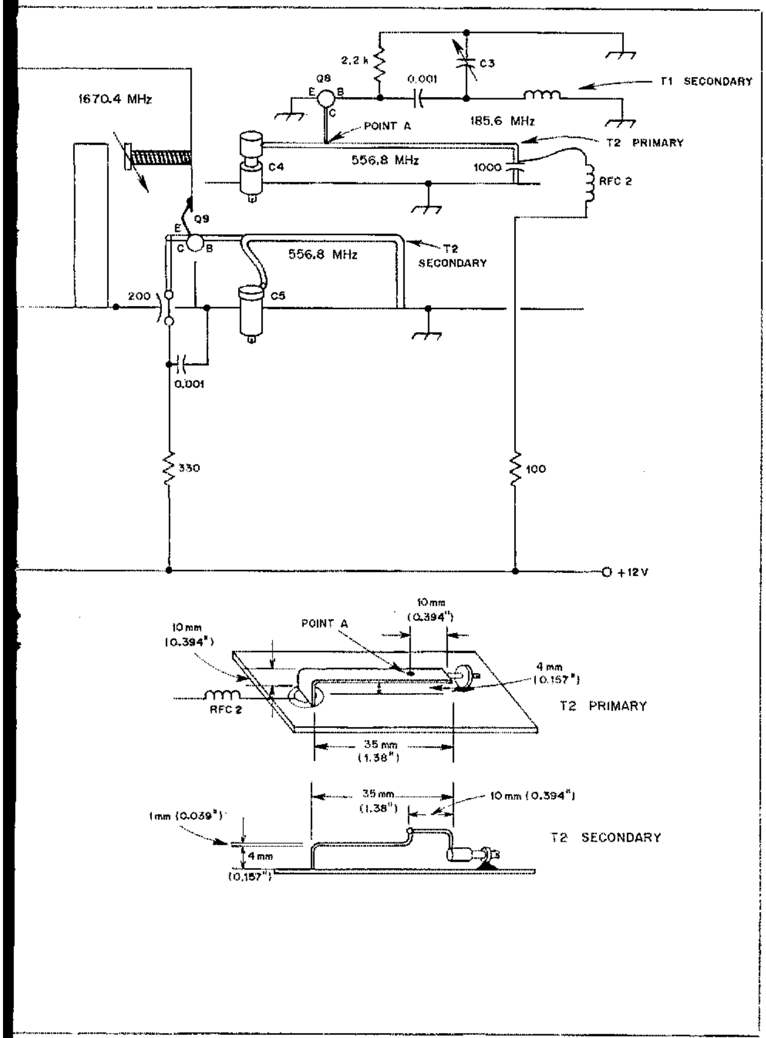
Fig. 7 — The rf amplifier, mixer and LO chain. The triplers, Q7 and Q8, are shown twice; once in schematic form (above) and once in mechanical layout form (upper right). All five cavities are identical; dimensions shown for the left-most cavity also apply to those on its right.

C1 — Miniature ceramic trimmer, 6-30 pF.
C2, C3 — Piston trimmer, 2-10 pF.
C4, C5 — Piston trimmer, 1-5 pF.
L1 — Seven turns of no. 18 AWG copper wire, air core, 6-mm (0.236 in.) diameter.
Q3, Q4, Q5, Q9 — Vhf/uhf amplifier, silicon npn, BFR-91.
Q6, Q7 — Video amplifier, silicon npn, BF-155.
Q8 — Uhf amplifier, silicon npn, BFY-90.
RFC1 — 50-mm (1.97 in.) length of copper wire air wound with a 3-mm (0.118 in.) diameter. The coil is inserted in a small copper or brass tube in the bottom of the cavity.
RFC2 — 100-mm (3.937 in.) length of copper

was operated over the Indian Ocean during the year of the First GARP Global Experiment (FGGE) from December 1, 1978 until November 30, 1979. It has now been moved west to another location to form part of the GOES-E/W system. This spacecraft is functionally identical to GOES-E and GOES-W but is being operated by ESA.

The Spacecraft and their Sensors

Some characteristics of the satellites are given in Table 2. All three spacecraft are spin-stabilized and rotate at 100 rpm with the spin axis nearly parallel to the N-S axis of the earth. They each carry a radiometer as the main meteorological payload. In each case the radiometer is used for imaging, using the same principle as that used for earth scanning. A line of data is collected by the spinning of the satellite about an axis parallel to the N-S axis of the earth, and successive lines are obtained by the stepping of the telescope to a new line of latitude after each spin of the spacecraft.



wire air wound with a 3-mm (0.118 in.) diameter.
T1 — Primary and secondary are each 3-1/2 turns of no. 18 AWG copper wire, air core, 6-mm (0.236 in.) diameter; the two windings are interleaved.

T2 — The primary is made from a 35 × 10-mm (1.38 × 0.394 in.) copper strap; the secondary is 35 mm (1.38 in.) of no. 18 AWG copper wire. See drawing above and photo for details.

Table 2

Main Characteristics of Geostationary Weather Satellites and APT-WEFAX Transmission

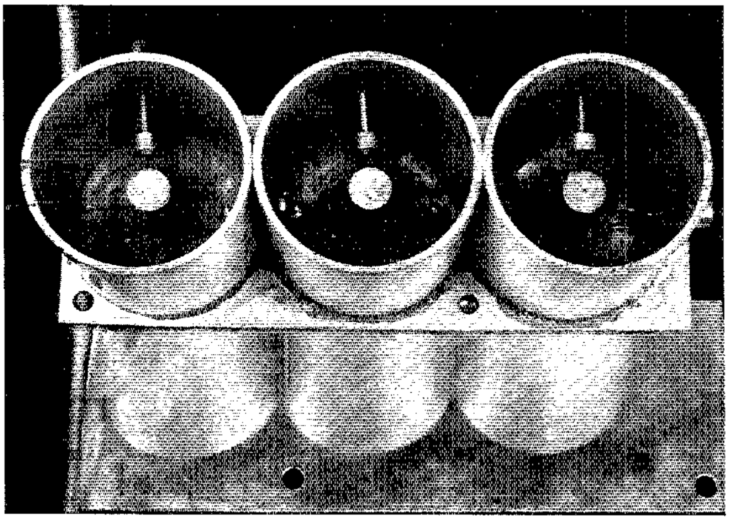
Rf	
Transmit antenna polarization	Linear hor.
Carrier modulation	Fm analog
Carrier deviation	±9 kHz
Rf bandwidth	26 kHz
Video	
Sub-carrier frequency	2400 Hz
Sub-carrier modulation	A-m
Black level	Minimum — 5%
White level	Maximum — 80%
Base band video	1600 Hz
Line rate	4 Hz (240 lines/min.)
Index of cooperation	267.36
Direction of horizontal scan	Left to right
Direction of vertical scan	Top to bottom

The differences among the three radiometer types incorporated in the satellites are relatively minor, except that Meteostat is the only spacecraft of the five to have a water-vapor channel, and scans from east to west and from south to north — the opposite of both GOES and GMS.

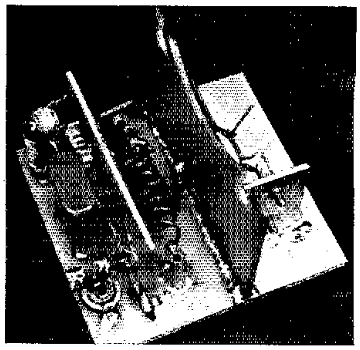
For information dissemination, all use the common frequency of 1691.0 MHz. As regards data formats, only the WEFAX transmissions have been standardized by the CGMS: This format is identical for all satellites, and standard recording equipment can be used worldwide. Two differences should be noted, however. Meteostat has an additional independent dissemination channel at 1694.5 MHz. Also, GMS transmissions have a 260-kHz bandwidth as opposed to the 26-kHz bandwidth of GOES and Meteostat. This would necessitate a change of filter in the receiver to ensure reception of both types of WEFAX transmissions. For further information on individual aspects of the satellites (dissemination schedule for instance), apply at the space agency liable for the spacecraft you wish to receive.

The APT-WEFAX Format

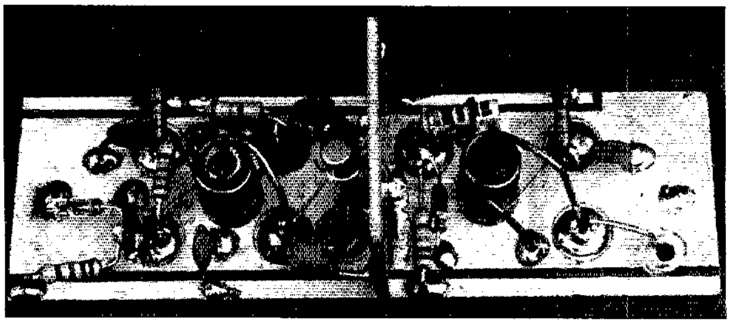
APT (automatic picture transmission) is a slow-scan image-transmission system. Its data is analog. WEFAX stands for Weather Facsimile.[3] The WEFAX format of the images from all geostationary satellites is shown in Fig. 2. The image is preceded by the transmission, for three seconds, of a square-wave signal at 300 Hz for the supply of current to the facsimile equipment. The line synchronization code which follows consists of 20 lines (five seconds). The black level transmitted at the beginning of these lines lasts 5% of the duration of the line (12.5 ms). The rest of



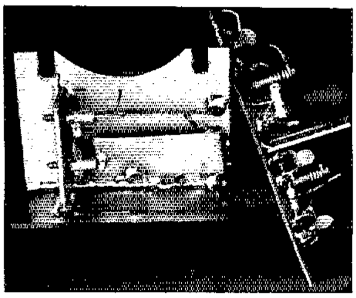
The preamplifier cavities from above, shown without lid.



The local oscillator and multiplying stages. Note the construction technique, using double-sided pc board as chassis, ground plane and shield.



The i-f amplifier. Note the pc-board shield separating input and output circuitry.



A side view of the local oscillator chain showing T2 at 556.8 MHz. The wire attached to the secondary connects to the base of Q9 when the LO assembly is mounted on the converter. On the right is another view of the i-f amplifier.

the line (237.5 ms) is at white level. After this synchronization code, the 800 lines of the image are transmitted. Each of these lines begins with a white level (in which there are seven phasing bars) of a duration of 1/21 of a line (11.9 ms). The rest of the line, bearing the image, lasts 238.1 ms. The image is followed by the transmission, for five seconds, of a 450-Hz square-wave signal to switch off the facsimile equipment.

Receiving the Satellites

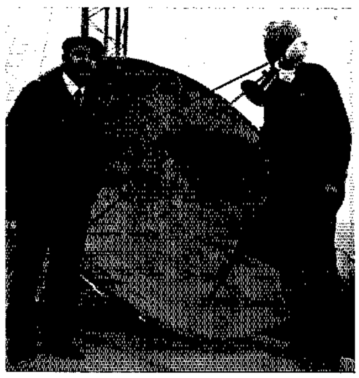
The 1691-MHz receiving system at I4MY is shown in Fig. 3. It uses a 2-meter (6 ft, 7 in.) diameter homemade parabolic dish. Using a surplus dish would undoubtedly make the project much easier. If higher quality transistors were used in the preamplifier than those called for here, a smaller dish could perhaps be used, but 2 meters is a desirable diameter for a consistently usable signal.

Two types of antenna feed were tried: a tubular radiator (Fig. 4), and a dipole with reflector (Fig. 5). Dipole feed is used here, although good results were obtained with both types. Since the signal from the satellite is horizontally polarized, the feed must be placed horizontally in the dish.

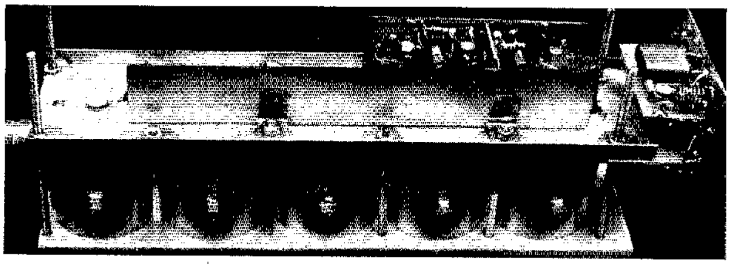
The 1691-MHz preamplifier, shown in Fig. 6, consists of two cascaded identical stages, each using a BFR-91 transistor. The three silver-plated resonant cavities are cut from a 50-mm copper or brass tube. In the center, each contains a coaxial line which is tuned with an air capacitor. These are made with fine-thread screws supported by nuts soldered to the sides of the cavities. The two emitters are soldered to the inner cavity sides. Adjust the bias potentiometers for 9 volts at the collectors of the two BFR-91 transistors.

The Down-converter and Tunable I-F

After preamplification, the satellite signal is converted to 20.6 MHz. A surplus BC-603 receiver is used as a tunable i-f. This receiver can easily be found in the surplus market[4] and can tune the 3.5-MHz bandwidth required to receive both



The authors and the 2-m (6 ft. 7 in.) parabolic dish. The feed is a dipole with reflector. The preamplifier is mounted at the antenna for minimum cable losses and is wrapped in a nylon bag.



The entire converter: the five cavities with their lid, and the LO and i-f amplifier assemblies.

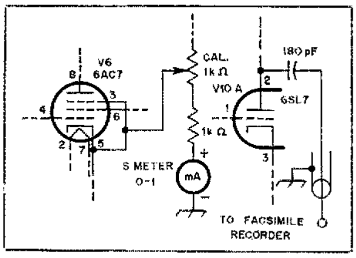


Fig. 9 — The modification to the BC-603 receiver is the addition of an S meter and an audio output for the "fax" recorder.

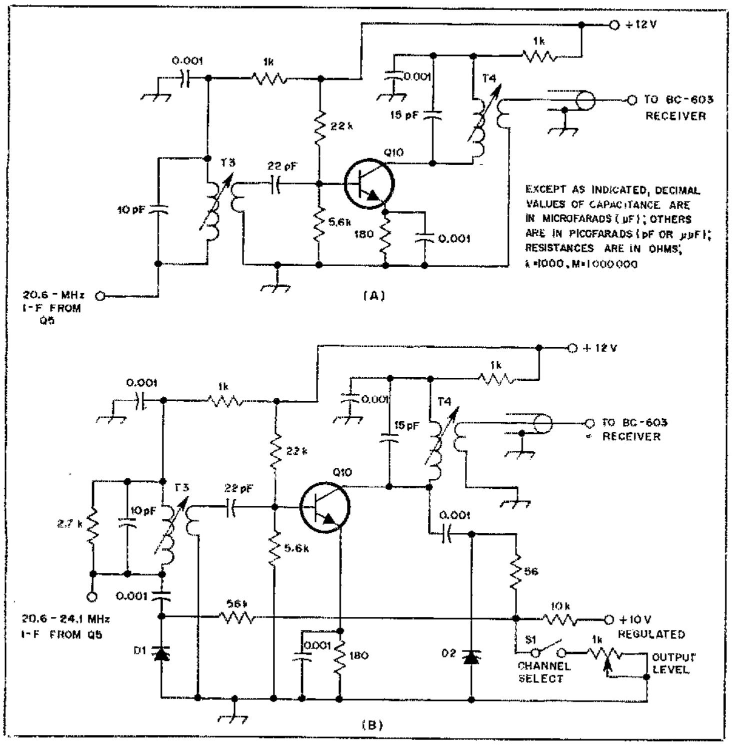


Fig. 8 — I-f amplifier circuit. At A is the fixed-tuned version; at B, the dual-channel version for reception of the Meteostat satellite.
D1, D2 — Varactor, BB-103.
Q10 — Video amplifier, silicon npn, BF-155.
T3, T4 — Primary: 16 turns of no. 24 AWG copper wire wound on a slug-tuned form 6-mm (0.236 in.) in diameter; secondary: a four-turn link of no. 18 AWG wire wound over the cold end (side nearest rf ground) of the primary winding.

Meteostat channels (1691 and 1694.5 MHz).

The down-converter consists of an rf amplifier, a local oscillator chain and an i-f amplifier, each built as separate assemblies. The 1691-MHz signal from the preamplifier is amplified by Q3 and Q4 of the rf amplifier/mixer/LO assembly (Fig. 7). It is then mixed with the 1670.4-MHz local oscillator signal in Q5. The five resonant cavities are exactly the same as those of the preamplifier already described. The two bias potentiometers for Q3 and Q4 are adjusted for 9 volts at each collector. The potentiometer for Q5 should be set for 10 volts at the collector and 0.2 volts at the base. Q6 is a 92.8-MHz overtone oscillator. The 470-Ω potentiometer should be adjusted for stable oscillation of the crystal. Q7 doubles this signal to 185.6 MHz. Q8 and Q9 are each triplers, resulting in an LO output frequency of 1670.4 MHz.

Two i-f amplifier circuits are shown in Fig. 8. Those planning to receive the Meteostat satellite should build the circuit at B. It can be tuned to either Meteostat channel with the two varicap diodes, D1 and D2. With S1 open, L6 and L8 should be tuned for maximum gain at 24.1 MHz. With S1 closed, set the potentiometer for maximum gain at 20.6 MHz. Switching between channels must be done very rapidly as sometimes there are only 17 seconds between two successive images transmitted on two different channels. This span of time is more than enough to switch S1 and push a tuning button on the BC-603. Those with no interest in Meteostat may build the simpler fixed-tuned circuit at A.

The BC-603 needs few modifications, and an accurate alignment is recommended. The addition of an S meter may be helpful to optimize the entire receiving system. Fig. 9 shows the addition of an S meter and an audio output connection for the facsimile recorder.

Final Remarks

A considerable number of rf amplifiers and cavities are used in our receiving system. More expensive, higher gain transistors could have allowed the cavity count to be reduced, in addition to allowing the use of a smaller receiving dish. The total cost of the system in this configuration is quite low, however, and the received image quality is excellent. QST

Notes

[1]Glassmeyer, "Circular Polarization and OSCAR Communications," *QST*, May 1980.
[2]*Meteostat Programme*, April 1977, and *Introduction to the Meteostat System*, November 1978, published by the European Space Agency.
[3]A Facsimile/Weather Satellite Reference Compendium:
Berman, "GOES Weather Satellite Picture Reception," Technical Correspondence, *QST*, March 1979.
Winkler, "Producing Weather Satellite Pictures at Lower Cost," *QST*, June 1978.
Johnston, "Locating Geosynchronous Satellites," *QST*, March 1978.
Righini and Emiliani, "Sync the Deskfax," *QST*, October 1976.
Winkler, "Facsimile Transceiver for Weather-Satellite Pictures," Technical Correspondence, *QST*, May 1974, and Feedback, *QST*, July 1974.
McKnight, "Evolution of an Amateur Weather-Satellite Picture Station," *QST*, April 1968, and Feedback, July 1968.
Anderson, "Amateur Reception of Weather Satellite Picture Transmissions," *QST*, November 1965.
[4]The BC-603 receiver is available as surplus from Fair Radio Sales, P. O. Box 1105 — 1016 E. Eureka St., Lima, OH 45802.

144-MHz Stop-Band TVI Filters†

Got TVI from your vhf transmitter? A high-pass filter won't help. Use a stop-band filter to notch out the beast!

The use of band-reject filters at the TV receiver is an attractive solution in the case of interference from 70-, 144- and 432-MHz transmissions, where TV reception may be on frequencies higher *or lower* than that of the amateur transmitter.

Even a simple series-tuned resonant circuit across the TV feed line can help and may sometimes attenuate strong local signals by 30 to 45 dB. A rather more elegant stop-band design for reducing strong signals is the "bridged-T" filter, which when correctly adjusted can provide a tunable, sharp, symmetrical null, even within the frequency band used for TV reception. Band-rejection filters of high Q can also be made using single or double stubs fashioned from coaxial cable.

Jan Martin Noedling, LA8AK, points out, however, that the technique of using stop-band filters to cure TVI caused by 144-MHz transmissions still receives relatively little coverage in most of the handbooks. Recently he encountered a problem of severe TVI when working "aurora" with 100 watts of output power on cw. For such transmissions his beam antenna needed to be directed virtually straight at a house some 33 feet (10 meters) distant, where his signals blanketed the TV receiver and blocked reception.

The Norwegian radio and TV interference investigation team found his equipment to be reasonably good; an article in the Dutch *Electron* (no. 11, 1978) encouraged him to try the use of stop-band filters tuned to 144 MHz and installed in the neighbor's TV feed line. See Fig. 1. The filter is capable of providing 50 to 60 dB of attenuation over all or part of the 144-MHz band. The parallel resonant circuit (L2-C2) is tuned to the center of the required rejection band by squeezing, pulling or bending turns. The series-resonant circuits (L1-C1 and L3-C3) are trimmed for maximum attenuation at the upper and lower frequency limits. The filter was aligned using a test circuit incorporating a 3-dB pad (see Fig. 2), tuning the resonant circuits to the frequencies shown in Table 1. A stable generator should be used for alignment. The pad is needed to prevent "short-circuiting" the signal generator output, as this can cause false indications. This simple arrangement cured LA8AK's TVI problems completely. QST

†Adapted from an item of the same title in the column by Pat Hawker, G3VA, "Technical Topics," *Radio Communication* (RSGB), March 1979, p. 232.

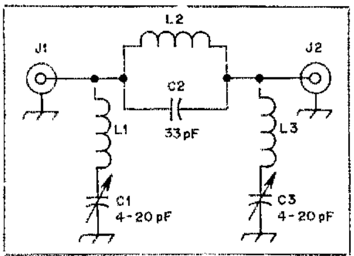


Fig. 1 — The 144-MHz stop-band filter. L1 and L3 are 10 turns of no. 16 AWG wire with a 3/16-inch inside diameter. L2 is two turns of no. 16 AWG wire with a 5/16-inch inside diameter. See text regarding length adjustment of inductors. C1 and C3 are trimmer capacitors. J1 and J2 are BNC jacks, soldered to the pc-board foil.

Table 1

Resonant Circuit Frequencies

These are frequencies to which the resonant circuits of the filter should be tuned, for maximum attenuation in different segments of the 2-meter band.

Circuit	*144 to 144.5 MHz*	*144 to 146 MHz*	*146 to 148 MHz*
L1-C1	144 MHz	144 MHz	146 MHz
L2-C2	144.25 MHz	145 MHz	147 MHz
L3-C3	144.5 MHz	146 MHz	148 MHz

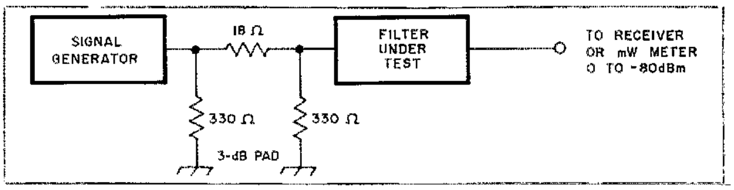
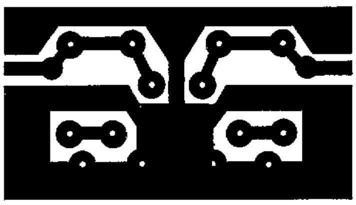


Fig. 2 — The recommended filter test circuit. See text.



Circuit-board etching pattern for the 144-MHz stop-band filter. Black represents copper. The pattern is shown at actual size from the foil side of the circuit board.

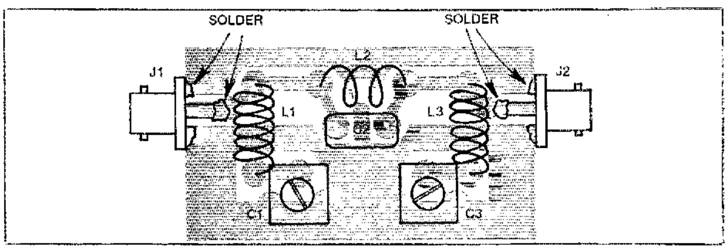


Fig. 3 — Parts-placement guide for the filter. The shaded area represents an X-ray view of the copper pattern. The two BNC connectors are each soldered to the board in three places as shown.

• *Basic Amateur Radio*

A Newcomer's Guide to FM Terminology

Confused by "quieting," "gain," "spread-spectrum" and other FM terms? Here is an easy-to-understand guide to these terms.

By Pete O'Dell,* AE8Q

When I got my first 2-meter rig I sat for hours, in awe, listening to the local "big guns" talk about how many dB of quieting so-and-so's signal had. They made fun of people with quarter-wave antennas, because "everybody" knew that gain antennas were always superior — the more gain the better! They tossed around other words that were incomprehensible to me at the time. Being reasonably gullible, I was impressed. Sound familiar? Let's see if we can demystify some of the terminology that you hear daily on your local repeater.

The chief advantage of fm communications is the "noise-free," painless sounds that come out of the speaker. If you think that "painless" is a poor adjective, just listen to your local 2-meter repeater for an hour or so, then try to listen to CB channel 19 for an equal amount of time. The howls, whistles and distortions coming from channel 19 are a function of the a-m mode of operation in conjunction with the overcrowding on that channel. In some areas, many of the 2-meter frequencies are crowded (probably not to the extent of channel 19), but you are not confronted with the noise because of the fm mode of operation. Fm receivers exhibit what is referred to as the *capture effect*.

The mathematics and physics of the capture effect are somewhat beyond the scope of this article; therefore, we will merely describe its effects. In an a-m system a signal voltage only 1/100 of the desired signal will still produce noticeable interference. In an fm system the desired signal need only be twice as strong as the other to completely mask its existence. That, in a nutshell, is the capture effect. If two stations happen to transmit at the same time (double) and if their signal levels at the repeater are approximately equal, then you will hear a garbled noise; fortunately, that does not seem to happen too often. The important difference comes when there is a marginal band opening and a very weak signal is coming through. A strong, local station will "capture" the receiver of the repeater and the listeners will not know that the weak signal is there.

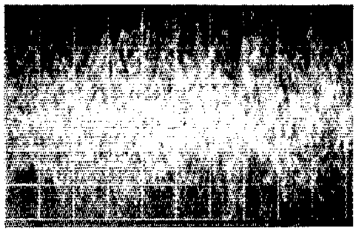


Fig. 1 — This is an oscilloscope display of the audio output of an unsquelched fm receiver with no signal present at the receiver input. In short, this is what noise looks like.

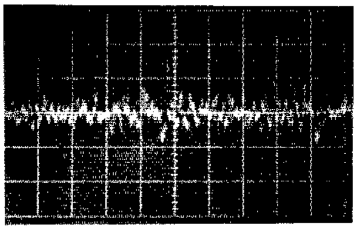


Fig. 2 — This display shows what happens to the audio output of an fm receiver when there is some signal present. The carrier has masked all but the strongest noise peaks. The receiver is "quieting."

One of the terms that the newcomer hears on fm that he does not hear on the other modes is "20 dB of quieting." Some hams talk about "full quieting" while others throw around initials such as "DFQ" (dead full quieting). Why the concern with quieting? The fm detector acts in a way to mask interference — regardless of whether that interference is man-made or natural. Typically, about 140 dB of gain will be required from the front end of a receiver through to the audio output. At the antenna input, there is a constantly varying voltage produced by the random movement of electrons on the antenna system; this is referred to as thermal-agitation noise. There are any number of other sources of minute "signals," all of which are amplified through the stages of the radio. The result is the rushing, white-noise sound that you hear from an unsquelched fm receiver (or any other high-gain receiver). An example is given in Fig. 1. The presence of an unmodulated carrier will begin to quiet the receiver, as depicted in Fig. 2.

You can observe this by connecting a signal generator to the input of an fm receiver. Attach an oscilloscope across the speaker terminals or any other convenient position in the audio chain. Unsquelch the receiver and you should see a pattern that looks roughly like a field of grass — growing both upward and downward. Adjust the output of the signal generator to a level below 0.1 microvolt. Then slowly increase the signal strength. You should see the average level of the noise begin to drop. When the average level drops to 1/10 the level with no signal applied, read the rf output from the signal generator. This figure, which will be on the order of 0.2 to 0.5 microvolt for a typical well-tuned amateur fm receiver, is the 20 dB sensitivity figure for the receiver. An ac-voltmeter is more accurate, but less graphic for educational purposes. If your reading is substantially off from the figure given by the manufacturer (assuming that you are using a reliable signal generator of known accuracy), you might want to retune the rf and i-f sections of the receiver. Tuning procedures will vary from one rig to another, but in general you will be safe tweaking the coils (or

*Basic Radio Editor

capacitors) for minimum noise on any crystal set; for a synthesized receiver, it would be wise to consult with the manufacturer or at least the service manual for the receiver. Generally, anyone who tunes receivers frequently will develop some skill at "tuning by ear." If you do not have an oscilloscope or an ac-voltmeter available, the "ear" method can be used. Once full quieting (Fig. 3) is reached, the "ear method" is useless. Keep the signal generator output low enough to produce a noisy signal for tuning purposes.

Squelch Tales

A standard squelch circuit cuts off the receiver audio output when there is no signal present. Typically, a transistor switch is employed to short-circuit the audio to ground, to block the audio from one of the final amplifying stages or to shut off one of the audio stages. Any of these systems will work fine when properly designed. How does the transistor switch know when a signal is present? Again, there are several ways of detecting the presence of a signal. In some units, audio is taken from the detector and routed to a high-pass filter which has its cutoff frequency well above normal voice frequencies. The high-frequency noise is then amplified and fed to a detector which rectifies the voltage and uses it as bias. When a carrier appears on frequency, the receiver "quiets" and the high-frequency noise disappears; therefore, the bias disappears, the switch switches and audio flows forth from the speaker. Other systems operate on the basis of detecting the presence of the carrier.

There are technically superior systems for squelching a receiver. The most practical system for repeater and fm use in general is what is referred to as *PL*. PL stands for *Private Line*; both terms are trademarks of Motorola. GE uses the term Channel Guard for this system, while other manufacturers have similar trademark names. The generic name for it is *continuous tone-coded squelch system*, which even in its acronymic form of CTCSS is quite unwieldy. Since PL is used as the generic in general amateur parlance, we will use it here.

In a PL-equipped transmitter, an encoder generates a precise tone from the second that the microphone button is pushed. This tone is used to modulate the transmitter signal at a very low level — on the order of 500-Hz deviation in a 5-kHz system. In this system there are 32 standard tones that range in frequency from 67.0 to 203.5 Hz. Whenever the transmitter is activated, this signal is there.

The standard squelch detector in the PL-equipped receiver is replaced with a PL decoder. Usually a high-pass filter passes the audio above 300-Hz to the audio stage, while a low-pass filter routes the PL tones to the decoder. The combination of the high-pass filter in the receiver and the low level of deviation of the PL signal from the transmitter means that, typically, the user does not hear the tone; hence, it is often referred to as a sub-audible system. If the tone is present (within ± 1.5 Hz or so), the decoder provides the proper bias to switch the audio output on. In commercial applications, the user is generally able to choose between PL or standard squelch simply by throwing a switch. There is nothing to stop one from wiring the squelch circuit so that either a PL or a non-PL signal will operate the switch. For instance, the standard squelch can be set to require a very strong signal to open while the PL is set to open on the weakest signal that the receiver can detect.

If PL is technically superior to standard squelch, then why is it not used widely to minimize interference? There are basically three reasons: prejudice, the desire not to limit access to those with PL and cost factors. The widespread prejudice against PL stems from the early days of the fm boom. A few snobbish gentlemen decided that they wanted to keep the masses out of their exclusive circle. They installed PL-only systems that kept the peasants away. Of course, if one of the peasants managed to come up with a PL rig, he was still not welcome unless he met their preconceived idea of perfection. These lids soon received the contempt that they deserved. Unfortunately, PL had become equated with these operators of closed repeaters; today, years later, PL is still pronounced guilty by association, without so much as a second thought.

If a receiver (in a repeater, for instance) is wired similar to one found in commercial service, it will either be on PL or on standard squelch, but not both. In that situation, to derive the benefits of PL operation, it would be necessary to exclude all signals that arrived at the receiver that do not have PL. That, of course, would exclude any transients who were not equipped for PL (or for the right PL tone). On the other hand, if wired as suggested above, the only signals that would be blocked would be the *weak ones without the proper PL tone*. Thus, the local base stations and any local mobile in the prime coverage area would not need PL. Mobiles expecting to operate from the fringes and portable (hand-held) stations would be likely to install a PL encoder. Under a dual-squelch system, PL would not "keep out the transients" and therefore, would not be "un-ham-like."

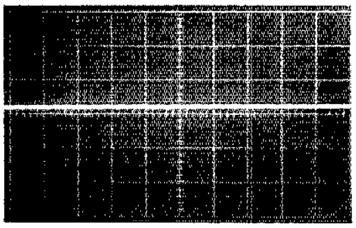


Fig. 3 — This display shows the output of a fully quieted fm receiver. There are no noise spikes present — all that can be seen is the base line indicating the presence of the unmodulated carrier.

At one time, cost factors were also significant. Besides the associated electronic circuitry, an encoder or decoder required an expensive reed or mechanical device (most of which operated on a tuning-fork principle). To go from one PL tone to another was expensive and time consuming. Digital electronics has changed all that. Several inexpensive, lightweight and field programmable encoders and decoders are on the market now. They draw little current and require no expensive reeds or devices for changing tones. If the manufacturers adopt PL as an additional "bell and whistle," it is doubtful that the cost increase per unit would be over $5 (some manufacturers have made a token effort in this direction).

Of these three reasons for not using PL, probably the most significant is the first — old prejudices die hard. In most areas of the United States, the 2-meter fm frequencies are full. The slightest bit of a band opening brings in weak signals that serve no useful function. A repeater that is constantly keying up only to spit out a couple of bursts of static and then shut off again is no fun to listen to. A dual-squelch system will keep out those unwanted weak signals, while allowing weak signals with the proper tone to come through. Strong signals would be unaffected. The cost is down and would go lower if manufacturers incorporated PL during the manufacturing stage. There isn't that much demand, yet. It's just that old prejudices die hard.

Gain, Gaining, Gone

One of the more confusing aspects of fm operation for the newcomer is likely to be the subject of antennas. Because no measurement standards have been agreed upon in the manufacturing industry, *QST* advertising policy prohibits advertisers from giving antenna gain figures in advertisements carried in *QST*. Most other electronics magazines do not have this type of policy; you've probably noticed their figures and wondered just what they mean. (So have a lot of other people, including a few electrical engineers who I know.)

Antenna gain is usually expressed in decibels (dB), and may be referenced to a dipole antenna (dBd). Sometimes reference is made to an isotropic radiator (dBi), which is a theoretical antenna that cannot exist in practice. An isotropic radiator is a point source that radiates an equal amount of energy in all directions. Its radiation pattern would be a sphere,

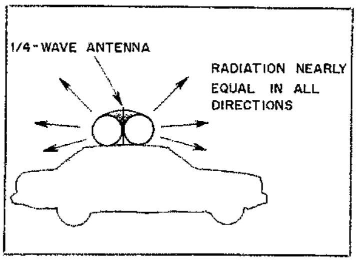


Fig. 4 — A quarter-wave antenna radiates "equally poor" in all directions.

but more about radiation patterns in a moment. For your information, a dipole has 2.14 dB gain over isotropic. Any time an antenna has gain, it is always at the expense of a loss in some direction. A dipole has no radiation off its ends, so its 2.14 dB gain over isotropic is in a broadside direction, at the expense of a loss off the ends.

It is important to know the reference when you compare gain figures, or the numbers can be misleading. If a particular antenna has 4 dB gain over a dipole, it will have 6.1 dB gain over an isotropic radiator. Ads can indicate this gain as either 4 dB or 6.1 dB; both numbers are correct, but the advertiser, for clarity, should indicate his reference antenna, either 4 dBd, or 6.1 dBi.

Because there are no standards for measuring gain, each manufacturer establishes his own procedures. Different procedures may produce different gain figures for the same antenna. Ad men will want to use the largest figure, to make the advertised antenna performance look good. It is fair to say that most of the advertisements appearing in Amateur Radio magazines are much more realistic than those appearing in some of the magazines oriented toward other personal radio services.

Some of you have noticed that most antennas are designed to be mounted with their radiators horizontal or vertical to the earth (quads are another story). The reason for this is a phenomenon called *polarization*. Every electromagnetic wave is made of two component parts — an electrical wave and a magnetic wave. The plane that the electrical wave lies in determines the polarization of the antenna. A rule of thumb is that the horizontal radiators produce horizontally polarized signals and vertical radiators produce vertically polarized signals. In "line-of-sight" communications, the only really critical thing is that both the transmitting and the receiving antenna be polarized in the same direction. When one is vertically polarized and the other is horizontal, there is an isolation of something on the order of 30 dB. Any gain patterns will also be distorted under these conditions. If the signal passes through an atmospheric duct, bounces off the ionosphere or bounces off a rock, the polarization may be "twisted" somewhat; then the polarization of the antennas is not as critical. Because most fm communication is conducted over a "line-of-sight" path, polarization is important.

Just about all the fm operation in North America is done with vertically polarized antennas. The simplest of these is the quarter wave. When mounted in the center of the roof of an automobile, a quarter wave presents a reasonable termination for 50-Ω coax. The radiation pattern of a quarter-wave vertical is omnidirectional; i.e., if it is mounted in the center of the roof and if there are no other objects on the roof, equal amounts of radiation will be going out toward the horizon in all compass directions. As the radiation angle above the horizon increases, the radiated energy drops off slowly. (Of course there is nothing radiated in a straight-up direction.) Suppose you take an ordinary doughnut and drop it over a vertical radiator. The doughnut will represent the strength of radiation going out from the antenna along an imaginary arc extending from the surface of the car roof up to the antenna itself (see Fig. 4). Some operators say quarter-wave antennas radiate "equally poor" in all directions, because no single direction or angle of radiation is highly favored over others.

Gain antennas come in two general varieties. Omnidirectional gain antennas are quite similar to the vertical quarter-wave antenna; beam antennas introduce a new dimension. Omnidirectional gain antennas generally look somewhat like their quarter-wave cousins, except they are always longer (for any given frequency). The most common of this variety is the 5/8-wave vertical. Unlike the quarter-wave, which is resonant and presents a fair match to 50-Ω coax, a 5/8-wave radiator is nonresonant, having a high capacitive reactance at its feed point. At the base of a 5/8-wave radiator you will find a housing that contains a matching network of one type or another.

The omnidirectional gain antennas change the radiation pattern of the antenna by compressing the vertical distribution of energy down from the high angles toward the horizon. Remember the doughnut that we slid down over the quarter-wave radiator? Just imagine now that a vandal comes along with a brick and very carefully mashes the doughnut flat. Ignore the mess on the roof of your car for the moment. The diameter of the doughnut increases because all the material that gave it height has been shoved down and compressed into a much smaller height, as depicted in Fig. 5. This is what happens with the gain antenna; more energy is radiated out toward the horizon. There is no magic here, though, because less energy is going out at high angles above the horizon.

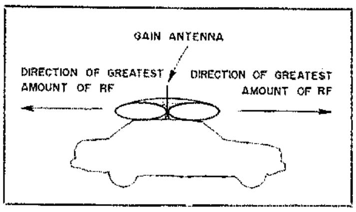


Fig. 5 — The radiation pattern for a gain antenna is somewhat flatter than that for a quarter-wave. This means that more of the signal goes out toward the horizon — as long as the roof of the car is parallel with the average terrain.

This discussion, so far, assumes that the ground plane (roof of the car) and the general terrain are parallel to each other. What happens if the ground plane is tilted at a 30° angle to the general terrain? Do we still have the strong lobes going out to the horizon? No, except along the two directions that are the axis of the tilt; this is illustrated in Fig. 6. The strong lobes go out in a direction that is parallel to the ground plane. Only if the ground plane is parallel to the general terrain do the lobes go toward the horizon.

In practical terms this means that the best antenna for mobile operation may be dictated by your geographical area. For instance, while living in West Virginia, I initially had a gain antenna mounted on my car. I noticed that as I neared the fringe area of the repeater, I would completely drop out when starting down a hill. When I would get to the bottom of the hill, the car would level out, and then the repeater would come back up (not as strong as at the top of the hill, of course). I replaced the gain antenna with a quarter-wave (at about a third the cost of the gain antenna). Bingo! I no longer dropped out when the car was tilted from being parallel with the general terrain (going up and down hills). On the other hand, I was recently in Baton Rouge, Louisiana, where it is pretty flat. I don't recall seeing a single quarter-wave 2-meter antenna in the parking lot. Depending on where you live and drive, a gain antenna may or may not be better than a quarter wave.

Omnidirectional gain antennas can be used at a fixed station by replacing the roof of the car with radials. This is fortunate — it would take a *large* tower to hold even a VW up in the air. Unless your tower is tilted quite a bit, it would seem reasonable to assume that a gain antenna mounted on the top of the tower will outperform a quarter-wave antenna every time.

Once a radiator becomes longer than 5/8-wave, the radiation pattern changes rather dramatically. Instead of extending out toward the horizon, the major lobes of radiation are at very high angles. Increased gain over a 5/8-wave antenna for the low-angle lobes can be achieved, though. One process called stacking,

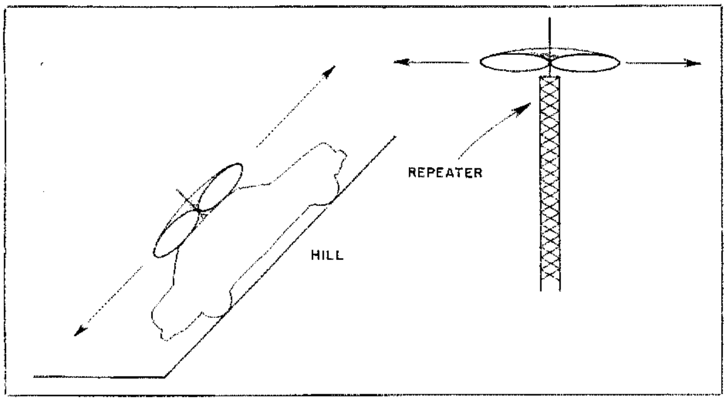


Fig. 6 — In extremely hilly country, a gain antenna may not perform as well as a quarter-wave antenna because the roof of the car is not always parallel to the average terrain: therefore, the main lobe is not always "aimed" at the horizon.

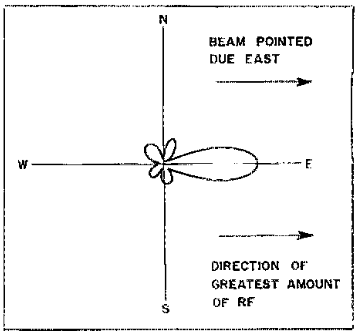


Fig. 7 — This is an overhead view of the radiation pattern of a beam antenna which is pointed due east. As with the other illustrations of antenna patterns in this article, the radiation pattern was drawn for illustration purposes only and should not be construed to be the actual pattern of any particular antenna.

consists of connecting 1/2-wavelength radiators to each other through 1/2-wavelength delay lines. But that is getting a little too complicated for this article. Those interested in pursuing this should read the "Mobile and Portable" chapter in *FM & Repeaters for the Radio Amateur.*

The other general type of gain antenna is the beam; any of the standard-format antenna such as the Yagi, quad or Quagi will perform quite well, as long as the antenna is mounted in such a way as to provide vertical polarization. Beam antennas pull the energy from the other horizontal directions and concentrate it in one direction. Fig. 7 depicts an example radiation pattern as viewed from above the antenna.[1] With most beams there may be several lobes, but only one of them should be extremely strong. Depending on design, the minor lobes will vary in strength and the major lobe may be short and fat.

Normally, the beam-type antenna will be mounted at a fixed location on a tower or at least on a mast above nearby objects that could degrade its performance. However, I did meet one ham recently who had a three-element quad mounted permanently on his car. He mounted a small TV-antenna rotator to a set of luggage racks that were attached to the car. The quad was bolted to a short mast installed in the rotator. Power for the rotator came from a small inverter. If you have need to get into a repeater from the deep fringe area and if you don't mind the curious glances from other motorists, you might consider a similar setup.

Coming Attractions

What is the future of fm operation? It seems likely at this point that the amateur service will continue to grow over the next decade — the rate of growth in the U.S. being largely in the hands of the FCC. There is no reason to think that new operators will not be attracted to fm operation on one or more bands. The 2-meter band is reaching a saturation point in all but sparsely populated areas of the U.S. With the advent of inexpensive "store-bought" rigs and converted CB sets[2] (all synthesized), 10-meter fm seems to be where 2-meter fm was about a decade ago — growing fast! The other vhf and uhf bands are nowhere near being saturated.

New technology is bringing new possibilities, too. *Spread-spectrum techniques* have been around for years in one form or another. These techniques hold some promise for better utilization of available frequencies — perhaps more so for some of the other services than for the amateur service. One spread-spectrum concept calls for a microprocessor to change the frequency of the transmitter several times per second in a very specific pattern. Of course, for reception it is necessary for the receiver to be controlled by a microprocessor and to hop in the same pattern as the transmitter.

Another suggestion we have heard about is modeled very closely after the mobile telephone systems. Here a microprocessor is used to cause the transmitter and receiver to look for an unused frequency (channel, repeater, etc.). VOX circuitry would keep signals off the air except when something is being said. Transmitter-receiver coordination would be maintained by a Digital PL signal (another highly descriptive Motorola trademark; computer buffs call it a data stream) which the receiver would search for and lock into.

None of this is terribly new or earth shaking. The military was using frequency-hopping techniques with radar back in the 1950s. The Improved Mobile Telephone System and the newer Advanced Mobile Telephone System have been using "intelligent" transceivers to search for vacant frequencies to use for years. Motorola introduced Digital PL nearly five years ago. The uses of inexpensive microprocessors are growing by leaps and bounds each day. It is not surprising that hams are beginning to talk of using spread spectrum now that microprocessors are making it inexpensive.

The technology for spread-spectrum techniques is available and waiting. The question is whether anyone will be able to make these techniques compatible with the traditions and values of Amateur Radio. On the surface it would appear that these techniques are far more exclusionary than PL. Anyone care to make a prediction? Before you answer that, think back a decade ago and ask yourself if you would have expected synthesized hand-helds.

Gain, quieting, PL and spread spectrum are all terms that are tossed about daily on repeaters. But there is another term that has fascinated me from the time that I first turned on a 2-meter rig. This term was thrown around with such authority that only an irreverent iconoclast would dare question its meaning. The first time that I heard an fm'er say "I'm *destinated*," I was struck by the vivid imagery that the strange word conjured up. Visualize a movie screen. There is a tight shot of Joe Ham talking into a microphone. Joe says, "I'm *destinated*." The camera begins to pull back and we see that Joe is sitting in a casket. He drops the microphone over the side of the casket, lies back and pulls the lid down on the casket. Slowly, the casket slides into the crematorium. "Destinated" sounds awfully final to me. QST

Notes

[1]For information on how to interpret this kind of pattern, see Hall, "The New Look for QST's Antenna Patterns," *QST*, July 1980, p. 26.

[2]Knickerbocker, Weise and Stielau, "CB-to-10 FM — Best Conversion Yet?", *73*, January 1980, p. 117.

Technical Correspondence

Conducted By
John C. Pelham,* W1JA

THE NEW BAUD GAME

☐ I am dismayed to find *QST* perpetuating the common myth that baud rate and bit rate are equivalent. The "FM/RPT" column, April 1980 *QST*, under the heading of "The Old Baud Game," mistakenly states that "Baud is the number of bits transferred in 1 second." A similar error was made in the "Washington Mailbox" column in June 1980 *QST*.

Actually, a baud is a unit of signaling rate, and is derived from the shortest signaling interval. For example, a signaling rate of 20 baud implies a signaling interval, that is, the time between changes of state, of 0.05 second. A bit is a unit of information. A bit/second (bps) is a unit of information transfer rate. The relation between signaling rate (baud rate) and information transfer rate (bit rate) on a channel is bits/second = bauds × no. of bits in one signaling interval.

The Baudot code used in the Teletype model 15 is an example in which the bit rate and baud rate have different values. The information rate is 42 bps and the signaling rate is 45.5 baud.

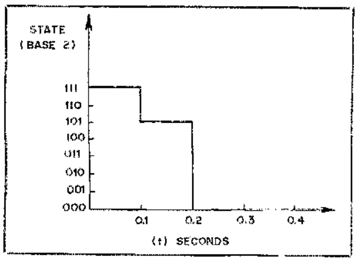


Fig. 1 — An eight-state coding scheme. In two signaling intervals, six bits (111101) have been sent.

Another example in which these rates differ is in schemes that employ multilevel coding. Most radio amateurs and computer hobbyists limit their thinking to the familiar two-state (mark/space) communication channel. The terms mark and space are relevant only in terms of bistate channels. One need not restrict oneself to two states (in fact, many commercial data communications services do not). Consider a channel which may have eight states. That is, if we were to examine the channel at any instant, we could find it in any one of eight conditions. For a baseband channel, these could be various voltage levels. For an audio-frequency channel, we could designate eight different audio frequencies.

Let's say that the shortest time between changes in state is 0.1 second. Thus the signaling rate is 10 baud. In this example, depicted in Fig. 1, three bits are used to distinguish among these eight states. Thus, the bit rate on this channel is 30 bits/second, while the signaling rate is only 10 baud. — *Robert S. Parnass, AJ9S, 8046 Knox Ave., Skokie, IL 60076.*

*Assistant Technical Editor, *QST*

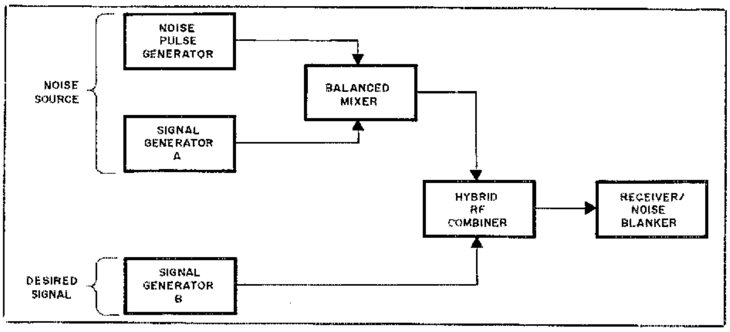


Fig. 2 — A test setup for quantitative noise-blanker measurements.

QUANTITATIVE NOISE-BLANKER TESTS

☐ While reading the ARRL book, *Weekend Projects for the Radio Amateur*, I noted with interest the construction article on the solid-state noise blanker.[1] One difficulty that is encountered with such a construction project is the lack of a good method to evaluate the finished product. There are two basic approaches to take toward evaluating a noise blanker. For a particular noise source being encountered under a specific set of receiving conditions, a qualitative approach like the one described in the construction article provides reasonably good indications that the blanker is working properly. Since qualitative evaluations are difficult to duplicate, a more precise method of evaluation must be used to obtain repeatable results and sets of data that can be easily compared.

Fig. 2 illustrates a proper setup for noise blanker tests. Signal generator A and a pulse generator are connected together with a balanced mixer, such as the Mini-Circuits ZAD series. The balanced mixer has a direct-coupled port; this allows the mixer to serve as an rf switch that is controlled by the pulse generator. This arrangement produces a pulsed rf output. Adjust the pulse generator to a pulse rate and duration typical of received impulse noise. This output is fed into an rf combiner, along with a second signal generator (B) which is used to provide the desired signal.[2] Signal generator A is typically set 1 kHz from the desired signal frequency. The rf-combiner output is then fed into the receiver/noise blanker under test. Using this method, various signal-level comparisons can be made. Since both the noise source and the desired signal are true rf signals within the receiver passband, a 50-μV noise vs. a 3-μV signal begins to mean something for quantitative comparison. I have found that a good blanker will be able to perform well with a strong noise level and weak desired signal, a weak noise level and strong desired signal, and equal noise/signal levels.

One further note of caution may be in order: Some noise blankers have rather high gain in the blanking signal path. This high gain can make proper alignment difficult because of the strong noise level present in the blanking path. If this becomes a problem, some method of gain reduction may have to be used to execute the alignment. Full gain can be restored before putting the noise blanker into the receiver. — *Richard L. Webster, K9ULW, ARRL TA, 1775 Henderson Dr., Marion, IA 52302.*

[1]Van Zant, "A Solid-State Noise Blanker," *Weekend Projects for the Radio Amateur*, ARRL; and *QST*, July 1971.
[2]"A Hybrid Combiner for Signal Generators," *The Radio Amateur's Handbook*, ARRL, 1980, p. 16-30.

STABLE TRANSMISSION-LINE OSCILLATOR

☐ I needed an extremely stable oscillator that required a minimum of stabilization time, and that would operate at room temperature without an oven. By stability, I am speaking of a few parts in 10^7 per hour, or a few hertz per day. I could tolerate only approximately plus or minus 0.3-Hz-per-hour drift or noise error. The output of the oscillator had to drive a frequency counter directly. It also needed to be easily variable to cover frequencies on the 75- and 80-meter bands, to utilize solid-state components and to be relatively easy to construct. While the Hartley, Colpitts or Clapp circuits could accomplish the requirements, it was evident that considerable attention had to be given to details of mechanical construction and selection of components.

The circuit which I devised, shown in Fig. 4, utilizes the best features of the Clapp oscillator. However,[3] it does not use a variable inductor. Instead, it incorporates an open-circuited transmission line as the major frequency-determining device. Being purely passive, the transmission line is extremely stable both mechanically and thermally. In addition, one usual source of instability, the capacitor between the base of the transistor and the tuned circuit, is eliminated.

The oscillator is operated at 10 times the

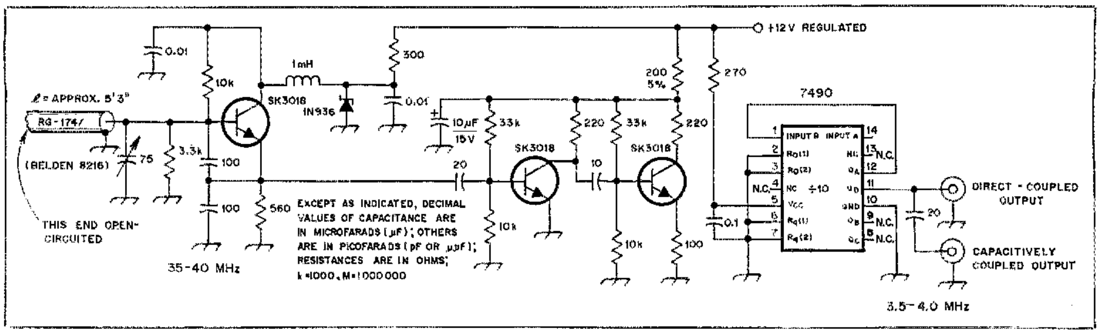


Fig. 3 — The stable oscillator devised by Baker consists of a 35- to 40-MHz oscillator using a length of coaxial cable as the main frequency-determining device. This frequency is divided by 10, resulting in an output frequency of 3.5 to 4.0 MHz.

output frequency. Two advantages are gained by this procedure. The length of transmission line required is well within workable limits (a little over 5 feet, occupying approximately 1 cubic inch). Any error or drift in the oscillator is divided by a factor of 10, i.e., a 1-Hz shift at 35 MHz is a shift of only 0.1 Hz at 3.5 MHz. The use of the 74LS90 IC makes the division simple and practical. The output of the unit is sufficient to drive counter circuits directly, and the frequency is not adversely affected by external coupling or loading.

Concerning construction, the following should be noted: C2 should be a stable variable capacitor. If necessary, C2 could be temperature compensated by padding with negative-temperature-coefficient capacitors. (I did not find this necessary.) The oscillator should be built in a mechanically solid manner in a heavy-gauge box. I used a printed circuit board to achieve maximum stability.

While the RG-174/U transmission line may be installed in any configuration, it is best to assure that the turns do not shift mechanically with respect to one another. Attention should be given to isolating the transmission line from severe changes in temperature. I used the shield case of a 2-inch (51-mm) panel meter for this purpose, and wrapped the coil of transmission line in fiberglass wool. I then packed everything in the meter case, and grounded it as a shield and temperature guard. — *John H. Baker, K3NZS, 6605 McCallum St., Philadelphia, PA 19119*

IMPROVING THE DELUXE NICAD CHARGER

☐ The May 1980 *QST* article entitled "A Deluxe NiCad Charger for Hand-Held Transceivers" raised high hopes on first glance, but fell short after closer inspection. Selecting the so-called constant-current mode of the charger does nothing more than effectively place the battery across the output of the bridge rectifier. The "constant" current is completely a function of the transformer losses and the battery condition. Also, the current is not adjustable.

The circuit shown in Fig. 4 uses the same bridge, switch and regulator, but offers selectable, adjustable constant-voltage or constant-current charging. Constant output voltage can be varied between at least 8 and 13 volts, with loads to 150 mA or more. Constant output current can be reliably set from 10 to 150 mA for battery voltages to at least 13 volts. — *Robin David Becker, WA2NYE, 2912 N. Calvert St., Baltimore, MD 21218.*

Feedback

☐ The QTH of Richard K. Thompson, KA5GYJ, listed in "Correspondence," June *QST*, page 61, should be Harlingen, Texas.

☐ An omission occurred in "The WARC Warriors" (March *QST*, page 60). Mr. Raymond E. Stone, W5RBO, is a contributor of $200 to the ARRL Foundation WARC Fund.

☐ W3EP/9, shown with his antenna array in "The World Above 50 MHz," July *QST*, page 65, has worked 31 *states* on 2 meters.

☐ Dr. Tom Linde, KAØW ("Stray," July *QST*, page 35), is a psychologist at the Veterans Medical Center in Knoxville, Iowa.

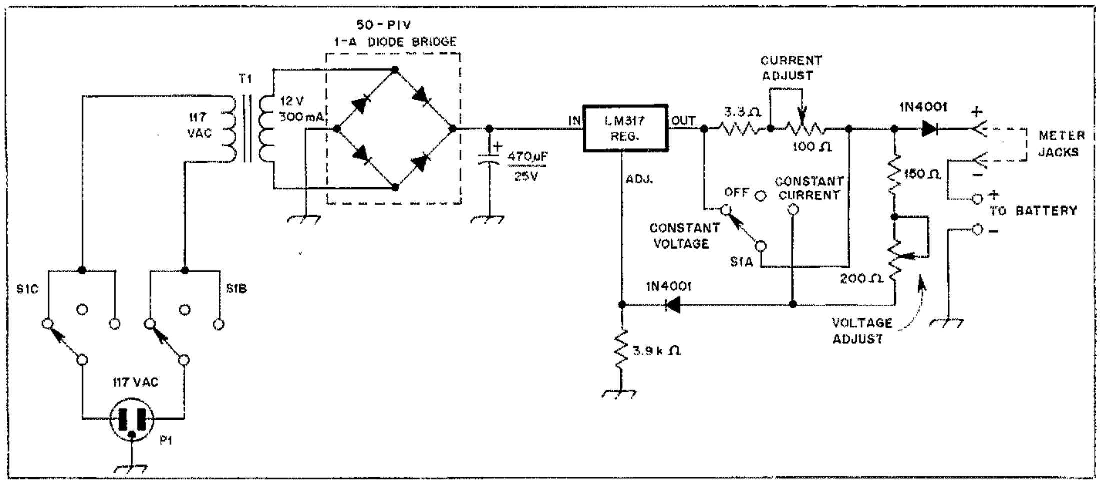


Fig. 4 — The NiCad charger from May 1980 *QST* can be improved as shown above, according to WA2NYE. T1 can be a Radio Shack no. 273-1385.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

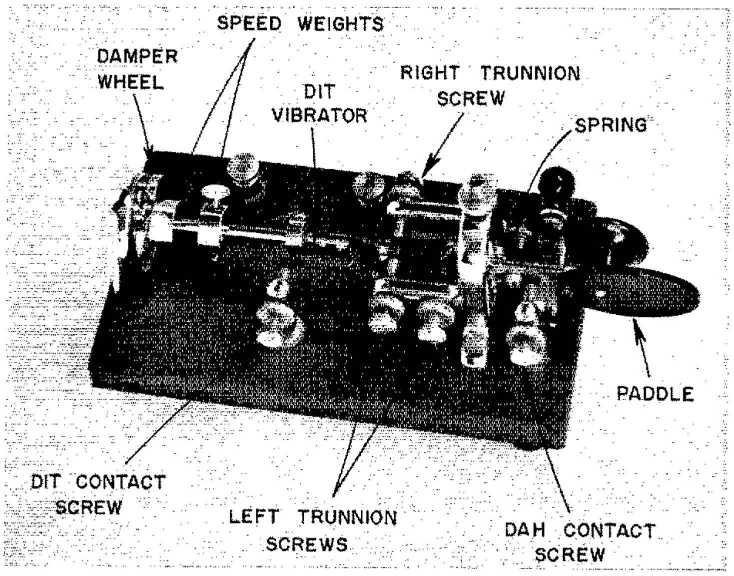
POWER-CONNECTOR STANDARDIZATION IMPROVES EMERGENCY COMMUNICATION

Amateur Radio emergency operations can be enhanced by compatibility of equipment. Frequently, during extended field operations, the need arises to lend a "lighter-plug" power cord or to power a transceiver from a borrowed power supply. The variety of power connectors supplied as original equipment on popular amateur gear make such interchange difficult, if not impractical.

The Central Ohio ARES has solved this problem, within its own group, by adopting an "ARES Standard Connector." On the basis of cost, availability and ease of installation, the Cinch-Jones 300 series, 2-pin connectors have been adopted for 12-V service with currents ranging up to 10 amperes, under continuous operation, or 15 amperes where demand is intermittent. This series has both male and female connectors for cable installation or chassis mounting. The connectors are also available with a locking device. A compatible nonlocking connector series is available from Radio Shack (male no. 274-201; female no. 274-202; chassis mount no. 274-203). The "standard" connectors are either permanently installed in the equipment or a short patch cord is made up to interface between the equipment and the "standard" connector. Following the industry standard, the larger pin is negative and the smaller pin is positive. The female connector is, of course, used on the power side with the male connector on the equipment side. For current requirements in excess of 15 amperes, the 400-series connectors are used with the even-numbered pins positive and the odd-numbered pins negative.

To facilitate interaction between groups in Ohio in any widespread emergency, the Ohio Council of Amateur Radio Clubs has recommended adoption of this procedure by all members. Emergency groups elsewhere might consider the same action, for amateurs often travel considerable distances to assist in major disasters. — *Robert R. Adams, W8BKO, EC, COARES, Columbus, Ohio*

ADJUSTMENT OF SPEED KEYS



Proper adjustment of a speed key, such as above, is provided in "Hints and Kinks" by W2PRO. His information on the nearly lost art is based on some early Western Union reference material in addition to some 33 years of pounding brass.

The adjustment of a speed key is not difficult, but it must be done carefully to get good and lasting results. The most important concern is to adjust the dit vibrator correctly. After the dits are correctly set, other adjustments come easily.

To adjust the speed key, proceed as follows (see the drawing):

1) Loosen both the right and left trunnion screws and the dit-contact screw. Carefully adjust the position of each screw so that the vibrator arm looks straight and is lightly butting up against the damper wheel. Tighten the right and left trunnion screws.

2) Slide the one or two weights on the vibrator arm to the end, or to the slowest dit position. Tighten the weights in place, making certain that the outermost weight is not touching the damper wheel.

3) Holding the thumb paddle to the right or dit position, readjust the left trunnion screws so that the vibrator dit arm can move to the left about 1/64 inch (0.40 mm). Tighten the left trunnion screws.

4) Hold the paddle in the steady series of dits position and allow the vibrator arm to come to rest.

5) Readjust the dit contact screw so that the contact makes a light contact with the contact of the vibrator arm. Tighten the dit screw. Release the paddle.

6) Test the Bug for proper dit adjustment by holding the paddle in the dit position and noting that the Bug can produce at least 40 well-formed dits in a series. Count the dits in bunches of 10 dits each by tapping your foot once for every 10 dits.

7) When the vibrator arm stops vibrating, note that the vibrator arm comes to rest lightly on the dit contact. Readjust the dit contact screw if necessary. Release the paddle and recheck step 6. This completes the dit adjustment.

8) To adjust the dah contacts, adjust the dah contact screw so that the distance between the paddle contact and the dah contact is about 1/64 inch (0.40 mm). Clearance is a matter of personal preference.

9) Adjust the degree of spring tension of the paddle to the almost completely unwound position. Although this adjustment is also a matter of personal preference, a light tension is favored.

10) For varying the dit speed, move the dit speed weight closer to the paddle for higher speeds. When two weights are part of the vibrator arm, always keep the outermost weight at the end of the arm, varying the speed of the dits by moving the innermost weight closer to the paddle. In general, leave the outermost weight positioned at the end of the arm.

11) Clean any dirt from the contacts by sandwiching a piece of bond paper between any closed contacts and whipping the paper through. Do this several times.

12) Check that all contacts open and close squarely. Recheck all screws, being sure they are all tight. — *Al D'Onofrio, W2PRO, Yonkers, New York*

FT-301 HINTS

Here are some modifications which I made to my Yaesu FT-301. Other '301 owners may be interested.

1) My FT-301 had poor cw waveshaping, resulting in extremely hard keying and minor key clicks. I eliminated the key clicks by changing C127 from 10 μF to 2.2 μF, and adding a 5-μF capacitor in parallel with C134. Both changes were done on PB-1433, the rf board.

2) Solid-state rigs seem to be sensitive to feed-line SWR, and my '301 was extremely so. I reduced this sensitivity by adding a 4.3-kΩ resistor in series with the anode end of D1304 on PB-1445, the LPF board. Now the output power remains nearly constant with an SWR of up to 2:1. Since this modification was performed, I gave my rig the ultimate test by accidentally transmitting with no antenna connected; the finals survived!

3) When the 250-Hz super-sharp cw filter I ordered from the F-T Corporation[1] arrived, I didn't want to give up the use of the 500-Hz Yaesu cw filter already installed. So I devised a method of installing both filters and switching between them. To perform this modification,

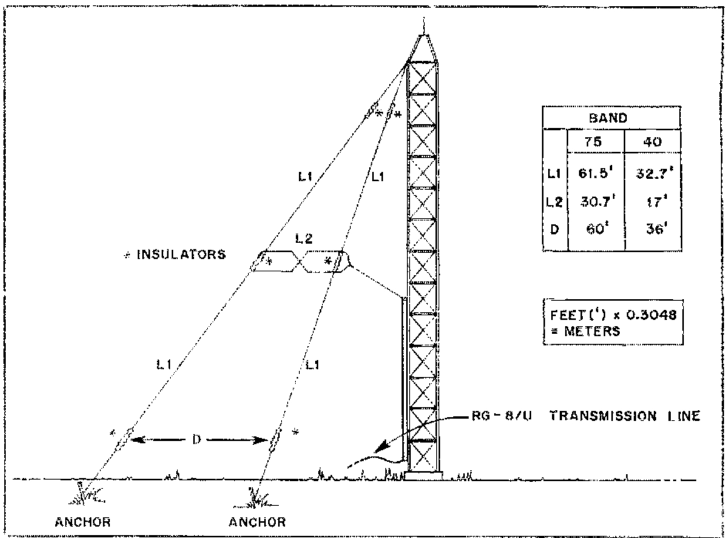
*Assistant Technical Editor, *QST*

cut the wires connected to the MOX-PTT switch and tape them aside (to be reconnected when the rig is sold). Remove the wire connected to pin 15 on the pc-card edge connector of PB-1435, filter board. In my unit, this wire was white with a black tracer. This wire comes from the MODE switch. Pull this wire back through the harness until it breaks out near the MODE switch. Connect it to the center terminal (common) of the spdt MOX-PTT switch. Remove the two white/violet wires connected to pin 14 of PB-1435 and, preserving their connection to each other, tape them aside. Connect a wire from the left MOX-PTT switch terminal to pin 15 of PB-1435. Connect a wire from the right MOX-PTT switch terminal to pin 14 of PB-1435. Install the new 250-Hz cw filter in the space allotted for the a-m filter on PB-1435, filter board. Now 250/500-Hz cw bandwidth switching is done with the front panel MOX-PTT switch! PTT with the microphone switch still functions in the normal manner. The cw carrier oscillator must be tuned precisely to the peak of this sharp filter since the transmitted cw signal passes through it. In cw transmit, apply a slight amount of drive and adjust TC-401 on PB-1436, i-f board, for maximum rf output.

4) My FT-301 had a sluggish VOX relay on cw, which resulted in a missing first dit when using moderate or high keying speeds. I performed an N6JF modification,[2] which speeds up the VOX attack time considerably on cw. A sluggish relay was only part of the problem; a slow-starting 9-MHz oscillator was the real culprit. Before starting, set the DRIVE control for a specific output level, which will be used as a reference for realignment after the modification. On PB-1433, rf board, change C126 to a 10-μF electrolytic capacitor. On PB-1436, i-f board, change C422 to 120 pF and C414 to 47 pF. On the VOX board, change R608 to 10 kΩ if your '301 has PB-1438; if you have PB-1685 change R622 to 10 kΩ. For realignment, peak the rf output through the 250-Hz cw filter with TC401 as in step 3 above. This gets the carrier oscillator back on frequency. If the 250-Hz cw filter is not installed, the correct frequency will have to be determined by other means, such as a frequency counter. Then adjust TC402 for the same output level that was set with the drive control at the start of the modification.

5) While the dynamic range of the receiver in the '301 is acceptable, I noted some overloading and IMD generation with a strong signal present in the receiver passband. The following modification, inspired by *The Radio Amateur's Handbook*,[3] doesn't give the '301 an uncrushable front end, but is extremely easy to implement. Before starting the modification, tune in a signal from the crystal calibrator, peak it with the PRESELECTOR control, and note its S-meter reading. On PB-1433, rf board, install a 10-kΩ resistor from the drain of the mixer, Q103, to ground. A mounting location for this resistor has already been provided by Yaesu! The empty holes are labeled R123, just next to Q103 on the board. The addition of this resistor has decreased the gain of the mixer slightly, so now adjust the i-f gain potentiometer, VR301 on PB-1435, filter board, to return the calibrator signal to its original level on the S meter. — *John C. Pelham, W1JA*

[1]Fox-Tango Corp., P. O. Box 15944, W. Palm Beach, FL 33406.
[2]*The International Fox-Tango Club Newsletter*, June 1979.
[3]ARRL, *The Radio Amateur's Handbook*, 1979 or 1980 ed., p. 4-32.



When Carl Bissonnette, WA1AKR, chases DX he uses a sloper like the one illustrated. Carl's arrangement is fashioned after the famous 8JK beam. The feed system resembles that of the ZL Special.

THE WA1AKR 40- AND 75-METER SLOPERS

Several amateurs have suggested that I submit a description of my sloper antenna system for publication in "Hints and Kinks." Other amateurs may be interested in this adaptation of the 8JK beam. Construction information is shown for both the 75- and 40-meter bands.

As shown in the accompanying diagram, the array has two half-wave sloping elements joined by a 1/8-wave, 300-ohm phasing line. Transposing the phasing line should bring the element currents into phase. I find the antenna is broadbanded. There appears to be no need for a Transmatch.

If one desires to suspend an additional sloper from the tower for a directional change, installation of remote switching at the top of the tower will permit the use of a single transmission line. Otherwise, separate transmission lines will be required.

Ends of the antenna are suspended by ropes with the tops placed roughly 1 foot away from the tower. An angle of 45 degrees between the antenna and ground should be maintained. Do not use an angle greater than 50 degrees. Resonance with the dimensions shown should occur near 3.8 MHz for the 75-meter sloper and 7.150 for the 40-meter antenna.

How well do my antennas work? I have contacted stations "across the pond" while competing with the big boys who sport three and four-element beams. I have also experienced little difficulty in working VKs and ZLs. — *Carl Bissonnette, WA1AKR, Fairhaven, Massachusetts*

CAVITY DUPLEXER CONSTRUCTION NOTES

A few construction notes may help those who might wish to build the duplexer cavities as noted on page 266 of the ARRL *VHF Manual*. When soldering the 0.020-inch stock to the center 1-1/4-inch pipe, I found the best approach is to insert the stock into the pipe without cutting the slits first. A Sears chrome-plated 15/16 socket fits snugly inside the shim stock after being inserted in the 1-1/4-inch pipe. The solder will not adhere to the chrome. This method makes cleaning up the excess solder easier. Slits may be cut after the cleanup by using a pair of aircraft shears which are used upside down. This will curl the finger stock inward and give firm contact to the tuning slug.

For those who are not adept at soldering large joints, the following may be of some help when soldering 4-inch copper pipe to the brass or copper base. This mass of metal makes quite a heatsink and therefore should be heated for at least three or four minutes before attempting to solder. With a brush, wipe Nokorode pretinning paste flux on the area, and then apply a heavy rosin-filled solder for the filler.

Don't be concerned if you find that lumps, bumps or depressions develop as you work around the pipe. Once you have a reasonable amount of solder applied, you can then wipe the joint with a clean dry rag that's been dipped in paste flux. Heat a small section at a time, and when the solder is shiny use the wiping cloth. I suggest that the wiping be done immediately after the initial soldering has taken place, since the assembly should be evenly heated by this time. After wiping the joint, any excess solder that has run over the base can be scraped from the base with a sharp wood chisel. However, leave a 1/4-inch width of solder on the base. A round metal or wood file will take off any excess. The entire joint can then be sanded with an 80-grit paper.

Another note about solder: There are times you may want to insert one pipe into another but do not want the solder to travel too far up the assembly. Take a graphite pencil and draw a wide line around the assembly at the point you want the solder to stop. If the assembly is soldered with the graphite line at the high point, the solder will not flow beyond it. — *Herb Patterson, WA1ZMV, Madison, Connecticut*

Product Review

Conducted By Paul K. Pagel,* N1FB

Azden PCS-2000 2-Meter FM Transceiver

What comes in a small package that can be made even smaller, has 12 push-button controls and a full 25 watts of output power? The Azden PCS-2000, a versatile and well-made 2-meter rig that's designed to satisfy the most demanding fm operator.

You say your subcompact car doesn't have enough knee room for a small bird, much less an underdash radio? The Azden's remote cable option cuts the size down to a miniscule 2-1/2 × 8 × 3-1/2 inches (64 × 203 × 89 mm). Want to call up a favorite repeater (or simplex) frequency without fiddling with the 12 buttons on the control panel? Just hit MI CALL on the microphone. Want to find a vacant frequency? Turn the scan knob to V.

*Assistant Technical Editor, ARRL

The PCS-2000 can do all this, and more. It may take you a week or so to become familiar with its formidable list of features — as well as a few quirks. But once you've mastered them, you'll have a rig that will do just about everything except clear a busy repeater.

What doesn't it do? The list is short. It doesn't stay on frequency in the scan mode, for one thing. That problem is shared by all scanners, of course, but it's a bit annoying to find yourself 30 kHz up from where you thought you were — just as you're about to jump into a QSO. Perhaps someone will design a 3-second delay circuit to keep the rig on frequency until you really wish to move on. Once you've located a "busy" frequency by means of the scan function, you'll have to make it "permanent" by hitting the UP 10K (or DOWN 10K) button — twice. Then you punch the other button (DOWN or UP) to return to the repeater frequency. It's all accomplished in a matter of seconds, but takes some getting used to.

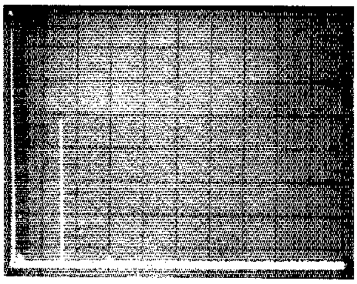
Another difficulty that can be overcome with some practice is the lack of backlighting for the push buttons. Trying to read them while driving at night is no easy task. For the sake of the rest of us on the highways, you may want to memorize the function of each button before attempting to operate at night.

Once you have the hang of it, operating the '2000 is a pleasure. Every control, both on the microphone and the control panel, is designed for ease of access. LEDs indicate frequency [the readout numbers are a full half inch (13 mm) high], signal strength, power output, which of the six memory frequencies is in use, and whether the memory mode is in use. The controls on the standard microphone are well placed — you're not likely to punch the wrong button while driving.

The standard microphone boasts six functions — PTT, call up memory 1, up 10 kHz, down 10 kHz, volume and squelch. It provides enough versatility to keep the user from having to deal with the multitude of switches and keyboard buttons on the control unit while operating mobile. About the only thing you can't do from the microphone is scan.

A brief summary of the steps needed to get the rig going provides an idea of what it can do. (1) Turn on power. (2) Set squelch and select high or low power. (3) Write in a memory frequency (let's say it's to be 146.88) by: pushing the M ADRS (memory address) button until the LED is on the first position; push the combination of MHz UP, 100K UP (or DOWN), and 10K UP (or DOWN) buttons to display 6.880 on the frequency readout; and push M WRITE. The

The Azden PCS-2000 2-meter fm transceiver. While a multitude of functions may be initiated from the front panel, the unit presents a neat and uncluttered appearance.



ARRL lab spectral photograph of the output of the Azden PCS-2000 transceiver. Vertical divisions are 10 dB each; horizontal divisions, 100 MHz. The fundamental frequency at 144 MHz has been attenuated approximately 32 dB by means of a two-cavity notch filter in order to prevent overload distortion in the spectrum analyzer. The second harmonic is down approximately 72 dB. This photograph represents a worst-case test. The PCS-2000 complies with current FCC specifications regarding spectral purity.

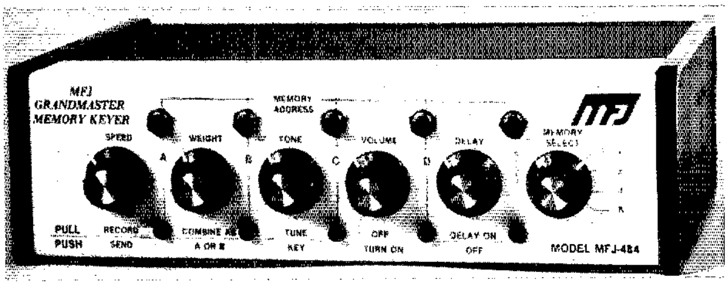
Azden PCS-2000 2-Meter FM Transceiver

Manufacturer's claimed specifications (except where indicated)	*Measured in ARRL lab*
Frequency coverage: 144.000 to 148.995 MHz in 5-kHz steps.	
Power requirements: 13.8 V dc ± 15% at 5.0 A transmit, 0.7 A receive.	
Output power: 25 W (high), 5 W (low).	27 W (high); 7 W (low).
Spurious emission: −60 dB or better.	−72 dB.
Microphone input impedance: 500 ohms, nominal.	
Antenna output impedance: 50 ohms, nominal.	
Sensitivity: 0.28 μV for 20 dB of quieting.	
Selectivity: ± 6 kHz (−6 dB), ± 15 kHz (−60 dB).	
Price class: $300 (without optional accessories).	
Manufacturer: Japan Piezo Company, Ltd., Tokyo, Japan.	
Importer: Amateur-Wholesale Electronics, 8817 S.W. 129th Terr., Miami, FL 33176.	
Dimensions (HWD): 2-1/2 × 8 × 11-1/4 in. (65 × 200 × 285 mm) including cabinet projections.	
Weight: 5.5 lbs (2.5 kg).	

other five memories are stored in a similar manner. (4) Push the ±600 SHIFT button until the LED comes on at the −600 mark. (5) Select internal (control panel) or external (microphone) VOL and SQUELCH. (6) Select preferred type of scan — vacant, busy or free. (7) Hit the PTT switch. (8) To change frequency, push either M SCAN (to scan the six memories you've selected) or one or more of the UP and DOWN buttons.

If it sounds complicated, it is — at least compared with a no-frills 2-meter rig. After looking through the 22-page instruction manual, you'll know all of the '2000's capabilities. If you're not satisfied with all this, you can order several options. Aside from the remote cable kit already mentioned ($30), you can add a Touch-Tone mic kit ($40) a base-station microphone with built-in amplifier, a MARS-CAP kit, ac power supply ($50) and external speaker.

"Convenient" is the most appropriate word for the PCS-2000. In describing the usefulness of the remote cable kit, for example, the manual suggests: "When using this transceive [*sic*] as a fixed station, you can perform QSO in bed while setting the main unit on a desk." What more could you ask from your 2-meter fm rig! — *Joel P. Kleinman, WA1ZUY*



Four memory positions are featured in the MFJ-484 Grandmaster keyer. At the user's option, these four memories can be bridged to accept a 100-character message.

MFJ-484 GRANDMASTER KEYER

It has been interesting to observe MFJ Enterprises, Inc. ascend from a tiny supplier of audio and R-C active filter modules to its present strong position in the amateur equipment manufacturing community. Not only has its product line expanded almost exponentially in the past 10 years, but the complexity of the products and the quality of the workmanship has increased. The '484 Grandmaster memory keyer is an example of Martin F. Jue's (MFJ) efforts to produce a quality line of amateur wares. Dollar for dollar, the '484 keyer seems to offer the cw enthusiast a handful of useful keyer options.

When I opened the keyer cabinet I fully expected to see the Curtis Electro Devices 8044 and 8047 keyer and memory ICs reposing on the circuit board, because the 8044 is used by MFJ and others in various models of keyers. But the interior view disclosed 19 ICs and seven bipolar transistors instead! Indeed, this appeared to be a "busy" circuit board! The packaging and circuit-board layout had that "sanitary" look that many of us appreciate.

MFJ-484 Features

The code speed is variable from 8 to 50 wpm. I was happy to observe that the speed did not "bunch up" over a small part of the adjustment range of the control, a condition which is characteristic of some commercial and homemade keyers.

The weight control, when set for normal operation, establishes a 1:3:1 dit/dah/space ratio. Clockwise rotation of the control initiates progressively more weighting.

There is a built-in sidetone oscillator and monitor speaker in the '484. The sidetone pitch can be adjusted from the front panel of the unit. Similarly, there is a sidetone volume control located on the front panel.

The memory features of the keyer permit the operator to place 25 characters into any of the four memory positions, A, B, C and D. Memories can be combined to provide up to three 50-character messages, or all four memories can be bridged to accommodate a 100-character message. By utilizing the memory-selector switch it is possible to choose between 12 individual 25-character messages. The switch has positions 1, 2, 3 and K. The K position is for combining the four memories when a 100-character message is required. Momentary push-button switches are located on the keyer front panel. They are used for addressing the four memories.

A memory-delay control is provided so that a message can be repeated automatically. The time delay between the repeat of the message is variable from 0 to 2 minutes. Automatic repeating will continue until the paddle is tapped, the reset button pushed or the delay control is deactivated. When the control is set fully counter-clockwise the delay is defeated to permit the message to be repeated instantly.

The RESET switch is used to stop the message. The same effect will be brought about

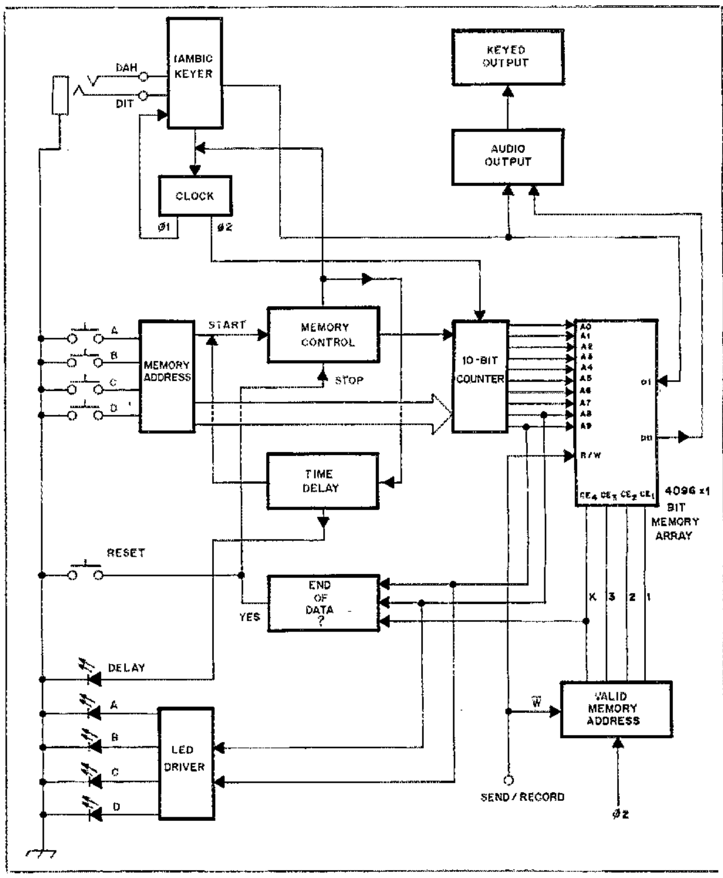


Fig. 1 — Block diagram of the MFJ-484 Grandmaster Memory Keyer.

MFJ-484 Keyer

Claimed Specifications

Size (HWD): 2 × 8 × 6 inches (51 × 203 × 152 mm).
Power requirements: External 12-15 volts dc or 117-volt ac adaptor.
Keying characteristics: Dot and dash memories, adjustable weight control, sidetone and sidetone monitor.
Memory feature: Up to 12 each 25-character messages. Bridge the memories for up to three 50-character messages or combine memories A, B, C and D for 100-character message. Message delay and message-repeat features included. Memory-saver battery provision included also.
Keying modes: Up to −300 volts at 10 mA max., or up to +300 volts at 100 mA max.
Color: Eggshell and brown.
Price class: $140.
Manufacturer: MFJ Enterprises, Inc., Box 494, Mississippi State, MS 39762. Toll free no. is 800-647-1800.

if the paddle is tapped during a transmitted-message period. LED indicators show the state of the memories. They illuminate when the memories are addressed and become extinguished when the memories are full or have been fully utilized during a message period. The LEDs also enable the operator to know which memory is in service. A fifth LED will light during activation of the time-delay feature.

There is provision in the '484 keyer for a memory-saver battery (9 V). If the 117-volt ac service is interrupted, the battery is switched into the circuit automatically. If the keyer sidetone is not used during the power-outage period, the battery will provide approximately three hours of service before it is depleted. Longer periods of operation can be had by connecting an external battery of higher capacity to the battery jack on the rear of the keyer.

The keyer comes with a 117-volt ac adaptor. This unit plugs into the rear of the keyer. It can be connected to the '484 at all times, and can be attached while an external dc supply is connected to the keyer. With this arrangement, the dc supply will take over when the operating voltage from the ac adaptor vanishes: A 12- to 15-volt dc supply is recommended by the manufacturer.

Other Features

A squeeze key or conventional paddle can be used with the MFJ-484, since the circuit permits iambic keying. Grid-block or positive-voltage keying can be accommodated by this keyer. Damage to the keyer will not result if the wrong keying mode is chosen by the operator. The two outputs are protected from this kind of potential damage. A maximum voltage of −300 at 10 mA is the limit for grid-block keying. Direct keying of positive voltage can be done at levels up to +300 volts at 100 mA maximum.

Practical Considerations

I have used the '484 keyer for several weeks on a daily basis at W1FB. Operation took place on 80 through 10 meters at the 1-kW dc input level. End-fed and coaxial-fed antennas were used without rf energy affecting the keyer, the memory circuit or the sidetone operation. It appears to be rf-tight, provided shielded cables are used between the paddle and the keyer, and between the keyer and the transmitter.

The only difficulty experienced with the product occurred when it was first tried: The paddle jack was wired in reverse (dots and dashes reversed). The two appropriate wires on the jack were reversed and all was as it should be! — *Doug DeMaw, W1FB*

HEATH COMPANY MODEL SA-7010 TRI-BAND YAGI

Pictures can, at times, tell more than words. This may be true when describing a hardware item like the Heath SA-7010 4-element tri-band Yagi for 20, 15 and 10 meters. The purchaser is usually interested in two things when buying a beam antenna — performance, and the structural properties of the system. This review contains photographs of the key structural points to be discussed. It should be easy for the reader to form his or her own conclusions after inspecting the close-up views of Heath's new antenna. Performance data are included for those who want to compare our published results with the specifications of other brands and models of similar antennas.

The SA-7010 is advertised as a 4-element antenna. This does not mean that four elements are used during operation on any one band. Rather, there are three elements in service at a given time. The fourth element is a separate reflector for the 10-meter band. The designer included the extra element in order to obtain optimum spacing of the elements during 10-meter operation. A trap type of reflector is used during operation on 15 and 20 meters; the 10-meter reflector is full size, and has no traps.

Structural Details

A view of the assembled and operational SA-7010 is shown at the beginning of this review. It is installed at W1FB on a 50-foot (15-m) Rohn 25 tower. The director is in the foreground. Four traps are used in director, as is the case with the driven element. The rear element has ony two traps. It is the 15- and 20-meter reflector.

Figs. 2 and 3 illustrate the ruggedness of the mounting hardware for the boom-to-element unions (Fig. 2) and the boom-to-mast junction (Fig. 3). The latter consists of rugged aluminum castings which contain groove-type teeth for secure clamping of the boom to the mast.

Dimensions for the assembled antenna are 16 × 34 feet (4.9 × 10.4 meters). The boom is formed by joining two sections of 2-inch (51-mm) OD aluminum tubing. Each of the elements with traps contain graduated-size aluminum tubing [1-1/4, 1-1/8 and 7/16 inch (32, 29 and 11 mm).OD sections] to permit tapering of the elements. This ensures structural soundness while reducing the overall weight of the system. The 10-meter reflector contains sections of 7/8, 5/8 and 7/16 inch (22, 16 and 11 mm) tubing.

A check of the balance point of the assembled beam showed it to be exactly at the mast-to-boom clamping site. This is important in the interest of reduced stress on the mounting hardware. Conductive grease is provided with the kit for use where the tubing sections are joined. This prevents corrosion and subsequent resistive electrical joints.

I was not highly impressed with the element-clamp bolts which are used to lock the

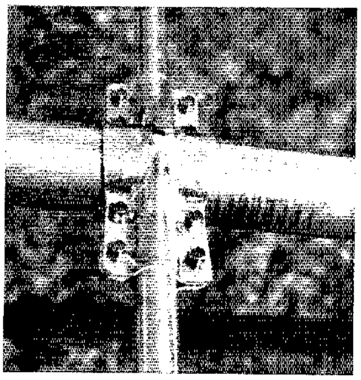
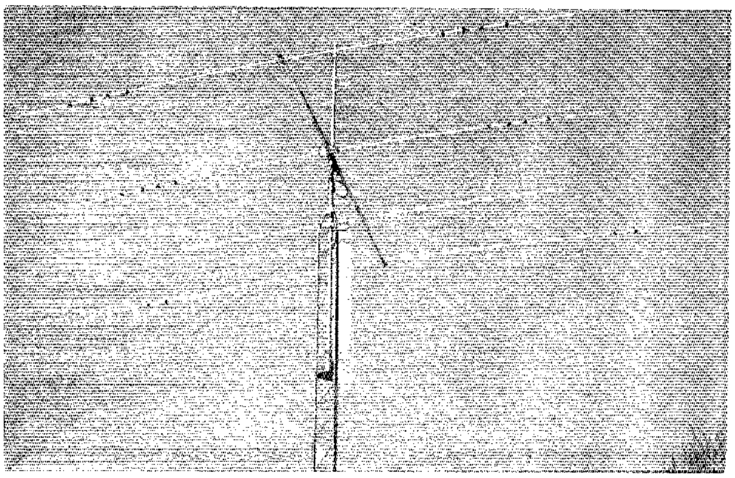


Fig. 2 — Closeup view of the element-to-boom clamps of the triband Yagi.



The Heath SA-7010 tri-band Yagi assembled and operational.

Heath SA-7010 Claimed Specifications

Weight: 40 pounds (18 kg).
Impedance: 50 ohms.
Maximum rf power input: 1 kW.
VSWR (at resonance): Less than 1.5:1. (See Fig. 4 for ARRL lab measurement.)
Turning radius: 17.4 feet (5.3 meters).
Surface area: 5.4 square feet (0.5 square meters)
Maximum wind survival: 80 mi/hr (128.7 km/hr).
Price class: $200.
Manufacturer: Heath Company, Benton Harbor, MI 49022.

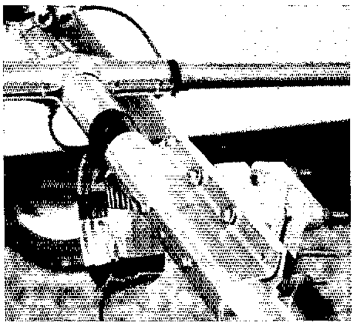


Fig. 3 — A cast-aluminum clamp offers a strong union between the 2-inch OD boom and the mast.

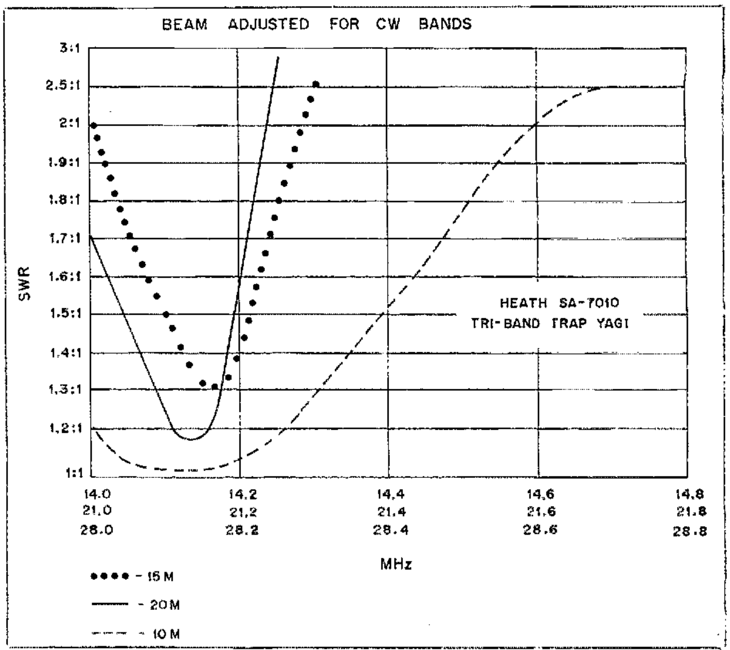


Fig. 4 — SWR curves for the 20-, 15- and 10-meter bands with the elements adjusted for cw operation. Dimensions are those specified in the instruction manual. Tests were performed with the beam at 50 feet on an unguyed tower.

telescoping sections of tubing. They might be considered one of the two weak points in the system; during assembly, two of the clamp bolts broke before the tension was sufficient to lock the tubing sections together. Most of the clamp bolts are bowed somewhat when the torque on them is ample to hold the element sections together. This is complicated by the application of the conductive grease, which allows the tubing sections to slip inside one another unless high torque is applied to the bolts. In fact, a few days after the beam was erected, a bolt snapped on the reflector and down came the end of the element, plus one trap! The practical cure is to replace the kit clamps with stainless-steel hose clamps. Perhaps the manufacturer will consider this as a production change in the future![1]

Electrical Aspects

This antenna can be tuned for the phone or cw portions of the three bands. The bandwidth will not allow full coverage of each band without substantial SWR at one extreme of the frequency spread. The review model was tuned for the cw segments. The resultant SWR curves were obtained with the antenna in place on the tower (Fig. 4). On 15 and 20 meters, the lowest SWR occurs quite high in the cw parts of the bands. In my opinion, it would be much better to provide adjustment dimensions which would allow the SWR to "bottom out" at 14.050 and 21.050 MHz. This is especially important because the highest cw activity is found in the bottom 50 kHz of each band. It can be seen from the curves that the SWR is fairly high in the lower portions of the bands, except on 10

[1]The Heath Company has informed the ARRL lab that new clamps are being tested and will be available in the future.

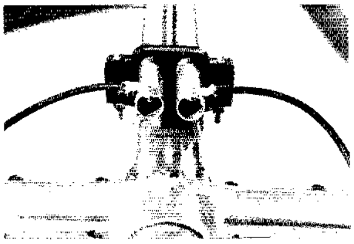


Fig. 5 — This view of the beta-match tubing shows 8-32 nuts and screws holding the driven-element connection wires in place on the matching section (see text).

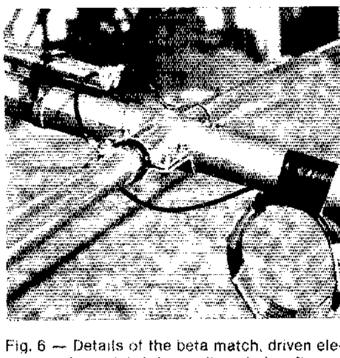


Fig. 6 — Details of the beta match, driven element and coaxial rf decoupling choke after assembly of the beam was completed. Plastic inserts insulate the halves of the driven element from the boom. The beta match provides a dc return for lightning protection.

meters. These curves were obtained after tuning the beam in accordance with the instruction book.

Impedance matching (50 ohms) is accomplished with a beta match. The beta match tubes are mounted "piggy back" style on the boom, as shown in Fig. 5. This is where the second weak spot was observed. The manufacturer supplies two sheet-metal screws for use in attaching the driven element jumpers to the matching section. In order to obtain good tension at this important electrical junction, I replaced the screws with no. 8-32 bolts and nuts. The screw holes in the beta match tubes stripped before there was sufficient tension to hold the jumper wires in place. Noncorrosive weatherproof sealant was added after the bolts were in place.

Fig. 6 shows details of the decoupling choke which is fashioned from RG-58A/U coaxial cable. It contains 11 turns of coax. The ID is 6 inches (150 mm).

Performance

It took eight hours to sort, assemble and adjust the antenna. Installation on the tower required some 30 minutes (courtesy of W1VD). The reviewer is entirely satisfied with the antenna, structurally and electrically, now that the two mechanical weak points have been resolved. It received its first significant test during the ARRL DX Contest early in 1980. Of the first 30 "pileups" encountered, W1FB was acknowledged on the initial try in all but three instances. It took two attempts to break two of the pileups and four tries to nail down the third. (Dc input to the transmitter was 1 kW.) Overall performance is markedly better than with the previous low-cost triband trap Yagi that was on the tower. — *Doug DeMaw, W1FB*

QST

Try a collapsible 2-meter quad

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September 1980 *Volume LXIV Number 9*

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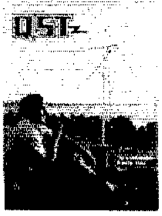
THE COVER



Considering a power increase for portable vhf operation? Try this neat portable quad instead. See page 26. *(photo courtesy WA9GDZ/6)*

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ASCII, Baudot and the Radio Amateur

Use of the ASCII computer code by U.S. amateurs has been permitted since March 17, 1980. ASCII has some similarities to the RTTYer's Baudot code . . . and some differences, too.

By George W. Henry, Jr.,* K9GWT

The 1970s brought a revolution to Amateur Radio RTTY equipment and techniques, the latest being the addition of the ASCII computer code. For the past few months, radio amateurs in the United States have been authorized by the FCC to use the American Standard Code for Information Interchange (ASCII), as well as the older Baudot code for RTTY communications. This paper discusses the differences between the two codes, provides some definitions for RTTY terms and examines the various interfacing standards used with ASCII and Baudot terminals.

RTTY Codes

Newcomers to Amateur Radio RTTY soon discover a whole new set of terms unique to RTTY equipment. Chief among these are the words *mark* and *space*. To be fair, these terms really are not unique to RTTY since they originated with land-line telegraph service before 1900. Nevertheless, current usage associates mark and space with something RTTYers do to or with machines.

The terms *mark* and *space* date from early pen and moving-paper strip recording of telegraph signals. The pen was solenoid operated so that the pen was lowered when the sending key was down, marking the moving strip; key-up time was represented by the blank space between marks. Of course, an operator familiar with the Morse code would then have to read the tape. One tale has it that the strip recording came first in telegraph operations and was used until the operators discovered that they could mentally decipher the code by listening to the rhythm of the mechanical sounder. Some strip-pen telegraph recorders are still to be found in use to this day.

Teleprinter machines also use solenoids (called selector magnets) that open and close in response to a signal current (loop current). Following the convention of telegraph recording, the current-on condition of the signal circuit, or loop, is called the *mark* state of the TTY signal; the current-off condition is called *space*. However, the TTY codes differ from telegraph codes in that variable-length mark or space conditions (dit, dah and spaces between them in telegraph codes) are not used to form the characters. Rather, the TTY codes use equal time-length pulses which can be set to either mark or space. Letters, numbers and symbols are encoded by different combinations of mark or space pulses.

In a teleprinter machine, the normal "rest" condition of the selector-magnet solenoids is with loop current on. Interruption of the loop current releases the selector magnet, allowing rotation of a cam in the machine. Transmission of a TTY character begins with a space pulse (current off), called the *start* pulse. The start pulse signals to the machine that reception of a character has begun. Immediately after the start pulse, a series of *data* pulses are transmitted with mark or space condition as indicated by the encoding for the desired character. The number of data pulses used to represent the letters, numbers and symbols varies with the TTY code being used; Baudot code uses five data pulses, ASCII uses eight. Immediately after the last data pulse, a *stop* pulse is included which is always a mark pulse. The stop pulse, therefore, always occurs in a fixed time after the start pulse (after five data pulses in Baudot and eight in ASCII). The stop pulse gives the machine a "rest time" to prepare for the beginning of the next character, maintaining receive machine synchronization with the transmitted signal. The time length of the start and each data pulse are the same and are often called the unit-pulse or select-pulse time. The stop-pulse length varies from code to code and even with speeds within a code, as will be explained later. In general, the minimum stop-pulse length can be one or two times as long as the unit-pulse time; stop pulses may be as long as desired since the machine is "at rest" until the next start pulse is received. This type of TTY code that uses start, data and stop pulses in the construction of each character is called an asynchronous or start-stop serial code. Other codes also in commercial use include synchronous serial codes, in which start and stop pulses are not attached to the data pulses for each character, and parallel data codes, in which each data pulse is assigned a separate wire to and from the terminal device. Such codes are found in common use with computer and line-printer devices. FCC regulations currently authorize amateurs to use either the Baudot or the ASCII serial asynchronous TTY codes.

The Baudot TTY Code

One of the first data codes used with mechanical printing machines uses a total of five data pulses to represent the alphabet, numerals and symbols. This code is commonly called the Baudot or Murray telegraph code, after the work done by these two pioneers. Although commonly called the Baudot code in the United States, a similar code is usually called the Murray code in other parts of the world and is formally defined as the International Telegraphic Alphabet No. 2 Baudot Code in part 97.69 of the FCC Rules and Regulations. This standard defines the codes for letters, numerals and the slant or fraction bar but allows variations in the choice of code combinations for punctuation. U.S. amateurs have generally adopted a version of the so-called "Military Standard" code arrangement for punctuation, largely because of the ready availability of military surplus machines in the post-1945 years. Amateurs in other countries (particularly in Europe) have standardized on the International Consultive Committee for Telephone and Telegraph (CCITT) No. 2 code arrangement, which is similar to the U.S. standard but has minor symbol and code-arrangement differences.

Since each of the five data pulses can be

*HAL Communications Corp., Box 365, Urbana, IL 61801

in either a mark or space condition (two possible states per pulse), a total of $2 \times 2 \times 2 \times 2 \times 2 = 2^5 = 32$ different code combinations are possible. Since it is necessary to provide transmission of all 26 letters, 10 numerals and punctuation, the 32 code combinations are not sufficient. This problem is solved by using the codes twice; once in the *letters* (LTRS) case and again in the *figures* (FIGS) case. Two special characters, LTRS and FIGS, are used to indicate to the printer whether the following characters will be of the letters or figures case. The printer has a latching mechanism that "remembers" or stores the last received LTRS or FIGS character so that it remains in the last received case until changed. Control operations such as LTRS, FIGS, carriage return (CR), line feed (LF), space bar (SP) and blank (BLNK = no print or carriage movement) are assigned to both the LTRS and FIGS case so that they can be sent in either case. The remaining 26 code combinations have different letter or numeral/symbol meanings, depending upon whether preceded by a LTRS or FIGS character.

Keyboards on Baudot machines such as the Teletype Corp. models 15 and 28 differ from standard typewriter keyboards, having only three rows of keys with the related letter and number/symbol on each keytop (Q and 1, K and (, and so on). The typist soon discovers this difference! Newer electronic terminals such as the HAL DS2000 and DS3100 have standard keyboard arrangements and automatically insert LTRS or FIGS characters as they are needed. The Baudot code itself is restricted to upper-case letters only since insufficient codes are available to represent lower-case letters.

The Baudot code has seen extensive commercial use throughout the world and is still actively utilized for international wire, press and weather communications. Because of the ready availability of Baudot mechanical equipment, this code will continue to be quite popular among radio amateurs. Nevertheless, the lack of code space for control, extended punctuation or lower-case letters is a severe limitation of the five-unit Baudot code. These limitations are particularly inconvenient in computer-terminal applications, even though various serial and parallel data-coding schemes have been used with computers. Fig. 1 shows a time diagram of typical Baudot characters, and Table 1 shows the Baudot data code for both the U.S. and CCITT No. 2 alphabet. Notice that the waveform drawing of Fig. 1 shows the *current* waveform, with mark represented by the upper deflection: If the same data were observed on an RS-232 data line, mark would be represented by a downward or *negative* deflection, but more about RS-232 later. Also, the bits in Fig. 1 are arranged in a left-to-right order, as would be observed on an oscilloscope. The bits in Table 1, however, are arranged in *descending* order (b5 to b1), conforming to the standard binary representation. Thus the letter D shown in Fig. 1 would be written as the binary character 01001.

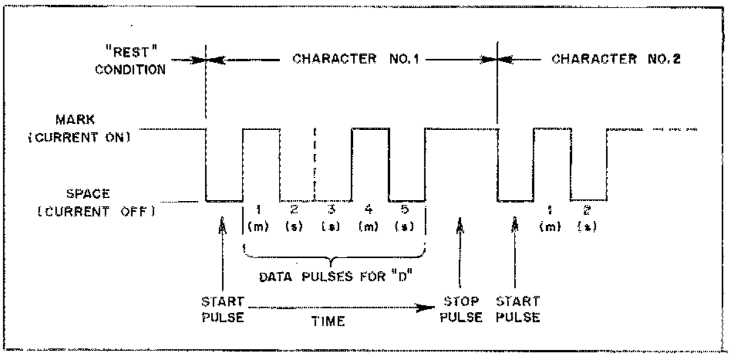

Fig. 1 — Time sequence of a typical Baudot character, the letter D.

ASCII

In 1968, the American National Standards Institute (ANSI) adopted the American National Standard Code for Information Interchange (ASCII), ANSI Standard X3.4-1968. This code uses seven data pulses to specify the letter, number, symbol or control operation desired. An eighth data pulse, called the *parity* bit, is provided for optional error checking. As with the Baudot code, the ASCII standard as approved for U.S. amateur use is asynchronous and serial with both start and stop pulses.

Table 1

The Baudot Data Code

Bit Number 54321	*Letters*	*U.S Figures*	*CCITT No. 2 Figures*
00000	BLANK	BLANK	BLANK
00001	E	3	3
00010	LF	LF	LF
00011	A	—	—
00100	SPACE	SPACE	SPACE
00101	S	BELL	'
00110	I	8	8
00111	U	7	7
01000	CR	CR	CR
01001	D	$	WRU
01010	R	4	4
01011	J	'	BELL
01100	N	,	,
01101	F	!	!
01110	C	:	:
01111	K	(	(
10000	T	5	5
10001	Z	"	+
10010	L	)	)
10011	W	2	2
10100	H	#	£
10101	Y	6	6
10110	P	Ø	Ø
10111	Q	1	1
11000	O	9	9
11001	B	?	?
11010	G	&	&
11011	FIGS	FIGS	FIGS
11100	M	.	.
11101	X	/	/
11110	V	;	=
11111	LTRS	LTRS	LTRS

Note: FIGS-H (10100) may also be used for MOTOR STOP function. "1" = mark = hole in punched tape

Whereas the five-unit Baudot code was arranged by Murray so that the most frequently used letters are represented by the least number of mark holes punched in paper tape, ASCII has been arranged to optimize computer applications. The code has been particularly designed for rapid collation of alphanumeric lists, one data bit difference between upper- and lower-case letters, and isolation of all control operations from printing operations. A time diagram of a typical ASCII character is shown in Fig. 2. Table 2 shows the ASCII data code. As noted for the Baudot-waveform drawing, Fig. 2 shows the loop current with mark represented by the upward deflection; an oscilloscope trace of an RS-232 data circuit would be inverted, with mark as the more negative deflection. Also the bits in Table 2 are arranged in binary number order (b7 to b1). Thus, the letter S in Fig. 2 would be written as the binary number 0101 0011, with the eighth (parity) bit set to space (0), as indicated.

As can be seen from the code table, many more punctuation symbols are included in ASCII than in Baudot. ASCII also includes a large number of control characters designed for print control of the terminal itself, formatting of data to the computer, and control of other hardware devices by the terminal. Although these control functions are defined by the ANSI definition, variations in the use of the control characters abound in the differing commercial applications.

The keyboards of both mechanical and electronic ASCII terminals are arranged similar to the "standard" typewriter keyboard, thus minimizing any retraining required when an operator moves from a typewriter to a terminal. The "extra" ASCII keys are arranged around the periphery of the standard keyset if they are provided at the terminal keyboard.

A common abbreviation of the full 128-character ASCII code restricts the

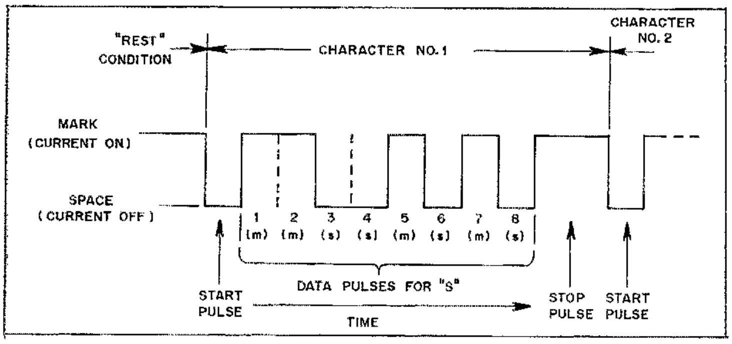

Fig. 2 — Time sequence of a typical ASCII character, the letter s. The eighth or parity bit may be set for any of four conditions: (1) always mark, (2) always space, (3) odd parity or (4) even parity. All four choices are in common usage.

Table 2

The ASCII Data Code

	7	0	0	0	0	1	1	1	1
	6	0	0	1	1	0	0	1	1
	5	0	1	0	1	0	1	0	1
4321									
0000		NUL	DLE	SPC	∅	@	P		p
0001		SOH	DC1	!	1	A	Q	a	q
0010		STX	DC2	"	2	B	R	b	r
00011		ETX	DC3	#	3	C	S	c	s
0 1 0 0		EOT	DC4	$	4	D	T	d	t
0 1 0 1		ENQ	NAK	%	5	E	U	e	u
0 1 1 0		ACK	SYN	&	6	F	V	f	v
0 1 1 1		BEL	ETB	'	7	G	W	g	w
1000		BS	CAN	(	8	H	X	h	x
1001		HT	EM	)	9	I	Y	i	y
1010		LF	SUB	*	:	J	Z	j	z
1011		VT	ESC	+	;	K	[	k	{
1100		FF	FS	,	<	L	\	l	|
1101		CR	GS	–	=	M	]	m	}
1110		SO	RS	.	>	N	^	n	~
1111		SI	US	/	?	0	_	o	DEL

ACK = acknowledge
BEL = signal bell
BS = backspace (←)
CAN = cancel
CR = carriage return
DC1 = device control 1
DC2 = device control 2
DC3 = device control 3
DC4 = device control 4
DEL = (delete)
DLE = data link escape
ENQ = enquiry (WRU)
EM = end of medium
EOT = end of trans.
ESC = escape
ETB = end of block
ETX = end of text
FF = form feed (home)
FS = file separator
GS = group separator
HT = horizontal tab (→)
LF = line feed (↓)
NAK = not acknowledge
NUL = null
RS = record separator
SI = shift in
SO = shift out
SOH = start of heading
SPC = space
STX = start of text
SUB = substitute
SYN = synchronous idle
US = unit separator
VT = vertical tab (↑)

Note: "1" = mark = hole in punched tape

alphabetic letters to upper-case only, often called CAPS-LOCK or CAPLK. In general, these terminals transmit the upper-case ASCII code for a letter whether the SHIFT key is used or not; they may or may not be capable of transmitting all of the control codes. These terminals usually print (or display) the upper-case letter when either the upper- or lower-case letter ASCII code is received. The Teletype model 33 is an example of a popular upper-case-only ASCII terminal. Other terminals, such as the Teletype model 43 or the HAL DS3100 ASR, have user-selectable upper/lower case or upper-case-only (CAPSLK) transmit/receive features.

W1AW ASCII Bulletins

W1AW now runs ASCII bulletins 26 times each week. Following each regular RTTY transmission, the bulletins are repeated on ASCII. The W1AW schedule is in "Operating News," in April and October *QST*, and a copy is available from Hq. for an s.a.s.e. The ASCII transmissions are at 110 baud with 170-Hz shift. The eighth bit, parity, is always sent as a space and is followed by two stop bits.

The optional eighth data bit may be set to four conditions: (1) always mark, (2) always space, (3) odd parity, or (4) even parity. All four choices are in common usage. Simple non error-detecting terminals usually set the eighth bit to be always a mark or space (usually space). Parity is sometimes used with computer and data interconnections where error-detection is desired. When used, the parity bit is controlled so as to set the total number of mark data bits in the ASCII character to be always even or odd (even or odd parity). For example, if odd parity is used with the ASCII character C (first seven bits = 100 0011), the eighth parity bit will be set to space to give an odd number (3) of data bits (0100 0011). Conversely, the odd-parity eight-bit code for the letter B would be 1100 0010. (Logic convention has it that lowest order bits are placed to the right; thus the bit order in the binary representation is 8765 4321.) Upon reception, the receiving terminal simply counts the number of mark pulses in each ASCII 8-bit character. If an odd number is counted, it is *assumed* that no errors occurred. Notice, however, that even if a bit error is detected, there is insufficient data to determine which bit was wrong, and therefore no error *correction* is provided by the parity check itself. Also, if there are two bit errors in the same ASCII character, the parity count will still be odd, and no error indication is given even though two errors occurred. Thus, parity checking will not give complete error detection and does not provide for error correction. Some applications require more sophisticated error detection and correction schemes. Even parity works in a similar manner, except that the eighth bit is chosen to make the total number of mark pulses even rather than odd. The U.S. amateur regulations do not specify a requirement for use of the eighth data bit; it may be set to mark, space, odd or even parity, depending upon the preference of the operator and the capability of his equipment. Relatively simple terminals do not provide parity options; more sophisticated equipment such as the DS3100 ASR do.

Speeds and Baud Rates

The transmission rate of Baudot TTY signals is usually specified in words per minute, much like that used for telegraph codes. Actually, the speed is given in the *approximate* number of five-letter-plus-space combinations transmitted in a *continuous sequence* of start-stop characters in a one-minute interval. Convenient choices of gear ratios and motor-shaft speeds have resulted in the use of noninteger wpm rates. Common usage, however has rounded the exact speeds to easily remembered numbers. Thus, "60 speed" Baudot is actually sent at 61.33 wpm and "75 speed" is really 76.67 wpm.

A major problem occurs with the use of

words per minute as a TTY speed specification because of the varying length of stop pulses in use. For example, "60 speed" Baudot TTY has 22-ms-long start and data pulses and a 31-ms stop pulse; the Western Union "65 speed" also has 22-ms start and data pulses, but the stop pulse is also 22-ms long; electronic terminals commonly use 22-ms start and data pulses and 33-ms stop pulses (1.5 times the data-pulse width). All of these three codes are compatible and may be received on the same printer or terminal since the stop-pulse length is a *minimum* time. The common factor between these codes is the 22-ms length of the data, or unit pulse. Therefore, a new data-rate specification has been adopted, the *baud* rate, which is the reciprocal of the data- or unit- or select-pulse width:

Baud rate = 1/t, where t = length of unit pulse.

Using this definition, all three of the above codes have a data rate of 45.45 baud, commonly abbreviated to "45 baud."

As noted above, the length of the stop pulse varies between codes, being from 1.0 to 2.0 times as long as the unit (or data) pulse; multipliers of 1.0, 1.42, and 1.5 are commonly used with the Baudot codes. Standard Baudot data rates and speeds are shown in Table 3.

U.S. amateurs are authorized to use all of the Baudot data rates shown in Table 3, with the exception of 100 baud. This rate has seen limited commercial use in Europe. The 45-baud data rate is by far the most popular worldwide amateur data rate. A limited amount of amateur use of 74 baud ("100 speed") has been noted on the high-frequency bands. Most commercial RTTY transmissions on high frequencies use 50, 57 and 74 baud, with little 45-baud activity.

ASCII data rates are commonly specified as a baud rate, although a character-per-second (cps) or words-per-minute (wpm) rate may also be given. The lowest standard ASCII data rate in common usage is 110 baud. ASCII characters sent at 110 baud are usually sent with a 2-unit-wide stop pulse, although the 1-unit stop pulse may also be found in some applications. Above 110 baud, it is common to make the stop pulse one unit pulse in length. The standard ASCII data rates commonly used with asynchronous serial transmission are shown in Table 4.

The ASCII data rates up to 300 baud are authorized for U.S. amateur use on frequencies between 3.500 and 21.250 MHz. Data rates up to 1200 baud are permitted between 28 and 225 MHz; up to 19,600 baud may be used above 420 MHz. The 110-baud rate is by far the most practical for 3.5 to 21.5 MHz use, again because of the ready availability of equipment as well as the increased susceptibility of the higher data rates to noise, static, interference and so forth. Vhf fm amateur activity finds 110 and 300 baud useful for terminal-to-terminal communications, and 300 and 1200 baud for computer-related activities such as exchanging programs and the like. The very high data rates (1800, 2400, 4800 and 9600 baud) really find their best application in high-speed computer-terminal data links. The 150 and 600 baud rates are recognized ANSI and Electronic Industries Association (EIA) standards, but have seen limited use to date. Some home-computer systems are also using 250, 500 and 1100 baud for cassette interfaces, not necessarily with ASCII encoding of the data. The FCC regulations (Part 97.69) specify *maximum* baud rates for each frequency range, but do not require use of the standard rates. Therefore, nonstandard baud rates may be used with ASCII encoding, but this may not be practical for lack of compatibility with existing terminal equipment.

Loop Circuits

The first commercial applications of teleprinter machines used direct-wire telegraph connections between machines. A simple series circuit was used to connect the two machines and a dc power supply. This simple loop circuit is shown in Fig. 3. This connection is also called a neutral-loop circuit.

As discussed earlier, the printing mechanisms use solenoids or selector magnets to sense the presence (mark) or absence (space) of the loop current. The letters typed on the sending keyboard are encoded with proper mark and space pulses by mechanically driven keyboard contacts. Since the keyboards and selector magnets of both machines are series connected, text typed on one keyboard is reproduced on both printers. Connection of the keyboard directly to its associated printer is called a local loop and results in what is called half duplex (HDX), giving local copy of transmitted text, termed local echo. The two machines could be connected with two separate circuits so that keyboard no. 1 is connected through a loop supply and wire to the selector magnets of printer no. 2; keyboard no. 2 is then connected to printer no. 1 with a second loop circuit. This type of connection is called full duplex (FDX). Note that the full-duplex connection uses two signal, or loop, circuits and does not provide local reproduction or echo of transmitted text. Most Amateur Radio connection of teleprinters is in the half-duplex configuration. The full-duplex connection is commonly used with computer terminals. The computer itself may then supply a reproduction of the transmitted text to the printer, but in this case the remote or computer-generated echo provides confirmation that typed text has been properly processed in the computer.

The battery or dc loop supply in Fig. 3 is used to maintain the current in the selector magnets during mark pulses. The actual current in the loop is adjusted with the series loop resistor. Selector magnets

Table 3

Baudot Data Rates and Speeds

Baud Rate	*Data Pulse (ms)*	*Stop Pulse (ms)*	*WPM*	*Common Name*
45.45	22.0	22.0	65.00	Western Union
	22.0	31.0	61.33	"60 speed"
	22.0	33.0	60.61	45 baud
50.00	20.0	30.0	66.67	European; 50 baud
56.92	17.57	25.00	76.68	"75 speed"
	17.57	26.36	75.89	57 baud
74.20	13.47	19.18	100.00	"100 speed"
	13.47	20.21	98.98	74 baud
100.0	10.00	15.00	133.33	100 baud

Table 4

ASCII Data Rates

Baud Rate	*Data Pulse (ms)*	*Stop Pulse (ms)*	*CPS*	*WPM*
110	9.091	9.091	11.0	110
	9.091	18.182	10.0	100
150	6.667	6.667	15.0	150
300	3.333	3.333	30.0	300
600	1.667	1.667	60.0	600
1200	0.8333	0.8333	120	1200
1800	0.5556	0.5556	180	1800
2400	0.4167	0.4167	240	2400
4800	0.2083	0.2083	480	4800
9600	0.1041	0.1041	960	9600
19200	0.0520	0.0520	1920	19200

$$\text{CPS} = \text{characters per second} = \frac{1}{\text{START} + 8\,(\text{DATA}) + \text{STOP}}$$

$$\text{WPM} = \text{words per minute} = \frac{\text{CPS}}{6} \times 60$$

= number of 5-letter-plus-space groups per minute.

have been designed for mark loop currents of 60 or 20 mA dc, with 60 mA being by far the most common for older machines such as the Teletype Corp. model 15 or 28. Newer Baudot machines and most ASCII machines and terminals use electronic interface circuits that accept a wide range of loop currents (10 to 120 mA for the HAL DS3100, for example); a 20-mA loop current is quite commonly used with ASCII terminals.

Since the dc resistance of the machine selector magnets is rather low (100 to 300 ohms, typically), it would at first seem that a low-voltage loop supply could be used. However, the inductance of the magnet is usually quite high (on the order of 4 henrys for a model 15), causing a delay in the current rise time. This, in turn, delays the selector magnet response to a mark pulse, distorting the signal. This distortion can be severe enough to cause misprinting of received text, particularly if other forms of distortion are present (such as caused by variations in the radio signal). The effect of this inductive distortion is reduced considerably if the L/R ratio (L is solenoid inductance and R is total loop resistance) is reduced by increasing R. Increasing R requires that the dc voltage be increased to maintain the required 60-mA loop current. In general, the higher the loop voltage and loop resistance used, the lower the distortion. In practice, loop power-supply voltages between 100 and 300 Vdc are common; 130- and 260-volt supplies were often used with model 15, 19 and 28 Teletype machines. Modern TTY systems use a 150- to 200-volt loop power supply and a 2000- to 3000-ohm loop resistance to set the 60-mA loop current. Because of the related keying circuitry, the demodulator unit of a good RTTY system usually includes the loop power supply and current-limiting resistor.

The simple circuit of Fig. 3 has proved impractical for long-distance wire use because of the inclusion of ground resistance in the loop circuit; variations in ground resistance from rain, terrain and so forth, cause variations in loop current and therefore in machine performance. Two telegraph wires could be used to provide a totally wire circuit, but at the expense of twice as many telegraph wires per signal circuit. Another approach commonly used in telegraph circuits involves reversing the current flow in the loop between mark and space pulses. Thus, in an east-west circuit, current flowing to the west might represent mark and current flow to the east would represent space. Current polarity-sensing devices, called polar relays, are then used to sense the direction of current flow. The polar relays then key local loops to operate the machines at each end. This considerably complicates the connections at both ends and requires local-loop supplies at each station as well as supplies to generate the

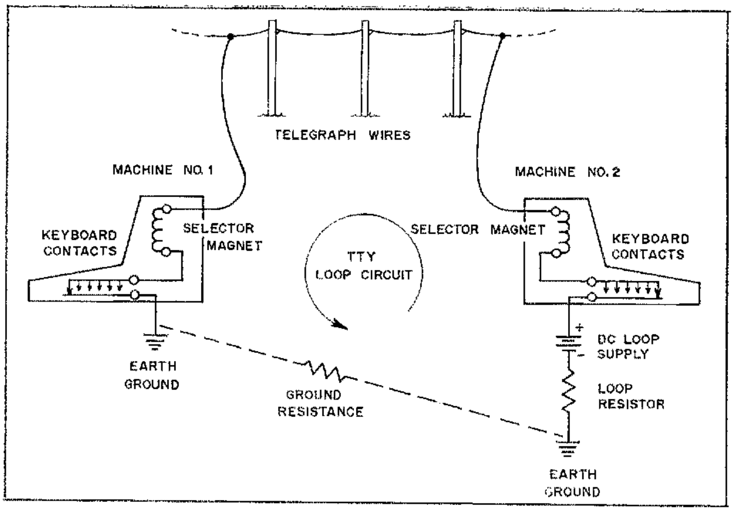

Fig. 3 — A simple teleprinter loop circuit. Current flow represents the mark condition. Open keyboard contacts at either machine result in no current, representing the space condition. Current, when it flows, travels in one direction only. A connection such as this is called a neutral-loop circuit (as opposed to a polar-loop circuit in which current flows continually, reversing direction for mark and space conditions).

two polarities of signal current. Properly adjusted polar relays are very sensitive and can give excellent low-distortion operation. Fortunately, amateur RTTY operations do not need the polar relay, and such devices are best removed from surplus printers when they are encountered; the rf hash generated in a polar relay can be considerable!

Virtually all of the commonly available Baudot machines can be used with 60 to 20 mA high-voltage loop circuits. Therefore, to maintain compatibility with this existing equipment, use of the high-voltage current-loop interface is strongly recommended, even if electronic terminals are also used. Well-designed Baudot electronic terminals will include a high-voltage loop interface circuit.

On the other hand, the newer ASCII machines (such as the Teletype Corp. models 33, 35 and 43) are available with a wide variety of input/output (I/O) interfaces. These devices usually include a high-current, low-voltage selector-magnet assembly (500 mA, 10 to 30 volts is typical), an internal magnet-driver transistor and power supply, and an electronic interface to the data connections. These machines may be supplied with a 20-mA loop-interface circuit (or RS-232, TTL or other interface standards).

RS-232 Data Interface

The EIA has defined a new standard for interconnection of terminals, modems and computers in *EIA Standard RS-232-C* (August 1969). This interface standard specifies *voltage* levels for mark and space, rather than the current levels used in a loop circuit. The basic RS-232-C voltage ranges are shown in Fig. 4.

Note that mark, normally considered to be a logic 1, is represeted by a negative voltage and the logic 0 by a positive voltage. Thus, the RS-232 interface standard can be thought of as a polar voltage standard. Also, note that RS-232 voltage levels really are *not* transistor-transistor logic (TTL) compatible (in spite of some claims you may read to the contrary)! Users should carefully examine "psuedo RS-232-compatible" equipment to make sure no damage will be caused to their RS-232-interfaced equipment. The RS-232-C standard also includes definition of con-

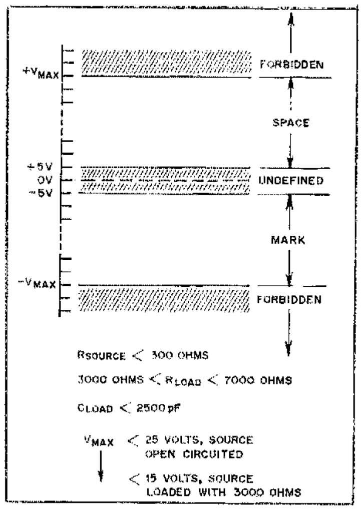

Fig. 4 — RS-232-C voltage standards. Note that these voltages are *not* compatible with TTL integrated circuits.

Table 5

RS-232-C Interface Connector

Pin Number	*Circuit*	*Description*	*Abbreviation*
1	AA	Protective Ground	PG
2	BA	Transmitted Data	TXD
3	BB	Received Data	RXD
4	CA	Request to Send	RTS
5	CB	Clear to Send	CTS
6	CC	Data Set Ready	DSR
7	AB	Signal Ground (Common Return)	SG
8	CF	Received Line Signal Detector	CD
9	—	Reserved for data set testing	
10	—	Reserved for data set testing	
11	—	Unassigned	
12	SCF	Secondary Received Line Sig. Detc.	
13	SCB	Secondary Clear to Send	
14	SBA	Secondary Transmit Data	
15	DB	Transmit Signal Clock	TXC
16	SBB	Secondary Received Data	
17	DD	Receive Signal Clock	RXC
18	—	Unassigned	
19	SCA	Secondary Request to Send	
20	CD	Data Terminal Ready	DTR
21	CG	Signal Quality Indicator	
22	CE	Ring Indicator	RI
23	CH/CI	Data Rate Selector (DTE/DCE Source)	
24	DA	Transmit Signal Clock to Modem	
25	—	Unassigned	

Use of a 25-pin connector is assumed but not defined in the RS-232-C standard. Commercial usage has seen the adoption of the TRW-Cinch D-Subminiature connector series (DB25P and DB25S), also manufactured by many other firms (Amphenol 17-10250 and 17-20250, for example). In general, the male pin connector (DB25P or 17-20250) is installed on the data terminal, but other arrangements may be found on some equipment.

trol signals to pass between originating and receiving devices, and even defines the connector-pin assignment. The RS-232 connector signal and pin assignments are shown in Table 5.

The control signals such as DATA TERMINAL READY (DTR), REQUEST TO SEND (RTS), and so forth, are often called *handshaking* signals; they provide status indicators between data devices (terminal to and from a modulator/demodulator or modem, for example). All control-signal voltage and impedance levels also conform to the RS-232-C standard shown in Fig. 4. Control signals are considered to be active or on when the voltage is positive; a negative-voltage control signal is off or inactive. The terms "mark" and "space" are usually not used when describing RS-232 control signals. Thus a positive voltage on pin 5 (CB = CLEAR TO SEND) is the terminal's signal to the data circuit that the terminal is ready to receive data. Also, an open-circuit or no-voltage condition on an RS-232 signal is interpreted as a "mark" or "active" condition.

Other Data-Connection Standards

A number of other data-connection standards may be found in use in commercial equipment. Chief among these is an interface that is compatible with the popular TTL integrated circuits, a TTL-compatible interface. TTL interconnections are particularly useful when directly interfacing computers or other digital devices. Although TTL and RS-232 interface standards are not directly compatible, a number of line-receiver and line-driver integrated circuits are available.

A common data standard used in U.S. military applications is the MIL-188 Data Standard. MIL-188 is very similar to the RS-232 standard, with the exception that logic voltages are inverted — mark is represented by positive voltages and space by negative voltages.

Other data interfaces are to be found for CMOS logic integrated-circuit connections. Interfaces for both +5-volt and +12-volt CMOS operation are in use. QST

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EIA Standard RS-269-B Synchronous Signaling Rates for Data Transmission

EIA Standard RS-363 Standard for Specifying Signal Quality for Transmitting and Receiving Data Processing Terminal Equipments Using Serial Data Transmission at the Interface with Non-Synchronous Data Communication Equipment

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Strays

QST congratulates . . .

☐ David H. Houghton, who reached his 80th birthday on August 31. Dave worked longer at League headquarters (54 years!) than any other person. He came to Hq. in 1922 and for 43 years was *QST*'s Circulation Manager. From 1941 to 1976, Dave was the Treasurer of the ARRL.

☐ Chip Margelli, K7JA, who has been named assistant vice president and sales manager for Amateur Radio at Yaesu Electronics.

SUNSPOT NUMBER INFORMATION

☐ Sunspot number information has been compiled and disseminated by the Swiss for many years. The program is expected to end this year. If this happens, similar information will be made available by the American Association of Variable Star Observers (AAVSO).

The AAVSO has been a major contributor to the Zurich program since 1974, operating with encouragement, technical advice and financial assistance from the National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado. The American effort is under the direction of Casper H. Hosfield, KA2DKD, Mahwah, New Jersey, chairman of the Solar Division of AAVSO. — *Ed Tilton, W1HDQ*

HAMS HELP "TALL SHIPS"

☐ Virginia Beach, Virginia, area hams recently helped pass position reports for ships during a sailing-ship race. The "tall ships" departed Cartegena, Colombia in early May, with intermediate stops in Norfolk and Boston, and arrived in Kristiansand, Norway, in late June. U.S. amateurs in New England, Florida and Texas also participated in the project. — *Gay E. Milius, Jr., W4UG, Virginia Beach, Virginia*

A High-Performance Synthesized 2-Meter Transmitter

Give spurs the boot! An on-frequency VCO is featured in this well-heeled 12-watt transmitter.

By Albert Helfrick,* K2BLA

This 2-meter transmitter is the culmination of a two-year study to produce a synthesized fm transmitter that does not suffer from any of the ills that plague much of the synthesized 2-meter equipment currently being used. Two requirements were stipulated: First, the entire 2-meter band should be capable of being covered with 5-kHz channel spacing throughout; second, there should be no audible reference whine or microphonics.

In the design of vhf phase-locked synthesizers, it is not difficult to achieve any one of these requirements. In some designs, however, it is very difficult, if not impossible, to achieve *all* of the requirements *simultaneously,* while observing other, almost obvious, requirements such as reasonable cost, size and parts availability. Several synthesizer types were built for the transmitter: two mixing and multiplying types using LSI synthesizer chips, one employing direct synthesis using a 5-kHz reference and, finally, a direct or on-frequency synthesizer using a 10-kHz reference.

An ON-OFF switch and the frequency-selector switches are the only controls mounted on the front panel of the synthesized 2-meter transmitter. A microphone connector and accessory plug are located on the rear panel.

Circuit Description

Several features of this transmitter are unique. First, the VCO in the synthesizer operates at the same frequency as the transmitter output stage. That implies that there are no mixers or multipliers to produce spurious outputs, which greatly simplifies the tuning of the power amplifiers. The entire 2-meter band can be covered without any significant spurious outputs.

*RD 1, Box 87, Boonton, NJ 07005

A dual-modulus (or "pulse-swallowing") divider is a type of programmable divider which allows very high frequencies to be divided by any integer with the use of only one high-frequency integrated circuit. The heart of the circuit, shown in Fig. 1, is U6, a dual-modulus, divide-by-10/11 ECL integrated circuit. The output of this chip drives two presettable TTL down-counters, called the main counter and the swallow counter. Both counters are preset at the same time, and each is clocked down simultaneously with the output of the prescaler. The swallow counter necessarily has a smaller number preset than the main counter, and thus reaches zero before the main counter does. Upon reaching zero, the swallow counter switches the mode of the ECL prescaler from divide-by-11 to divide-by-10 operation, and the main counter continues toward zero. When the main counter reaches zero, both counters are preset to their respective numbers and the process begins again.

If M is the number preset into the main counter and N is the number preset into the swallow counter, the total number of input cycles to the ECL prescaler is

$$P = 11N + (M - N)10$$
$$= 10M + N$$

The output frequency of a properly locked phase-locked loop is the reference frequency times the programmable divider ratio, or in this case

$$F_{out} = (10\ kHz)(10M + N)$$

The values of both M and N are selectable; that is, N goes from zero to nine and is selected by the tens-of-kHz switch, while M goes from 1440 to 1479 and is selected from the MHz and hundreds-of-kHz switches. The two most significant digits of the number M (i.e., 14) are permanently wired into the counter and are not selectable.

The Loop Reference Frequency

A second unique feature is the use of a 10-kHz loop reference frequency even though the channel spacing is 5 kHz. There are several ways of keeping all traces of the reference frequency out of the transmitter output, one of these being the use of a carefully designed and implemented loop filter. A filter of this sort must not degrade the lockup time, capture range, lock range or loop stability. If the high-frequency capability of the loop is reduced too much, excessive noise and microphonics can become a problem. The use of a higher loop-reference frequency allows a wider loop bandwidth with the same level of reference sidebands. Quite simply, the higher the reference frequency, the better.

Normally, if a 10-kHz reference frequency were used with a phase-locked loop, only frequences that were exact multiples of 10 kHz could be generated, which would not be acceptable for 2-meter fm operation. The method of obtaining 5-kHz resolution while using a 10-kHz reference is called "reference pulling." See Fig. 2. This "pulling" involves shifting the 10-kHz reference frequency very slightly so that the 144-MHz output frequency moves up by about 5 kHz. This technique does not produce an exact 5-kHz shift on all channels, with the greatest error being at the band edges. If the frequency shift were set at exactly 5 kHz at the center of the band, however, the error at the band edges would be 40 Hz, hardly enough to cause problems with even the fussiest repeaters.

The VCO

The last and most important feature of this transmitter is the low-microphonic VCO, Fig. 3. Designing a phase-locked loop that is to be modulated for fm use is a very difficult task. Changing the

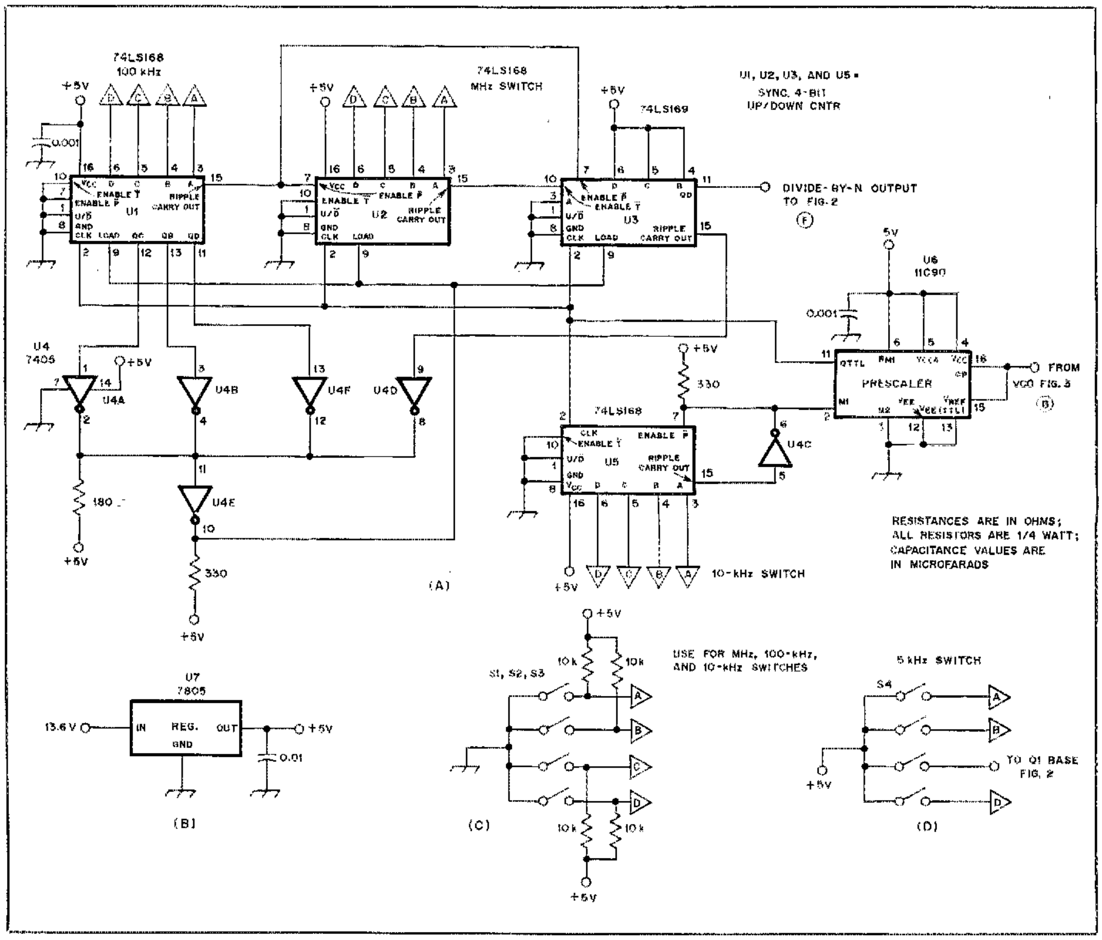


Fig. 1 — The programmable divider chain. S1 through S4, inclusive, are BCD-encoded switches. A toggle switch may be used at S4 if desired.

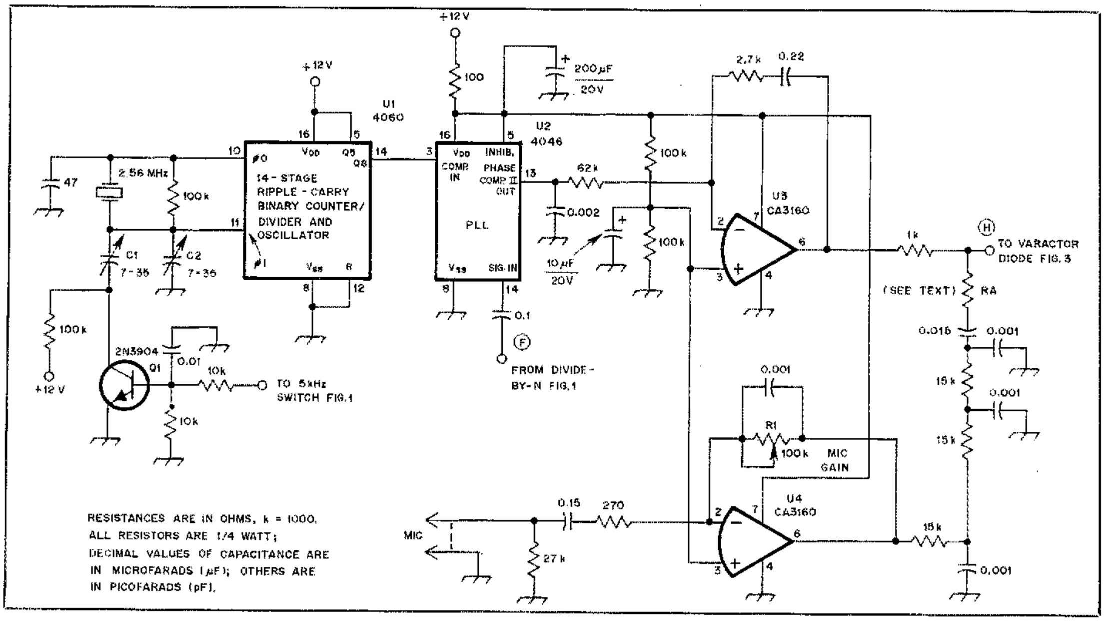


Fig. 2 — Shown here are the reference oscillator and phase detector. Q1 is used to "pull" the reference frequency, permitting approximately 5-kHz shifting on all channels.

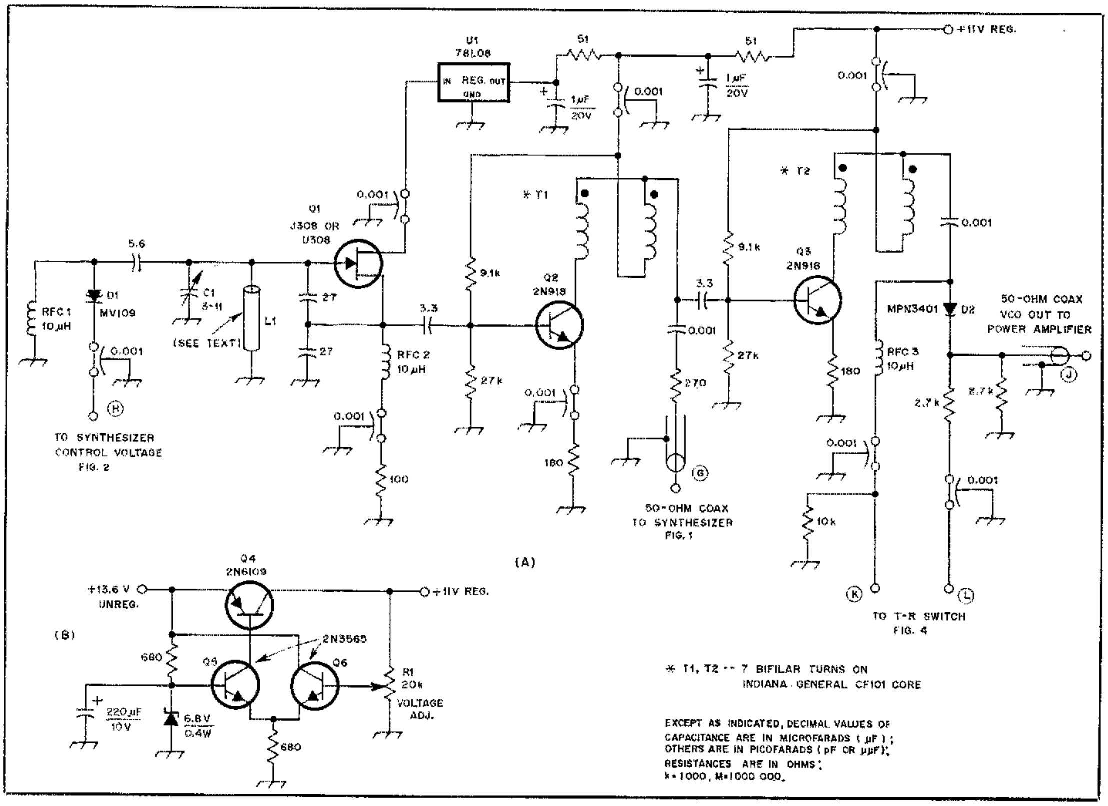


Fig. 3 — The VCO and associated buffers are shown at A, while the 11-volt regulator circuit may be seen at B; it was included to reduce the possibility of undesired "alternator whine" modulation.

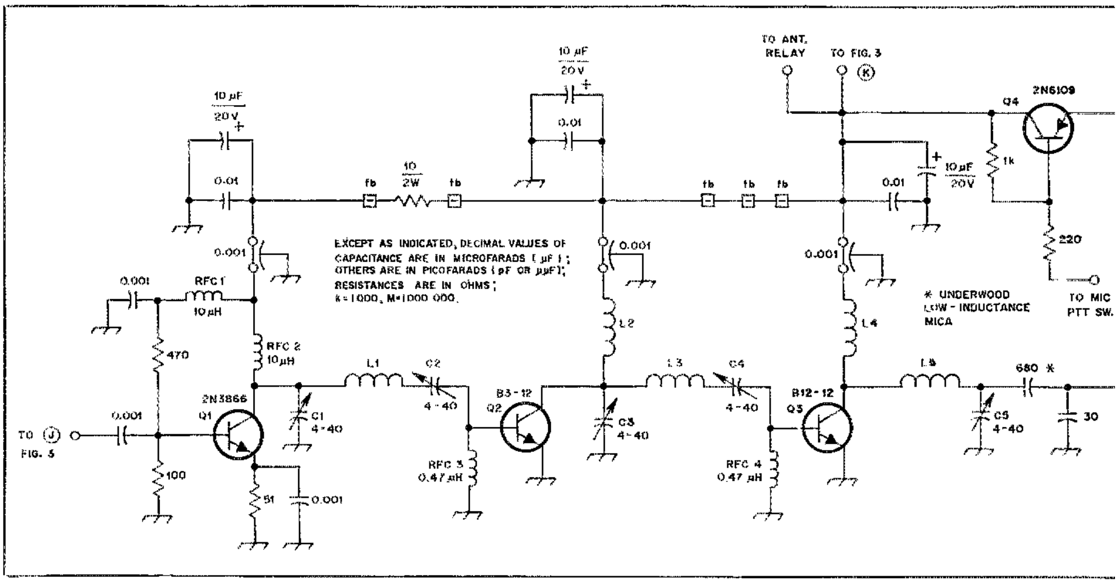


Fig. 4 — This diagram shows the amplifier stages. C1 through C5 are mica compression trimmers. The ferrite beads may be any of the commonly

frequency of the VCO to provide modulation is exactly what the phase-locked loop is supposed to prevent — i.e., any change in frequency caused by noise, microphonics or other disturbances. It is necessary to restrict the capabilities of the loop so that it will not cancel any attempt to modulate the VCO. This implies that any modulation introduced from other sources, such as noise within the VCO circuit, from external sources or microphonics, will not be appreciably removed by the loop, either. Therefore, the VCO must be constructed to have a low level of microphonics and phase noise, and be free of modulation from noise on the power-supply lines.

To accomplish these objectives, the VCO is constructed rigidly and mounted in a cast-aluminum box. The oscillator has a small amount of inductance and a large amount of capacitance, which reduces the effect of stray capacitance from surrounding objects. The inductor itself is a small piece of coaxial cable (details appear later). The cable is totally shielded from its environment and is not affected by nearby components, as would be its wire-wound counterpart. Last, sufficient power-line filtering and a separate voltage regulator are provided for the oscillator.

Construction

Fig. 4 is the diagram for the amplifier stages. The entire transmitter is mounted inside a 7-1/2 × 6 × 3-in. (190 × 150 × 76-mm) aluminum box. Only an ON-OFF switch, pilot lamp and the frequency-selector switches are mounted on the front panel. Connections to the microphone and external equipment (such as a receiver and antenna changeover relay) are made at the rear of the enclosure.

The VCO, two buffer amplifiers, PIN diode switch, and the voltage regulator are all mounted in a 1-1/2 × 2- × 4-in. (38- × 50- × 100-mm) cast-aluminum box. Since the synthesizer operates continuously, a PIN diode switch is employed to prevent energy from leaking through the power amplifier and being radiated by the antenna. There is also a potential for interference with the companion receiver when operating simplex. During repeater operation, the receiver frequency is different from the transmitter frequency, so that the low-level leakage will not be a problem. An optional offset circuit may be added (as shown in Fig. 5) to eliminate any potential interference during simplex operation. This circuit causes the synthesizer to be shifted up or down 5 kHz between transmit and receive modes. If the operating frequency ends with the digit 5, the frequency is shifted down during periods of receive, and shifted up 5 kHz if the operating frequency ends with a zero. If the receiver filter is broad, the 5-kHz shift may not be sufficient. In this case, the same circuit may be applied to the one bit of the tens-of-kHz switch instead. This will cause a 10-kHz shift to occur.

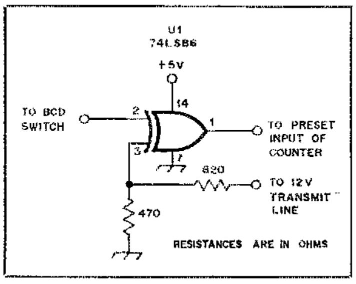


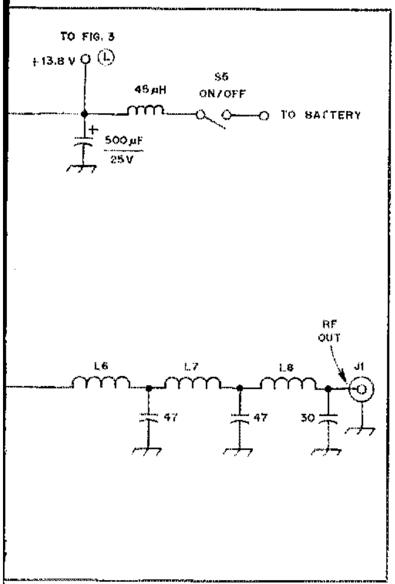
Fig. 5 — An optional transmit/receive frequency-offset-shifting circuit. This circuit will eliminate potential interference from the transmitter when operating simplex with a companion receiver.

The VCO Inductor

The coaxial cable used for the VCO inductor is a piece of miniature, semi-rigid, 50-ohm cable with a tetrafluoroetheleyne (TFE) dielectric. This cable is extremely expensive and difficult to locate. The cost is not hard to bear since so little of the cable is used. If semi-rigid cable of any sort is not available, a piece of miniature, flexible cable may be substituted with a slight increase in microphonics; types which may be employed are RG-188/U or RG-143/U. A larger diameter cable may be used with excellent results. Ensure that any cable used has TFE insulation so that it may be soldered to the pc board without melting or distorting the dielectric. Both semi-rigid and flexible cables must be *firmly* soldered to the pc board to be effective.

The synthesizer components other than the VCO and the speech amplifier are mounted on two double-sided pc boards, one containing the digital circuits and the other the reference oscillator/divider and the analog circuitry.

The speech amplifier is designed for use with a low-impedance dynamic microphone. The normal clipping characteristics of the CA3160 op amp are utilized for



available types.

modulation limiting. The MOSFET output of the amplifier provides a predictable clipping level for the speech amplifier. The unwanted harmonics of the clipped waveform are removed with an R-C low-pass filter. A similar op amp is used for the loop amplifier/filter.

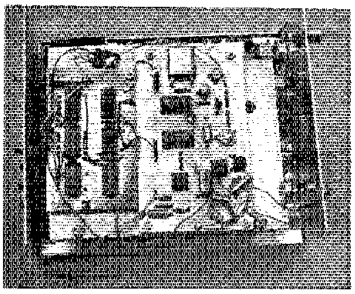
An 11-volt regulator is included for use with the speech amplifier and the loop amplifier. It was desired to use the regulator to reduce the susceptibility of the transmitter to be modulated by input voltage noise, producing so-called "alternator whine." It is important to note that a 3-terminal regulator is not suitable at this point because of an input-output voltage differential of only 1 volt at worst. Most 3-pin regulators have a drop-out voltage of 2 volts or more.

The Crystal Oscillator and Divider

The 2.56-MHz crystal oscillator drives a CMOS ripple counter that divides the crystal frequency down to 10 kHz (see Fig. 2). A variable capacitor is switched across the crystal with a transistor (Q1). The output frequency is raised about 5 kHz by switching this capacitor out of the circuit with the 5-kHz switch. The transistor switch is connected to the "4" bit of the switch which raises the output frequency 5 kHz for numbers of 4 or greater. The switch may be mechanically prevented from going beyond the digit 5 if desired.

The Power Amplifier

A three-stage, broadly tuned power amplifier provides about 12 watts of output. The first stage operates Class A and boosts the 50-mW signal from the VCO to



The programmable divider and the reference oscillator are visible on the top shelf. The VCO and the power amplifiers are mounted on the bottom of the enclosure.

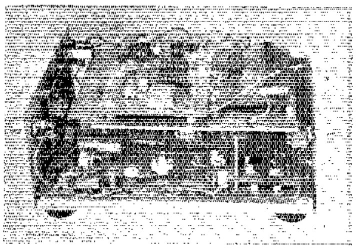
about 500 mW. The second stage, operating Class C, develops 3 watts of drive for the Class C final amplifier. A low-pass filter is used to remove any harmonic energy appearing at the output. All bypassing and tuning components throughout the power amplifier are specially selected for low inductance. Failure to use these special components will result in instabilities and possible component destruction. No pc-board pattern was produced. Instead, small islands were cut into double-sided pc-board material with a sharp knife and the copper peeled away.

Switching Circuitry

A solid-state switching circuit is used for switching the PIN diode and supplying the Vcc to the power amplifier stage. In addition, a terminal is provided at the back of the transmitter cabinet for use with an external changeover relay and receiver muting.

Check Out and Tune-Up

After the unit has been wired and checked to ensure correct assembly, power may be applied. Before depressing the PTT switch, check for overheating components or other unwanted symptoms. Once it has been determined that no catastrophic errors exist, adjust capacitor C1 while watching the VCO control voltage at point H (see Fig. 3). If the loop is locked, the voltage at H should change with the capacitor setting. With the frequency-selector switches set to 146 MHz, set C1 for a VCO control voltage of 5.5 volts. Check to see if the synthesizer is on the proper frequency by means of a frequency counter or by listening for the synthesizer signal with a 2-meter receiver. The frequency counter should be coupled to the VCO by removing the coaxial lead to the power amplifier and keying the mike PTT switch. While monitoring the synthesizer frequency and the VCO control voltage at point H, set the frequency-selector switches to 144 Mhz and 147.99 MHz, and determine that the loop remains locked. Set the switches to 146.005



The power amplifier is clearly visible in this side view. The transistors are mounted on the aluminum box for heat sinking.

MHz and adjust C26 for a counter reading of exactly 146.005 MHz. Move the switches to the 146.000 MHz position and adjust C25 for that frequency-counter reading.

Disconnect the counter and reconnect the power amplifier. With the frequency selector at 146.000 MHz, adjust C20 through C24, inclusive, for maximum power output. A wattmeter may be used as an indicator of power output. In the early stages of tuning up, the power output will be quite low, so careful attention must be paid to the wattmeter readings. The final power output should be on the order of 12 watts with an input current of approximately 2.5 A.

Microphone Gain and Modulation Levels

Set the mike gain and modulation levels with the aid of a deviation meter if possible. Without the aid of such a device, a cut-and-try approach may be used by asking for reports on the air or by using a receiver and comparing the modulation level of the transmitter to that of other stations heard. The microphone-gain potentiometer may be set so that clipping occurs only on loud voice peaks and so that normal speech produces peaks of about 10 volts peak-to-peak. The actual deviation is set by the value of R_A which can be anywhere between 0 and 15 kΩ.

Future Considerations

The pulse-swallowing synthesizer is especially suited to receiver applications because of its ability to program the required frequency offset for i-f shift. I am considering a matching receiver which will use a similar synthesizer and a VCO in the 133.3- to 137.3-MHz range for low-side injection. This receiver will be a simple, single-conversion affair with a 10.7-MHz i-f and a monolithic crystal filter.

Other dual-modulus schemes can be used such as 20/21, 40/41 and 63/64. The major advantage of the higher divisors is that higher frequencies (even into the uhf region) can be brought down to the frequency range of standard TTL devices. It is entirely possible to build a synthesized 1-GHz fm transceiver with only a few more components than are used in this 2-meter synthesized unit.

Constructing a Simple 5/8-Wavelength Vertical Antenna for 2 Meters

No loading coils — inexpensive — easy to build. Does that sound like the 5/8-λ antenna you've been wanting to build? You've got it now!

By E. J. Bauer,* W9WQ

A diligent search of the amateur journals will reveal a plentiful supply of articles concerning the use of the deservedly popular 5/8-λ antenna on the vhf bands. Being a recent convert to 2-meter fm operation, I took a closer look at this type of antenna. In the process of constructing several versions, I formulated some new ideas which may be of interest to those who derive satisfaction from making their own antennas.

Electrical Theory

Refer to Fig. 1A. The feed-point impedance of a 5/8-λ vertical antenna exhibits a resistive component in the vicinity of 50 ohms. It requires a suitably chosen series inductor, however, to cancel the capacitive reactance which also exists at that point. Only then will a reasonable impedance match be presented to a 50-ohm coaxial-cable feed line. One constructor, K4LPQ, obtained the required inductance by means of a short-circuited stub of coaxial line of proper length.[1] (If the required reactance is known, the length of the stub can be calculated). He improved the mechanical construction of the antenna by placing the stub inside the radiating element. See Fig. 1B. This approach requires an electrical connection to be made between the braid of the stub and the lower end of the radiator. Soldering such a connection would be difficult unless a material such as brass or copper is used for the radiator. If the center conductor of the stub is extended one-quarter wavelength beyond the inductive shorting point (as in Fig. 1C), a signal-frequency short will occur at that point. Furthermore, there is now no need for the stub to be made of coaxial cable. An insulated wire of suitable length (somewhat longer than an electrical quarter wavelength) is all that is needed to develop the required series inductance at the feed point of the antenna. It is only necessary to adjust the length of this stub until an acceptable VSWR is obtained. If desired, the radiator length can also be trimmed.

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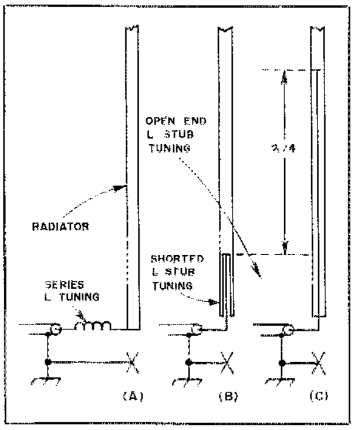

Fig. 1 — The three basic configurations of the 5/8-λ antenna mentioned in the text. The stub tuning method shown at C may be easily arranged mechanically.

Construction

I selected a surplus whip antenna to be used as the radiating element for the 5/8-λ vertical.[2] Cutting the fully extended whip at a distance of four feet (1.22 m) from the tip leaves the larger (base) end with a 3/8-in. (10-mm) OD section. This size tubing fits closely into the hole at the barbed end of a PVC pipe adapter. See Fig. 2. The hole in the threaded end of this same adapter mates snugly with the body of a PL-259 coaxial connector. Cement

[1]Notes appear on page 23.

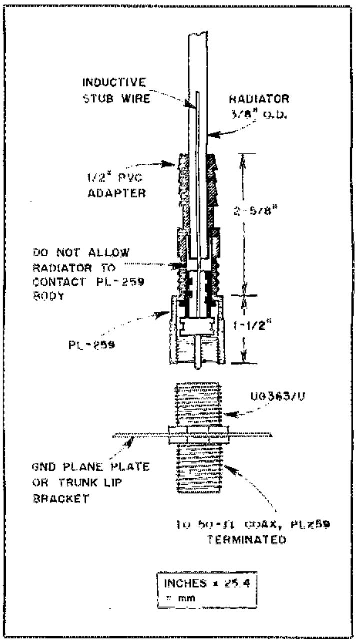

Fig. 2 — This drawing shows a cutaway view of the antenna assembly. A PVC pipe adapter allows simple and inexpensive construction.

the radiator to the adapter using a good adhesive. If epoxy is used, it would be advisable to roughen the inner surfaces of the plastic adapter to provide some "bite." It has been my experience that the bond between epoxy and PVC is marginal. Insert the radiator no more than 2 in. (51 mm) into the adapter and allow the adhesive to cure.

Solder approximately 28 in. (700 mm) of no. 18 solid, insulated wire to the pin of the PL-259. Larger wire may be used here, but the optimum length required for matching will be found to be somewhat longer. The inner diameter of this particular whip is 3/16 in. (4.8 mm) at this point and will easily accommodate no. 12 insulated wire.

Fig. 2 shows a UG-363/U connector being used as the junction for the radiator, ground plane and transmission line. This connector is expensive, so one might prefer to use the less expensive SO-239 connector.

Testing

Temporarily assemble the radiator/insulator assembly to the plug/wire portion, attach a ground plane and check the VSWR at two well-separated frequencies. The results will show whether the stub is too long or too short. It should be possible to get the VSWR below 1.5:1 across the repeater portion at the upper end of the 2-meter band. Shortening the stub to move the maximum VSWR point higher in frequency is easy. Should you overshoot, it is simple to start over again with a new piece of wire. Once you are satisfied with the results, the PL-259 can be cemented to the insulator. That's all there is to it. See you on 2 fm! QST

Notes

[1]Pentecost, "5/8-Wavelength Vertical Antenna for Mobile Work," *Ham Radio*, May 1976.

[2]Fair Radio Sales, P. O. Box 1105, 1016 E. Eureka St., Lima OH 45802, G01-51048 telescoping whip antenna.

The Shooter — A 3-Band Portable Antenna

Want a vertical you can put up or take down in a jiffy? Try this penny-pincher's Field Day special!

By E. W. "Twisty" Ljongquist,* W4DWK/W1CQS

When Wayne Stump, WB4ARZ, brought his little marvel over for me to see, I was admittedly more than a bit skeptical. His previous accounts of the lightweight antenna had aroused my curiosity. Could an antenna made from the miscellany found around the house or in the neighborhood live up to what I'd been told?

The day came when Wayne arrived with his compact bundle of hardware. I looked at the collection and then him, gesturing as I laughingly remarked, "you gotta be kidding!" His only answer was a smile as he set about assembling the various pieces of metal that were transformed in a matter of minutes into a vertical antenna. "Too flimsy to be practical," I told myself as he put on the final touches.

When I moved closer to the antenna, however, I realized I'd judged the book by the cover — for I found the construction to be quite sturdy. "Well, what do you think of it now?" he remarked.

My reply, "Not too bad an idea for the

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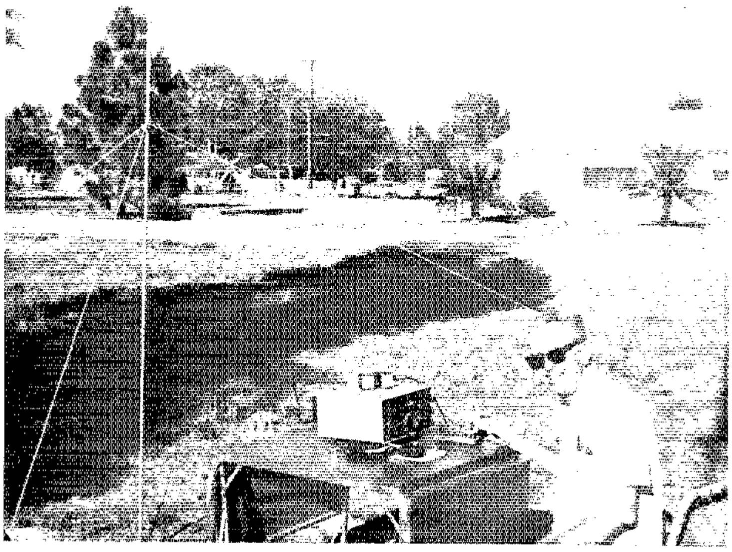

Fig. 1 — Wayne Stump, WB4ARZ, seated at this outdoor radio location in sunny Florida. His version of the vertical Shooter antenna is visible at the left.

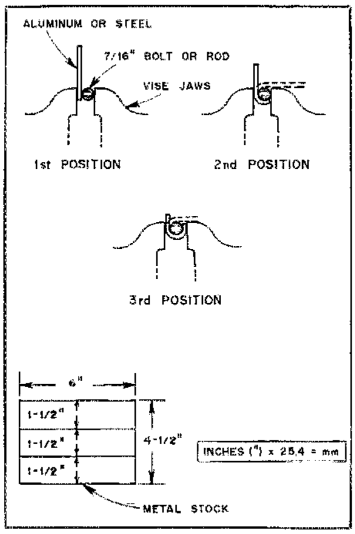

Fig. 2 — Dowels for the Shooter are made by placing the metal stock (shown at the bottom) in a vise along with a 7/16-inch (11-mm) dia bolt or rod. The metal is bent into a cylindrical shape as indicated by the three drawings. The dowels can be made from either aluminum or steel.

chap who enjoys jaunts to the 'boonies' or DXpeditions. As a matter of fact, I'd say it's nearly tailor made for someone like you who has a travel trailer!"

Wayne could sense that my doubts were rapidly disappearing. As I grasped the antenna and gave it a little tug, I declared with a tone of approval, "What a nifty vertical for Field Day. Even condominium of apartment dwellers can use it!"

A Simple Evening Project

Once the material has been gathered, the work of making this antenna should take little more than an hour. You might say it makes a good project for a rainy evening.

Look at Fig. 1, which shows Wayne at the key of a portable installation. You will see one of these vertical antennas positioned just to the left of the operating bench. The scene is rather typical of a basic Field Day station. Figs. 2, 3 and 4 provide details of the Shooter.

In knocked-down form, the entire package is very compact. The maximum length of the antenna segments is such that there should be no problem carrying the bundle or even shipping it by airplane. I estimate the weight to be about six pounds. All parts, except the conduit, can be fitted into a 6-inch cube and still leave enough spare room to accommodate a small L network. In my opinion, a portable antenna like this is nearly ideal, especially if you consider the fact that the total cost should be no more than $7.

Moments after Wayne left, I began a scavenger hunt around my QTH. That adventure netted most of the components needed to construct a copy of his vertical. Naturally, the odds and ends I found were not all identical to the parts he'd acquired. But the resulting variations I made in building the Shooter in no way impaired the performance.

The main ingredients of the antenna are two 10-foot (3.05-m) lengths of 5/8-inch (15.9-mm) OD thin-wall electrical conduit.[1] These may be purchased at an electric supply store or a place that handles building materials. Two couplers, suitable for that diameter conduit, are also required along with a washer that has a 5/8-inch opening. At the time of this writing a 10-foot length of this conduit sells for about $2.

To cut the conduit into the prescribed lengths, I recommend the use of a pipe cutter. Tools of this type are available at many hardware stores. Although a hacksaw will serve the purpose, a pipe cutter will provide a more even cut.

Preparing and Fastening the Sections

As you begin the construction of the antenna, cut one of the 10-foot lengths in half. Cut the other length at 6 feet (1.83 m), then provide a length of 27 inches (686 mm) and another of 6 inches (152 mm). File off the burrs and lay this material aside.

Three metal dowels are to be made. These aid in holding together the sections of the antenna, besides serving as a means for electrical continuity. I formed my dowels from a fairly stiff piece of aluminum chassis material that was 6 inches (152 mm) wide and long enough so that guidelines may be drawn on the metal as explained below.

Dowel dimensions are presented in Fig. 2. With the help of a square, draw the three guidelines across the piece of aluminum so that the lines are 1-1/2 inches (38 mm) apart.

Now obtain a bolt or rod, 7/16 inch (11 mm) in diameter, for shaping the dowel. The length of the bolt or rod should equal the length of the dowel. Clamp the

[1]Notes appear on page 25.

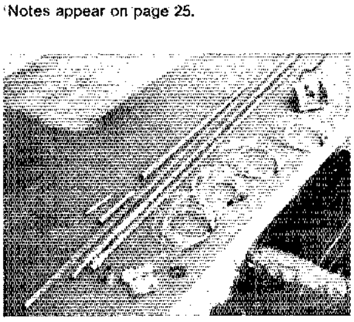

Fig. 3 — This is all there is to the Shooter except the pegs. When the antenna is being stored or transported, a good idea is to keep the guys and radials coiled and tied with plastic ties.

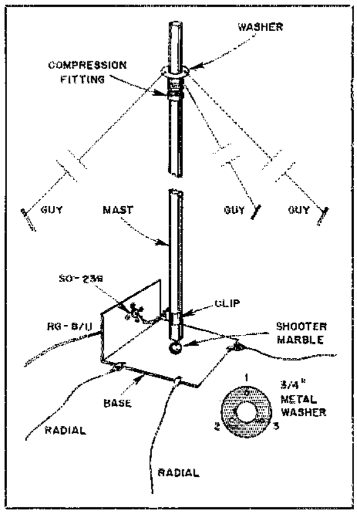

Fig. 4 — The Shooter is mounted and guyed as indicated by this illustration. A metal washer is drilled at points 1, 2 and 3 (equidistant from each other), and a guy is connected to each hole. The washer slips over a section of the conduit coming to rest atop one of the compression fittings. Ground radials are clipped to the metal base.

aluminum stock and the bolt in a vise with the bolt just catching the edge of the aluminum. Fig. 2 shows how this is done. Bend the stock around the bolt. Release the vise and reposition the aluminum so that it can again be bent further around the bolt once the pair has been reclamped in the vise. After this step, you should have a U-shaped end on the aluminum stock. Now cut off the straight section of the aluminum with snips or a hacksaw. Reclamp the U-section and the bolt in the vise and finish bending the dowel into a cylindrical shape with the help of a hammer and block of wood. With a little judicious work using pliers, you should then have a dowel that fits properly in the conduit. Fashion the remaining dowels in the same manner.

To begin putting the antenna sections together, insert one of the dowels into a 5-foot (1.52-m) section and another in a 6-foot (1.83-m) section. What you do with the third dowel is explained in Table 1.

Secure each dowel with a self tapping screw. This screw should be placed 1-1/2 inches (38 mm) from the end of the conduit. Two thin-wall compression couplers are to be installed as shown in Fig. 4. These reinforce the joints and aid the dowels in keeping the antenna straight.

As you may have gathered from Fig. 1, this vertical antenna is not self-supporting. Guys are clearly visible in the picture. Wayne and I guy our respective antennas in a slightly different manner. Because he has welding equipment, he brazed three wire loops on one of the compression nuts. Each loop serves as a terminal for a guy. On the other hand, I simply drilled three holes in a 3/4-inch (19-mm) flat washer which slides over the conduit. You can see how this is done by referring to Fig. 4. A guy is attached to each of the three holes.

Wayne chose plastic clothesline, but I wanted something lighter for guys. To save weight and storage space, I preferred a strong grade of nylon fish line that has a thickness about equal to that of a mason's or carpenter's chalk line. Where the antenna is to be installed at ground level, tent pegs are practical for anchoring the bottom ends of the guy lines.

The Shooter Base

Now, you may wonder why I dubbed my version of the vertical antenna the Shooter. Well, actually this "moniker" is related directly to what I use for the base insulator. Ever play "mibs" as a youngster? Remember the "glassies" or "shooters" that a flick of the thumb sent dashing toward your opponent's marbles? Well, that is exactly what serves as the base for my antenna. (I found one tucked away in a bureau drawer.) Of course you could use a cone-shaped stand-off insulator instead, but I liked the idea of the glassie. Mine is epoxied to the base to prevent it from getting lost.

Whereas Wayne fabricated a base plate from flat washers and a steel peg, one made in the following manner may be easier to fabricate. Aluminum stock that is left over from making the dowels could be cut to provide a 4 × 7 inch (100 × 175 mm) plate that can be bent at right angles 3 inches (75 mm) from one end. A 3/8-inch (9.5-mm) hole may be drilled in the center of the bottom of the base and a 3/4-inch (19-mm) hole placed in the upright part to accommodate the coaxial fitting. The base you see in Fig. 3 actually is a bracket from an old amplifier. Originally it held an amplifier tube in place at the socket.

Mount an SO-239 coaxial connector on the base. Solder a short length of flexible wire to the center conductor of the connector. The length should be such that you can make contact with the bottom of the antenna by means of a clip. Such a clip may be salvaged from an old fuse block that was a part of a main distribution box removed from house wiring. Solder the wire to the clip and then slide the clip onto the antenna. An alternative might be to bend a piece of spring-brass material to an equivalent shape.

A Vertical Needs Radials

A quarter-wave vertical antenna will not function properly without radials. In general, the more radials you provide, the better the signal will be. Ground rods introduce considerable ground loss, and for that reason are not considered effective rf grounds. I use only four radials, mainly for the sake of portability. Because of my location over the dry Florida sands, however, I should increase the number.

Table 1

Radiator Lengths

Band	*Length*
10 meters	A 6-foot section plus the 27-inch piece.
15 meters	A 6-foot section plus one 5-foot length. The third (loose) dowel can be used to change length if necessary.
20 meters	A 6-foot section, two 5-foot lengths plus a 6-inch piece. Use the loose dowel for connecting the top section.

While touching on the subject of radials, I do recommend a review of the excellent articles concerning ground systems and SWR written by both Jerry Sevick, W2FMI[2] and M. Walter Maxwell, W2DU.[3] A good resume of Maxwell's series is contained in the book, *Amateur Radio Techniques*, published by the RSGB.

I find much truth in the statement that SWR isn't everything. For instance, when I adjust my antenna, I frequently find that minimum SWR and maximum field strength do not coincide. In my opinion, a simple field-strength meter will tell you and me more about antenna performance than any SWR indicator.

A valid reason for having an SWR indicator, though, is that it will let you know if your rig will "like" what it sees as it looks into the transmission line. Some of the new transceivers have a nasty habit of popping out when the SWR goes over 2:1. Who needs that to happen? To compensate for mismatch and any reactance presented by the antenna system, an antenna tuner (more properly called an impedance-matching network) is desirable. The popular Transmatch circuit or even a simple L network should handle any matching requirements concerned with this portable vertical antenna. What the tuner does is to provide an adjusted load that is appropriate for a 50-ohm transmitter output. The tuner does not change a mismatch that may be present at the antenna feed point. For the portable vertical to have the best feed-point match in relation to the transmission line, a good radial system and adjustment of the antenna height are required.

Radiator Lengths for Each Band

To select the correct radiator elements for each of the three bands, choose the lengths from Table 1. Those dimensions are taken from *73 Vertical, Beam and Triangle Antennas*, an excellent antenna book written by Edward Noll, W3FQJ.[4] Those dimensions are for the cw portions of the respective bands. They can be found in Chart 2 on page 11 of Noll's book. You may disregard the transmission-line lengths suggested by Noll in connection with this antenna. As George Grammer, W1DF, says, "A line is just to carry the rf to the antenna." Very seldom, and only in special cases, is the line anything but that.

Although the antenna dimensions I've listed are mainly for the cw portions of each of the three bands, I find that with these same measurements operation in the phone segments is quite satisfactory. Only at the highest end of the bands did the SWR get up to 3:1. The signal reports I received while operating my FT-101B with the Shooter assured me that the signals are getting out.

Putting this antenna up is easy once you get used to the procedure. Lay the proper assembly (the elements for the particular band you've chosen) on the ground with the lower end approximately at the point of the erection. Install the compression couplings and tighten them snugly with pliers. Fasten two of the guys, allowing some slack. Incidentally, my guys are 16 feet (4.9 m) long. With the third guy in your hand and the third peg within reach, raise the antenna for a visual check. If the antenna is nearly vertical, set the third peg and fasten the bottom of the third guy. Should the antenna be too far out of plumb, you'd do better to lower it and rearrange it.

Once the radiator is up, lift the antenna enough so that the base can be slipped beneath, allowing the antenna to come to rest atop the marble. Then shift the base as needed to make the antenna plumb.

With the antenna in proper position, connect the coaxial transmission line to the SO-239 connector on the base. Lay out the radials in a random manner, clipping each one to the base as shown in Fig. 4. You are now ready to fire up the rig and make the tuning adjustments.

Tuning consists of setting the antenna tuner for minimum SWR, adjusting the conduit length if necessary (I did not have to make a length change) and observing the field-strength meter for maximum signal output. If you find that maximum signal strength does not occur at the same point as minimum SWR, do not be overly concerned. In that case a compromise will provide you with the best results.

Both Wayne and I hope that those amateurs who have pleaded for information about simple portable antennas will try the Shooter. We feel the small amount of effort required to make one will be well spent. It is not a real DX chaser, as compared to a quad mounted 60 feet above ground, but you can have fun with it. QST

Notes

[1]Electricians call this "half-inch conduit."

[2]Sevick, "The W2FMI Ground-Mounted Short Vertical," *QST*, March 1973, and "Short Ground-Radial Systems for Short Verticals," *QST*, April 1978.

[3]Maxwell, "Another Look at Reflections," Parts 1 through 7, *QST*, April, June, August and October 1973, April and December 1974, and August 1976. [No additional parts for this series are planned for *QST* appearance. — Ed.]

[4]Published by Editors and Engineers (Howard Sams).

A Portable Quad for 2 Meters†

Backpacking, boating or mountaintopping? Invest an afternoon's work and pack this novel directional gain antenna on your next expedition.

By R. J. Decesari,* WA9GDZ/6

Last year, while I was "hilltopping" in the San Diego area with my 2-meter fm transceiver, a band opening occurred in which stations from Los Angeles, Santa Barbara and further points north were copied on simplex frequencies. Establishing solid communications with the built-in quarter-wave whip antenna and 1-watt power of the transceiver (with weakening batteries) was rather difficult, even with the opening. Because of my intense desire to communicate with these DX stations, a need for either a directional gain antenna or a power amplifier was established. Since I didn't particularly desire toting and charging additional batteries for an amplifier, I set this concept aside. I then took a closer look at improving the antenna. This novel portable antenna configuration evolved from many hours of thinking and tinkering in my workshop.

Initial efforts to design a collapsible antenna centered on a conventional four-element Yagi configuration. Several models of the Yagi, whose elements all opened simultaneously, proved to be a nightmare in bell cranks and lever arms. From this attempt, I decided that all the elements should still be attached to a main boom, but the operator would open the elements individually during antenna set-up, thus eliminating the push rods and cranks. The Yagi design, with the elements folding on top of each other to minimize space, was still rather large considering element spacing and other required mechanical appendages and dimensions. At about this time, I happened to spot a big 20-meter quad while driving to work and immediately started to ponder the possibilities of using a quad for the intended portable antenna.

With only two elements, the quad

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†A patent is pending on the antenna system described in this article; commercial application of this construction technique is prohibited

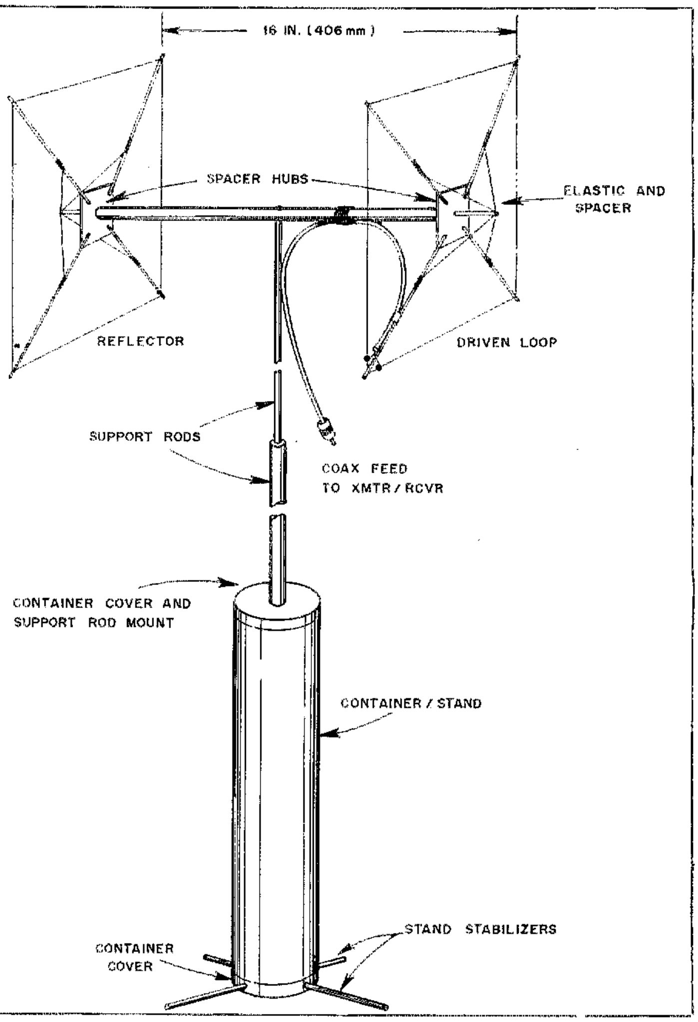


Fig. 1 — The basic portable quad assembly. The author used an element spacing of 16 in. (406 mm) so that the quad spacers would fold neatly between the hubs.

provides an excellent front-to-back ratio, as well as about 6 dB of forward gain. With a two-element quad, the element spacing for optimum reflector performance is between 0.15 λ and 0.2 λ. That works out to about 12 and 16 inches (305 and 406 mm) at 2 meters. Not a bad overall size for a 2-meter antenna! Now the problem was how to support the square loops. A quick lesson in geometry revealed that if an "X" configuration of spacers were used to support 144-MHz loops, then each leg of the "X" would also be about 16 inches! All that was left to do was design a center hub that would allow the spacers to fold to the longitudinal axis of the boom and the basic problem would be solved. Consequently, the garage workshop was put into overtime service and the preliminary model of the brainchild was fabricated.

A Quad is Born

Figs. 1 and 2 show the basic portable quad. Both driven and reflector elements fold back on top of each other, resulting in a structure about 17 inches (432 mm) long. The wire loop elements may be held in place around the boom with an elastic band. To support the antenna once it has been erected, the container is used as a stand. To provide more stability, four small removable struts slip into holes in the base of the container. Both the support rods and struts fit inside the container when the antenna is disassembled.

I have used two different methods of keeping the quad spacers erect. Both methods are successful. Fig. 3 shows the quad spacers held open by spring-steel clips. Each clip is fabricated from an ordinary paper binder with a hole drilled in it to allow it to be attached to the quad spacer. The clip is compressed and slid down the quad spacer until it engages the hub. This provides a rigid mechanical support to hold the spacer open when in use as well as allowing it to pivot back for storage in the container. Fig. 4 shows a slightly different method: A mechanical stop is machined into the hub, and elastic bands are used to hold the spacers erect. The bands are attached to an additional strut to hold the spacers open. When not in use, the strut pulls out and sits across the hub, and the spacers can be folded back. Details of each method are shown in Fig. 5.

The clip and hub assembly is possibly easier for the home builder to fabricate, with the exception of drilling the hole in the spring steel. A high-speed-steel or carbide-tipped drill set is required, since the spring steel is an extremely tough and brittle material. Care must be taken when drilling the holes since the clip material will tend to crack. It is recommended that the builder start with a small-diameter drill and proceed to sequentially larger drill diameters until the final diameter is reached. The clip should be expanded and

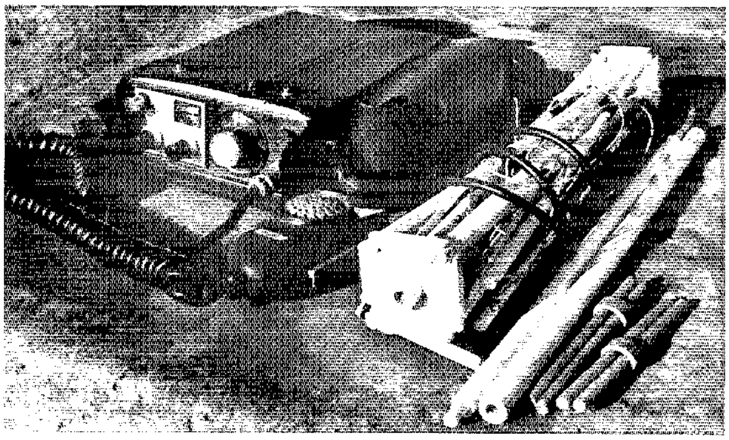


Fig. 2 — The portable quad in stow configuration. Two long dowels are used as support rods. Four smaller dowels are used to stabilize the container.

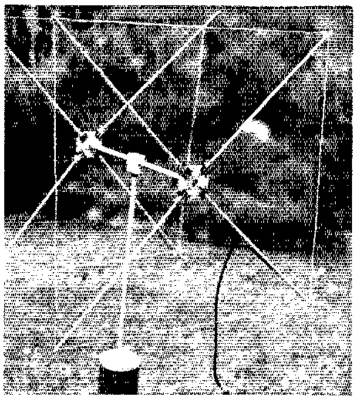


Fig. 3 — Paper-binder spring clips are used in this version of the quad to hold the spacers erect.

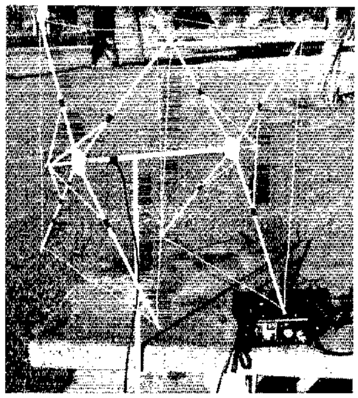


Fig. 4 — This version of the portable quad uses mechanical stops machined into the hub; elastic bands hold the spacers open

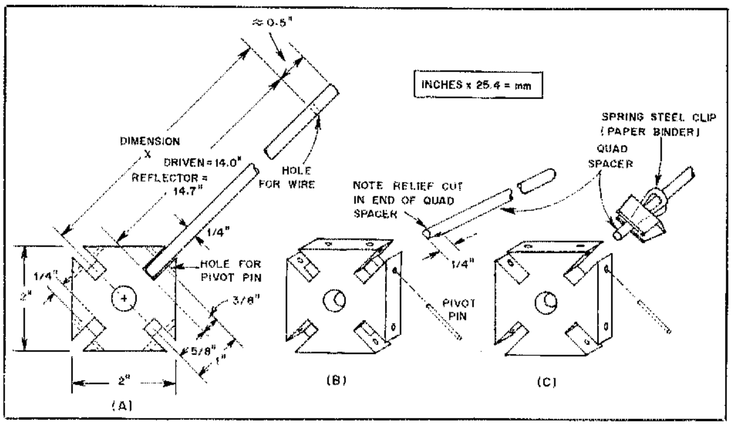


Fig. 5 — A detail of the spacer hub with spacer lengths for the director and reflector is shown at A. The hub is made from 1/4-inch (6.4-mm) plastic or hardwood material. The center-hole diameter can be whatever is necessary to match the diameter of your boom. The version of the hub with mechanical stops and elastic bands is shown at B. At C is the spacer hub version using spring clips.

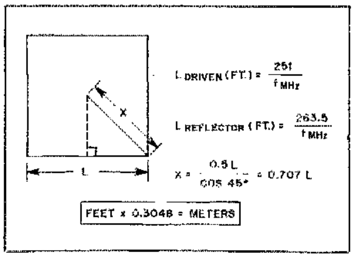


Fig. 6 — Quad loop dimensions. Dimension X is the distance from the center of the hub to the hole drilled in each spacer for the loop wire. At 146 MHz, dimension X for the driven element is 1.216 feet (14.6 inches), and dimension X for the reflector is 1.276 feet (15.3 inches).

fitted over a 1/4-inch (6.4-mm) piece of wood to be used as a drilling back. Use of a light oil is recommended to keep the drill tip cool.

Building Materials

The portable quad antenna may be fabricated from any one of several plastic or wood materials. The most inexpensive method is to use wood doweling, available at most hardware stores. Wood is inexpensive and easily worked with hand tools; 1/4-inch (6.4-mm) doweling may be used for the quad spacers, and 3/8- or 1/2-inch (9.5- or 12.7-mm) doweling may be used for the boom and support elements. A hardwood is recommended for the hub assembly, since a softwood may tend to crack along its grain if the hub is impacted or dropped. Plastics will also work well, but the cost will rise sharply if the material is purchased from a supplier. Plexiglas is an excellent candidate for the hub. Using a router and hand tools, I manufactured a set of Plexiglas hubs with no difficulty. Fiberglass or phenolic rods are also excellent for the quad elements and support.

The loops were made with no. 18 AWG insulated stranded copper wire, although enameled wire may also be used. If no insulation is used on the wire and wood doweling is used for the spacers, a coat of spar varnish in and around the spacer hole through which the wire runs is recommended. The loop wire terminates at one element by attaching to heavy-gauge copper-wire posts inserted into tightly fitting holes in the element. For the driven element, two posts are used to allow the RG-58/U feed-line braid and center conductor to be attached. A single post is used on the reflector to complete the loop circuitry.

The first model of this antenna had a tuning stub attached to the reflector loop. This allowed a certain degree of reflector tuning to maximize its performance. However, I discovered a computer maximization of quad loop and spacing dimensions.[1] This data was used in my subsequent 2-meter quad designs, and has simplified the antenna by eliminating the need for a reflector tuning stub. Fig. 6 shows quad dimensions derived from this data. The quads described in this article have been designed for 146 MHz, but the basic loop size equations will allow the builder to construct a model to any desired frequency in the 2-meter band to maximize results.

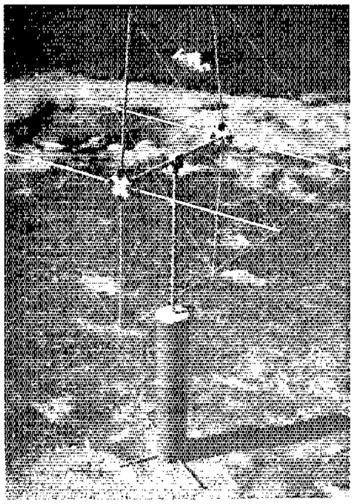
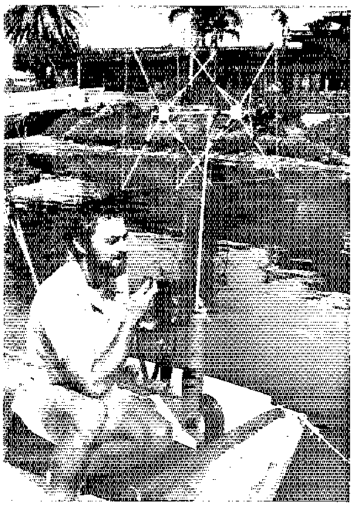


Fig. 7 — A vertically polarized portable quad. The feed point is at the extreme left of the photograph.



The author with the fully erected portable quad antenna. The bottom stand is also used as a storage container.

The storage container was made from a heavy cardboard tube originally used to store roll paper. Any rigid cylindrical housing of the proper dimensions may be used. Two wood end pieces were fabricated to cap the cardboard cylinder. The bottom end piece is cemented in place and has four holes drilled at 90° angles around the circumference. These holes hold 4-inch (102-mm) struts, which provide additional support when the antenna is erected. The top end piece is snug fitting and removable. It is of sufficient thickness (about 5/8 inch or 16 mm) to provide sufficient support for the antenna-supporting elements. A mounting hole for the supporting elements is drilled in the center of the top end piece. This hole is drilled only about three-quarters of the way through the end piece and should provide a snug fit for the antenna support. One or more antenna support elements may be used, depending on the height the builder wishes to have. Keep in mind, however, that the structure will be more prone to blow over, the higher above the ground it gets! Doweling and snug-fitting holes are used to mate the support elements and the antenna boom.

Polarization and Performance

The antennas shown in Figs. 1 through 4 all have 45° diagonal polarization. This is a compromise between vertical and horizontal polarization that allows both fm and ssb/cw (which is usually horizontally polarized) to be worked on 2 meters. Fig. 7 shows another version of the antenna, built for vertical polarization. Although analytical antenna-pattern and gain tests have not been conducted, the portable quad displays an excellent front-to-back ratio as well as gain. The antenna has been used in the field with very satisfying results. The best example of the performance of the antenna was demonstrated by comparison to a 5/8-wave whip antenna. In this demonstration, the 5/8-wave whip was placed on a table top inside the ham shack and excited with 15 watts. From a location in San Diego, the 5/8-wave whip was unable to trigger any of the Los Angeles repeaters about 150 miles to the north. With the portable quad sitting on the same table, full-quieting access was gained to the Los Angeles repeaters.

This antenna design provides a compact package for a directional-gain antenna ideally suited for portable operation. Furthermore, it can be built from readily available and inexpensive materials. I would like to thank my father-in-law for his encouragement and my wife Sue for her patience and indulgence. QST

[1] "Optimum gain element spacing found for the quad antenna," *World Radio News*, March 1978.

• *Basic Amateur Radio*

What Is A Filter?

If the psychiatrist says "Butterworth," do you respond "Pancake syrup"? Are you passive when you should be active? Feel trapped by filters? This one is for you.

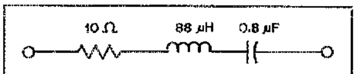
By Peter O'Dell,* AE8Q

What exactly is a filter? The average citizen will probably tell you about the piece of paper that goes in the basket of his automatic drip coffee pot. After the pot of coffee is brewed, he pulls out the filter and throws it in the trash — unless he is involved with gardening, in which case he probably meticulously scrapes the coffee grounds from the filter paper. Regardless, the once-white paper is now soiled brown. It has served its function by trapping small pieces of coffee grounds and oils within the paper. The larger chunks simple settle in against the filter paper and easily fall off if given a chance.

Some of you are probably mumbling that you could have watched Julia Child on Public TV to find out something as simple as this. Many of us have at one time or another jumped to the erroneous conclusion that the functioning of the filters normally found in electronic devices is similar to that of the coffee filter. It really isn't. How do these filters work?

With a few rather rare exceptions, an electronic filter does *not* trap or absorb unwanted energy; it merely refuses to accept it and refuses to pass it along. The operating principle involved is that the filter rejects unwanted energy. If a coffee filter functioned in a similar manner, coffee grounds would bounce off it (that could be messy). Brewed coffee would pass through, but the filter would remain white. Nothing would be trapped inside the filter. Although the distinction may seem to be trivial, it has far-reaching consequences when using filters in electronic circuits.

The electrical property associated with this rejection process is *impedance*. To be more precise, it is impedance matching that is involved. The source will have an impedance, the load will have an impedance, and the filter will have an impedance. The input impedance of the filter will vary with the frequency of the energy applied. (The impedance of the source and of the load may also vary with frequency, but that doesn't concern us here.) This impedance variation is the underlying principle of filter operation. To go into any detail on the theory of operation of filters is far beyond the scope of this article. A bibliography is included at the end.



FREQUENCY (Hz)	IMPEDANCE (Ω)
150	1243
300	497
600 (RESONANCE)	10
1200	498
2400	1244

(B)

Fig. 1 — Schematic diagram of simple series-resonant filter at A. At B, listed in tabular form, is the impedance vs frequency for the circuit for one and two octaves above and below resonance.

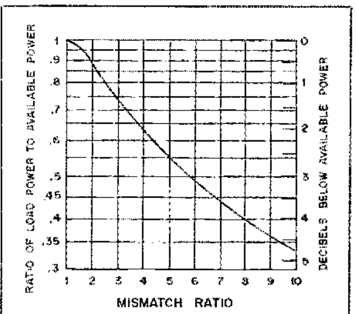


Fig. 2 — This graph depicts the relationship between power loss and mismatch.

Illustration

Suppose that we look at a very simple series-resonant circuit, Fig. 1A. A 10-ohm resistor is in series with an 88-mH inductor which is in series with a 0.8-μF capacitor. This circuit is resonant at 600 Hz. At resonance the impedance will be equal to the resistance of the circuit, 10 Ω. As we move away from resonance though, the impedance will change; the numerical value of the impedance is given in Fig. 1B for frequencies one and two octaves above and below the resonant frequency. (An octave is defined as a frequency ratio of 2 to 1.) Notice that the impedance is much higher as we move away from the resonant frequency.

One empirically observable relationship of impedance is $Z = E/I$ for any given frequency. Using the figures from the table (Fig. 1B), it becomes obvious that it takes progressively more voltage to force the same amount of current to flow in this circuit as we move further from the resonant frequency. This is the manner in which filters ***attenuate*** (reduce) signals. It simply takes a much bigger signal at the input to get the same amount from the output as we move away from resonance. The resistance has stayed the same (10 ohms in this case); the impedance increases because of the changing reactances with changes in frequency. Therefore, additional power is not consumed in the filter; the filter simply refuses to accept the power and pass it on for the unwanted frequencies.

The effect of a mismatch is depicted graphically in Fig. 2. Maximum power will be transferred from the source to the load when the source resistance equals the load resistance (assuming no reactances or situations where the reactances have been canceled out). The mismatch ratio is not a simple function of impedance ratios — unless there is a no-reactance situation. In this special case, the mismatch ratio is the ratio either of load resistance to source resistance or source resistance to load resistance, whichever results in a number larger than 1. When reactance is present, the mismatch ratio is ***always*** higher than the simple impedance ratio. How much

*Basic Radio Editor

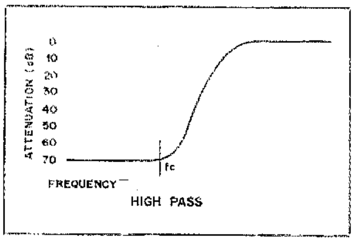


Fig. 3 — Response curve for hypothetical high-pass filter. Frequency increases from left to right.

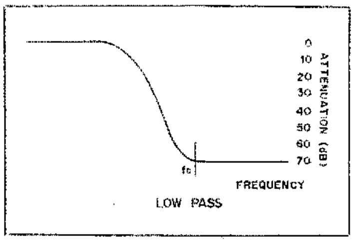


Fig. 4 — Response curve for hypothetical low-pass filter.

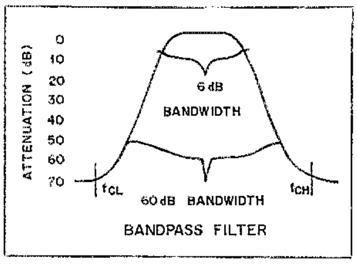


Fig. 5 — Response curve for hypothetical band-pass filter. Those points on the curve representing 6- and 60-dB down are indicated because they are commonly used to calculate the shape factor.

higher is determined by how much reactance is present. In the extreme case, a load impedance might be a pure reactance equal in value to the source resistance. The impedance/resistance ratio in this case is 1, but because a pure reactance can absorb no power, the mismatch ratio is infinity.

If the mismatch is not very great, most of the available power will be delivered to the load. About half the available power is realized when the mismatch is as great as 6 to 1. This is intended only to provide an idea of what is going on inside a filter.

Because filters are rejecting energy (not absorbing it), it is usually desirable to place them in a low-level portion of any given circuit. (This is true for most filters; however, there are some, such as low-pass filters for transmitters, which are placed at the output of circuits.) For instance, a crystal filter that is overdriven may become unstable and change frequency — in extreme cases the crystal may fracture. If a filter using toroids is overdriven, the core of the toroid may saturate, causing the inductance to change value and thus distorting the response of the filter.

Polytypic Group

Filters come in all shapes and sizes. They can be made from a wide range of components. They can be designed to do many different things. In a typical ssb transceiver we generally find either a crystal filter or a mechanical filter. In fm transceivers, we may find either a crystal or a ceramic filter. Regardless of the construction, filters pass (attenuate very little) some frequencies and reject (attenuate quite heavily) others.

Some specifications are usually provided with the filter to give the user an idea of the *shape* of the response. All that is meant by this is the relationship of output power to available input power over some range of frequencies. Usually this is expressed in terms of decibels or dB. Fig. 3 shows a diagram of a typical high-pass filter (vertical axis represents power level expressed in dB; horizontal axis represents frequency — low to high is from left to right). Signals below f_c are uniformly attenuated 70 dB, while signals only slightly above f_c show little attenuation. A high-pass filter could be useful between the antenna and a TV set to keep the fundamental signal from an amateur hf transmitter from overloading the front end of the TV set.

Fig. 4 depicts the response curve of a low-pass filter. The response of the low-pass filter is a mirror image of that of the high-pass filter. Most amateurs have low-pass filters on the output of their hf transmitters and amplifiers. I recently had a phone call from an amateur who had a severe case of TVI. Asked if he had installed a low-pass filter, he replied that he had two of them — both between the exciter and the amplifier! I suggested that he move one of them to the output of the amplifier. Be sure to buy or build a low-pass filter that will handle the power level that you are running; then put it immediately after the last amplifying device. Low-pass filters are designed to operate into a specific load impedance. In simple terms, if you are using 50-Ω coax feeding a 50-Ω aerial or a Transmatch, then use a 50-Ω low-pass filter; otherwise it may not act as a low-pass filter. Also, if a high SWR is present on the line, this may degrade the performance of the low-pass filter, as the filter may not be operating into its correct load impedance. (Perhaps this is how the old wive's tale about high SWR causing TVI got started.) Place the low-pass filter between the transmitter or amplifier and the matching network, if employed.

Fig. 5 shows a representative band-pass filter response curve. There is a low cutoff frequency and a high cutoff frequency. The frequencies between the two cutoff frequencies are passed with little attenuation. *Shape factor* or *skirt slectivity* is often mentioned in connection with band-pass filters. For instance, we can measure both points on the curve where the response is down 6 dB. Suppose at these points the bandwidth (difference between the high and low frequencies) is 2 kHz. Now suppose that we mark the points on the curve that are 60 dB down and find that we have a bandwidth of 4 kHz at this point. The 60/6 dB shape factor (slope) is calculated by simply dividing 4 kHz by 2 kHz, which equals 2. To make an intelligent interpretation of the slope factor, it is necessary to know at what points on the curve the bandwidths are measured for the calculation. Obviously, if a filter has a shape factor of 2 to 1 for 30/6 dB,

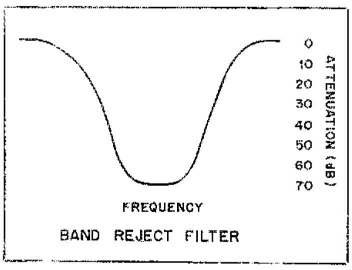


Fig. 6 — Response curve for hypothetical band-reject filter.

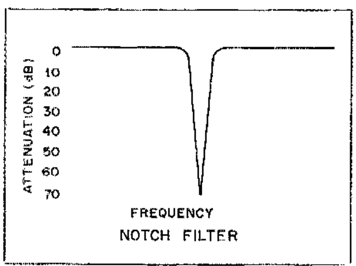


Fig. 7 — Response curve for hypothetical notch filter.

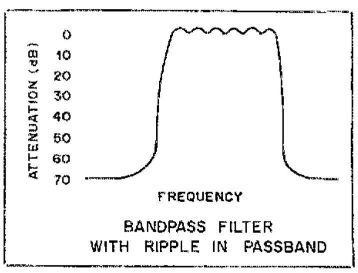


Fig. 8 — The wiggly lines in the band-pass response indicate ripple in the passband.

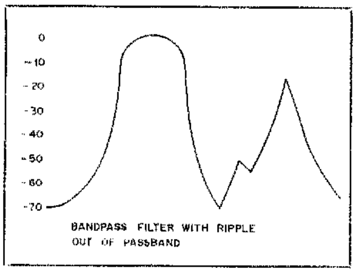


Fig. 9 — Ripple can also occur out of the passband.

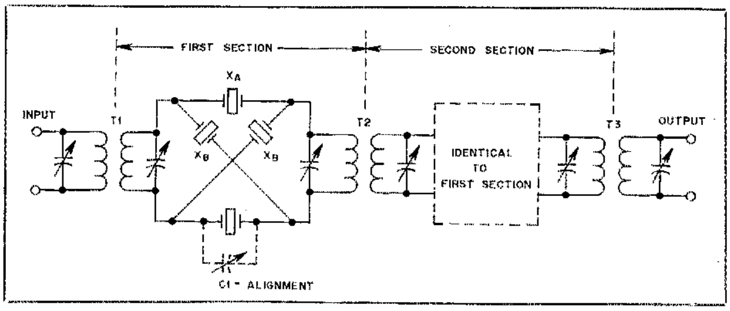


Fig. 12 — Schematic diagram of a two-section crystal lattice filter.

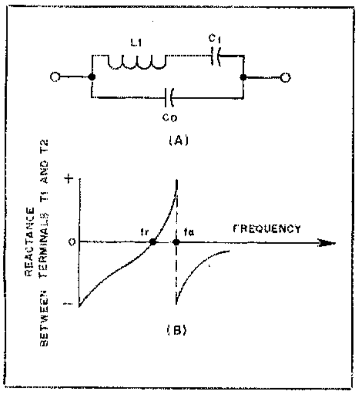


Fig. 10 — The equivalent electrical circuit of a piezoelectric crystal is shown at A. The reactance varies with frequency as in B.

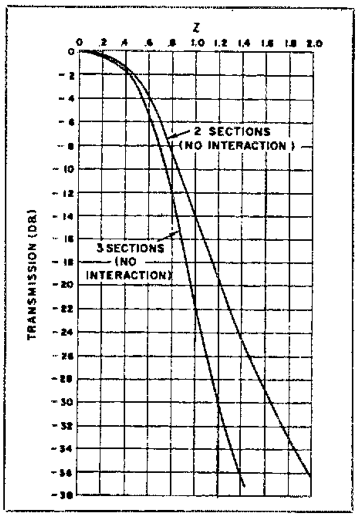


Fig. 13 — Theoretical selectivity characteristics of two and three cascaded identical filter sections when interaction because of mismatch is ignored. Z is proportional to the frequency difference from the center of the passband.

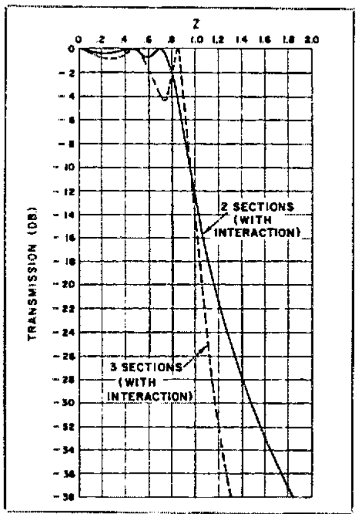


Fig. 14 — Theoretical selectivity characteristics of two and three identical cascaded filter sections when interaction is taken into account. These curves are steeper than those of Fig. 13, but there is considerable ripple in the passband.

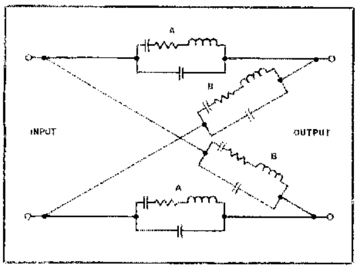


Fig. 11 — Equivalent circuit of a full-lattice crystal filter. Note that the lattice could be redrawn as a bridge circuit.

its response curve is going to be dramatically different from the above example. Given modern-day crowding on the hf band, a rule of thumb for filters is the steeper (the closer the ratio is to 1:1), the better.

The complement of the band-pass filter is the band-reject filter or band-stop (Fig. 6). Frequencies above and below a specified band are passed with little attenuation, while the frequencies within the band are heavily attenuated. Such a filter could be useful to an amateur living near a powerful shortwave broadcast station that operates between two of the amateur bands, such as 40 and 20 meters. A band-pass filter would serve to keep the high signal level of the broadcast station from overloading the front end of the amateur's receiver, but it would not degrade the amateur's ability to copy weak signals on 20 and 40 meters. Fig. 7 depicts the response curve of a special type of band-reject filter called a *notch filter*. Notch filters provide a very high level of attenuation for a narrow band of frequencies. Notch filters can be constructed for audio frequencies and intermediate frequencies (usually under 500 kHz). These filters are useful for "notching" out unwanted signals in the passband of a receiver, such as a carrier just slightly off frequency.

When a filter is mismatched, several things may occur. Fig. 8 graphically depicts one of these possibilities. Within the passband of the filter, there may be some variation in the amount of attenuation. You can expect to find variation on the order of 3 or 4 dB in some filters, depending on their design. This variation is called *ripple* (because of the ups and downs of the passband). Fig. 9 gives another example of what can happen if a filter is improperly designed or terminated. Here the ripple is not in the passband, but is outside the passband. Notice that in the example, at some frequency well removed from the passband, the rejection is only on the order of 25 dB. Depending on the application, ripple, in or out of the passband, may or may not be critical. How's that for leaving things wide open?

High-Q — Crystals Are a Filter's Best Friend

A quartz crystal acts as an extremely high-Q circuit. The equivalent electrical

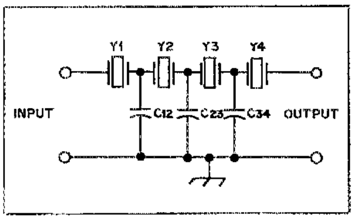


Fig. 15 — Details of a four-pole ladder filter.

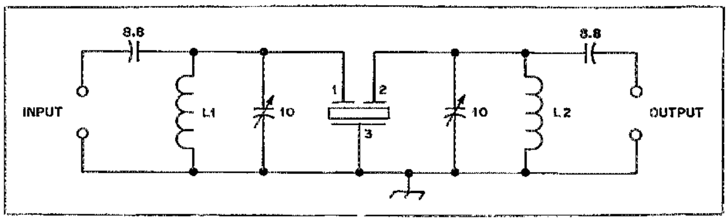


Fig. 16 — Typical circuit employing a monolithic crystal filter.

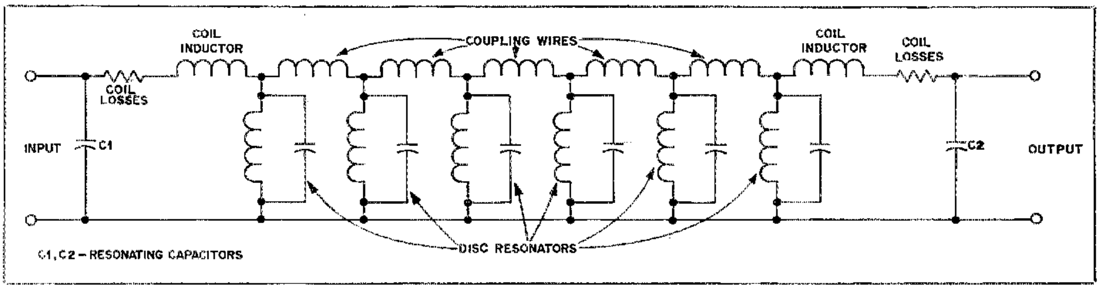


Fig. 17 — Analogous representation of a mechanical filter.

circuit is depicted in Fig. 10A. Fig. 10B shows a graph of the reactance vs. frequency for the crystal. Even though crystals can be used singly as filtering devices, the normal practice is to wire two or more together in various configurations to provide a desired response curve. Fig. 11 details a configuration known as the full-lattice filter (equivalent electrical circuits are shown instead of the crystals). Fig. 12 shows two full-lattice crystal filters cascaded to enhance the characteristics of the filter.

Theoretical selectivity curves for two- and three-section crystal filters are shown in Figs. 13 and 14. Fig. 13 assumes that there is no mismatch or interaction between sections. Fig. 14 provides data on what happens when there is interaction between the sections. Notice that the skirt selectivity has improved at the expense of introducing ripple into the passband. Filters, like most other things in life, often involve trade-offs. Another configuration of crystal filter, popular with European amateurs, is the ladder filter shown in Fig. 15. Fig. 16 shows a circuit employing a monolithic crystal filter. In this configuration a single piece of quartz is made to function as if it were two separate crystals. Crystal filters are high-Q devices that do a very good job of providing selectivity in rf circuits.

Another device that can provide a high degree of selectivity at frequencies up to 500 kHz is the mechanical filter. An electrical equivalent circuit of a typical mechanical filter is shown in Fig. 17. A mechanical device is designed so that it will vibrate at some very precise radio frequency.

Above certain frequencies it becomes

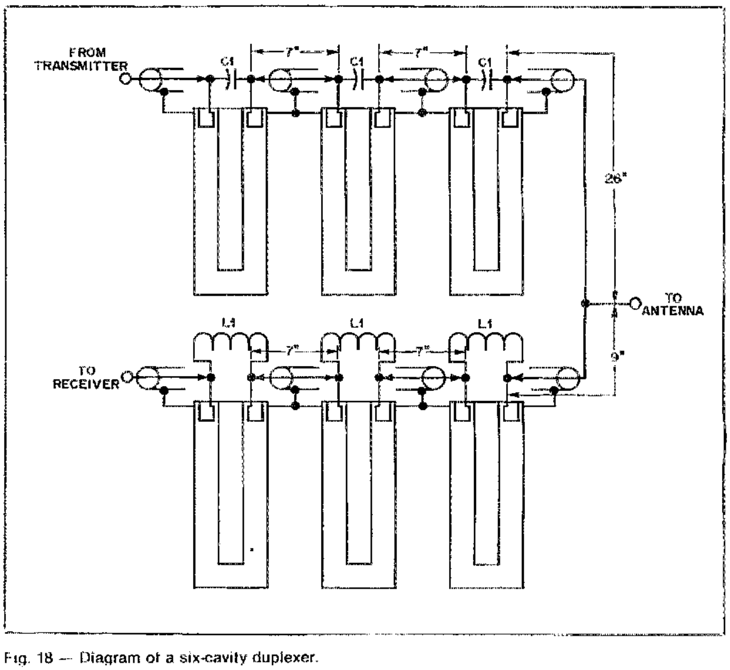


Fig. 18 — Diagram of a six-cavity duplexer.

very impractical to manufacture crystal filters; unfortunately, the need for selectivity does not decrease as the frequency goes up. Fig. 18 shows a duplexer for 2-meter operation — a highly selective filter that allows a repeater to operate both the transmitter and receiver simultaneously on the same antenna. Each leg of the duplexer is made up of three tuned cavities. Each tuned cavity acts as a series-resonant circuit; however, the cavities in and of themselves would not provide the isolation needed between the transmitter and receiver (100 dB or more). When a cavity is shunted with either a capacitor or inductor, a null is formed on one side of the passband. When the cavity is shunted with a capacitor, the null falls below the passband; an inductor causes it to fall above

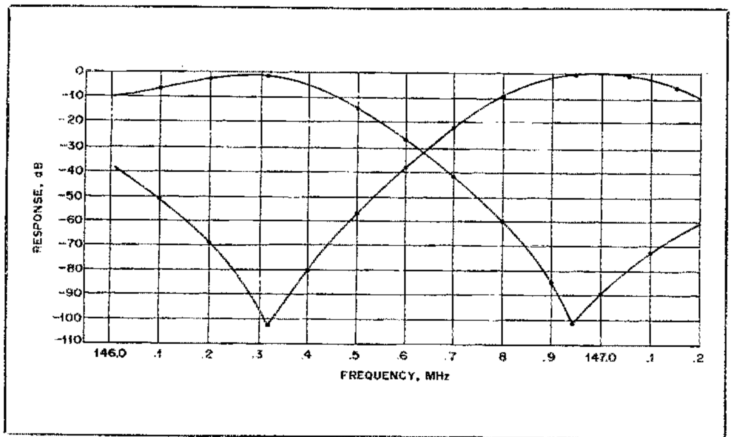


Fig. 19 — Frequency response of a six-cavity duplexer tuned for 146.34 MHz reception and 146.94 MHz transmission.

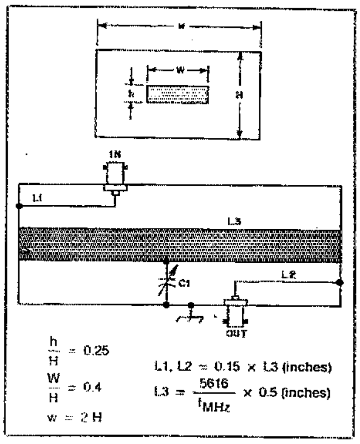


Fig. 21 — Configuration and design data for half-wavelength transmission-line filter.

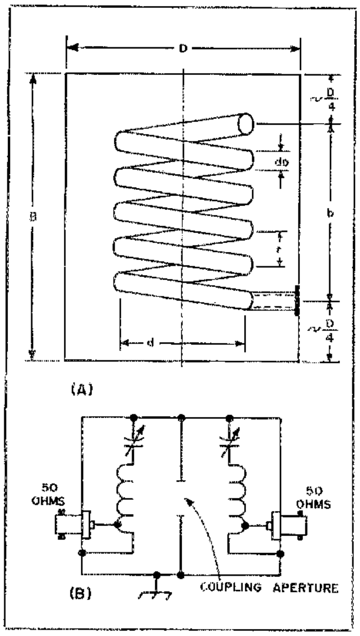


Fig. 20 — Details of helical-resonator design.

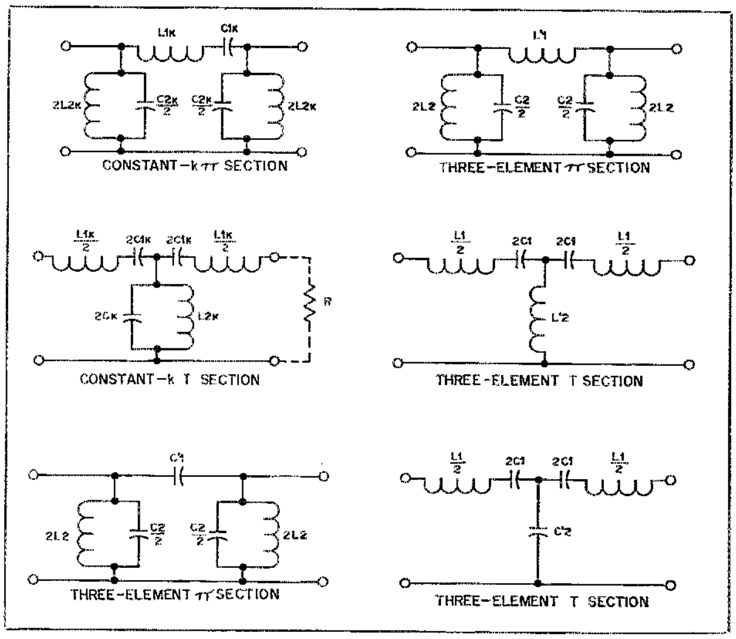


Fig. 22 — Several examples of band-pass filter configurations. Relative values of capacitance and inductance refer to formulas for calculating image-parameter design values.

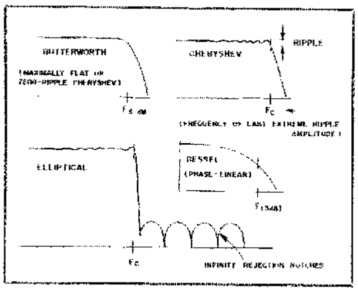


Fig. 23 — Band-pass response characteristics of "modern filters."

the passband. This pattern is shown in Fig. 19. These passbands combined with the nulls give us the isolation needed to allow the repeater to function without desense (receiver overloading from its own transmitter).

Another filter that is useful at vhf is the helical resonator. Fig. 20 provides a detailed view of a typical helical resonator. Many of the better high-band commercial fm transceivers have helical resonators in the front end. Helical resonators can be built for hf (of course, they are somewhat larger physically than their vhf cousins). Such filters are widely used by groups on Field Day or some of the larger multi-operator contest stations. Another filter often used at vhf and uhf is the stripline filter. A circuit board is etched in such a way that the foil is either a resonant quarter- or half-wavelength transmission line at the desired frequency. Fig. 21 shows a typical half-wavelength stripline filter.

If the Curve Fits . . .

The main problem with filter design is that what is often required in terms of response is a rather complex curve when plotted. Before the widespread availability

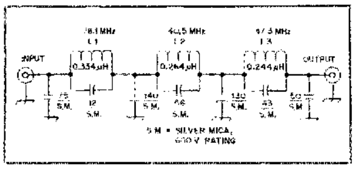
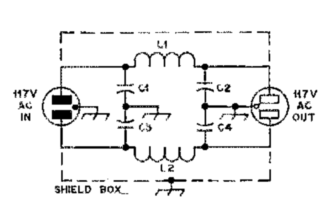


Fig. 24 — Low-pass filter suitable for use with an amateur transmitter. The coils are made from no. 14 enameled copper wire, and are formed on a 1/2-inch dia mandrel. L1 has 8 turns while L2 and L3 each have 6 turns. After the coils are formed, the capacitors are soldered across them, and the parallel branches are initially tuned to resonance by adjusting the turns spacing until a dip meter indicates resonance. The circuits are mounted and checked again. Finally, the shunt capacitors are soldered in. If silver-mica 600-volt capacitors are used, power capability will be 50 W at 28 MHz, 150 W at 21 MHz and 300 W below 14 MHz. All capacitances are in pF.



X_L = 50 ohms
X_C = 50 ohms

$$L1, L2 = \frac{X_L}{2\pi f_c} = \frac{50}{6.28 \times 0.5} = 15 \mu H$$

$$C1, C2, C3, C4 = \frac{1}{2\pi f_c X_c}$$

$$= \frac{1}{6.28 \times 0.5 \times 50} = .006 \mu F$$

1000 V, ceramic

Fig. 25 — Brute-force line filter with cutoff at 500 kHz. The wire size used in the coils must be large enough in cross section to handle the current taken by the equipment with which the filter is used. One half of this filter is suitable for dc-lead filtering.

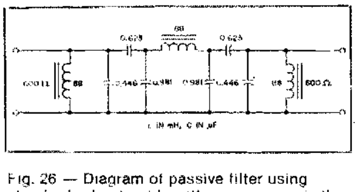


Fig. 26 — Diagram of passive filter using standard-value toroids with a response similar to original CRUD-O-Ject. All capacitances are in microfarads, and all capacitors should be of high-quality paper or polyester dielectric with 75 V or higher rating. See text for information on transforming input and output impedance to 4 or 8 Ω.

of high-speed computers and programmable calculators, approximations were used to calculate the value of components for a filter. The biggest fault of these designs (usually called image-parameter filters) is that they are not easily predictable out of the passband. Several different configurations of band-pass filters are given in Fig. 22.

The mathematics for calculating precisely designed filters has been known since the 1920s, but the complex calculations are too involved to perform without the assistance of a computer or programmable calculator. The general name for these designs is "modern filters," something of a misnomer. They may also be called by the name of the polynomial expression that defines them, such as Butterworth, elliptical or Chebyshev (Fig. 23). It is not usually possible to merely glance at the number and location of components that make up a filter and deduce what type it is — that depends on the shape of its response curve.

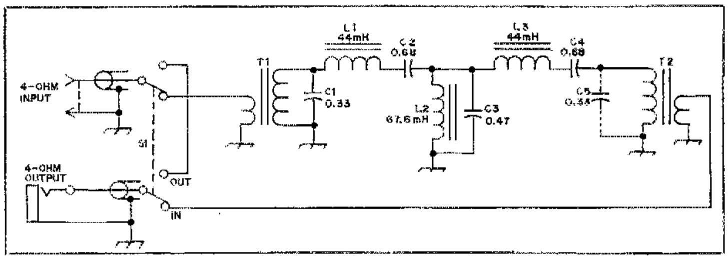


Fig. 27 — Circuit diagram of the SSB Crud-O-Ject. The capacitors should be of good quality (see Fig. 26). Capacitances are in µF.
L1, L3 — 44-mH toroid inductor.
L2 — Modified 88-mH toroid inductor. A total of 94 turns must be removed from the winding.
S1 — Dpdt toggle.
T1-T2 — 88-mH toroid inductor with 100 turns of no. 28 enam. wire wound over the original winding for the secondary.

Four for Your Shack

Here are four simple passive filters (active filters have recently been discussed thoroughly[1]), that you may find useful 'round your shack. Each of these circuits has appeared in *QST* or one or more of ARRL's other publications. Fig. 24 shows the circuit of a low-pass filter that is suitable for use with an amateur transmitter.[2] It should be constructed in a well-shielded metal container. Compartments should be constructed for each section of the filter.

Fig. 25 gives the details for a brute-force filter that was designed by Doug DeMaw.[3] A brute-force filter is a specialized low-pass filter that allows 60-Hz ac to flow unimpeded, but which filters out any rf component. Like the low-pass filter, this one should be constructed in a well-shielded metal box and should be placed in the ac line near the device that is being powered from it. This can either be an amateur transmitter (to keep rf from getting into the power line) or some device affected by rf from the power line (e.g., a stereo). The filter enclosure should be connected to a good earth ground.

Figs. 26 and 27 detail two passive audio filters that may be useful to an amateur whose receiver lacks sufficient selectivity. Both units are constructed from surplus 44- and 88-mH toroid inductors. Odd-value capacitors may be formed by using a capacitance meter to check paralleled capacitors until a proper combination is found. Fig. 26 is for a cw version of Hall and Myer's CRUD-O-Ject.[4,5] Although not the original circuit as it appeared in *QST*, it produces an equivalent response with fewer components. Fig. 27 is the schematic diagram of an ssb version of the CRUD-O-Ject.[6] Notice that the input/output impedance of the cw version is 600 Ω, while that of the ssb version is 4 Ω.

In the ssb version, a secondary winding has been added to the input and output inductors to transform the impedance of the filter to the 4-Ω value more compatible with today's equipment. A similar method may be used with the cw version; calculations indicate that 50 to 60 turns should provide a good match to the 4- or 8-Ω speaker and audio output stages commonly found in modern equipment. Additional construction details may be found by consulting the original articles listed in the notes.

What is a filter? If anyone writes to Hq. saying that it is a piece of white paper that turns brown in their coffee pot, I'll cry.

Notes

[1]Bloom, "Active Filters," *QST*, July 1980, p. 17.
[2]Welsh, "An Effective Low-Pass Filter," *QST*, January 1966, p. 16. (Essential information is reprinted in *ARRL Electronics Data Book*, p. 65.)
[3]*ARRL Electronics Data Book*, p. 61.
[4]Hall and Myers, "The CRUD-O-Ject," *QST*, February 1972, p. 11.
[5]Hallock, "Band-Pass Filters in Abundance," Technical Correspondence, *QST*, May 1972, p. 57.
[6]Myers, "The SSB Crud-O-Ject," *QST*, May 1974, p. 23.

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Fisk, "Helical-Resonator Design Techniques," *QST*, June 1976, p. 11.
Wetherhold, "Modern Design Methods Applied to the Speech Filter," *QST*, November 1967, p. 51; "Low-Loss Passive Bandpass CW Filters," *QST*, January 1972, p. 56; "Low-Pass Filters for Amateur Radio Transmitters," *QST*, December 1979, p. 44.
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ARRL Electronics Data Book, ARRL, Chapter 6.
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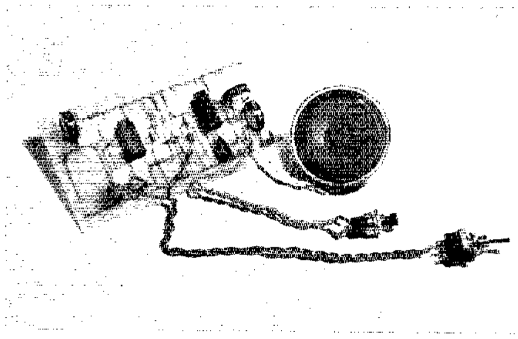
Solid State Design, ARRL, Chapters 3 and 5.

A 10-Minute Timer That Just Won't Quit

Station identification warning timers come in many sizes and shapes, and most circuits require manual resetting. This simple-to-build timer automatically resets itself after giving a 10-minute warning.



By L. B. Cebik,* W4RNL

For under $5, depending on the frills you add, you can build an automatic timer that just won't quit. If you need a versatile 10-minute timer, the circuit described below may fill the bill. Even if you do not need to be reminded to identify your station, the circuit combinations may give you some good ideas for other timing projects around the shack.

This automatic recycling timer will trigger both visual and audio warnings after 10 minutes of quiet: a set of lights and a tone pulse at half-second intervals for about 10 seconds. Then the timer begins a new 10-minute timing cycle. There are manual overrides so that you can prevent recycling and reset the timer at any time during the cycle.

IC — The Mainspring

Two common NE556 IC's make up the heart of the device. Each 556 contains two 555 timer circuits in a 14-pin DIP IC. This gives us four timers, each of which is set up to do a different job. Pin-out information is shown in Fig. 1. The 555 (or one section of a 556) has been around for quite a while, but few of us really make use of its versatility. Fig. 2 shows the two basic configurations: as a monostable timer and as an astable oscillator. Timing and frequency formulas accompany the figure.

In the monostable mode, a negative (ground) trigger pulse to pin 2 of the 555 (pins 6 and 8 of the 556) starts the timing cycle, whose period is determined by C1 and R1. When the cycle is complete, the high output on pin 3 (pins 5 and 9 of the 556) goes low and remains in that state until the trigger (pin 2) is again grounded.

Fig. 3 shows two timers in series. In Fig. 3A, the trigger of U1 is held high by the 10-kΩ resistor to the Vcc supply. When U1 has finished its on period, its output goes low, briefly discharging the 0.01-μF capacitor and providing a short negative pulse to the trigger of U2, which then starts its cycle. Fig. 3B adds one extra step to 3A. The output of U2 is connected to the trigger pin of U1 through a 0.01-μF capacitor. The trigger of U1 is held high until it receives the end-of-cycle pulse from U2. Now the two timers cycle each other automatically.

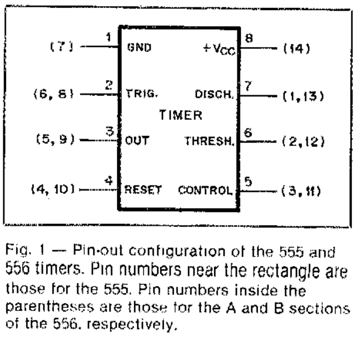


Fig. 1 — Pin-out configuration of the 555 and 556 timers. Pin numbers near the rectangle are those for the 555. Pin numbers inside the parentheses are those for the A and B sections of the 556, respectively.

Any number of timers can be sequenced. W4EEE has a blinking LED name tag made from four timers. Three of them are set to about a third of a second and light LEDs. The fourth is set to about one second and has no LED. The result is a visual display of the suffix of W4EEE's call, all in the space of two chips.

In Fig. 3A, notice that the reset (pin 4) of each timer is held high by connecting it to the Vcc supply. In Fig. 3B, pin 4 of both chips is held high through a 10-kΩ resistor. When the reset pin is momentarily grounded through the push-button switch, both timers are brought back to the beginning of their cycles. This measure is sometimes necessary with long timing cycles when power is first applied, because both timers may begin their cycles together rather than sequentially. By connecting the reset switch to the trigger of U1 also, we begin the sequence of timing. (If the timing cycle of U1 is short, place a 0.01-μF capacitor between the switch and the junction of pin 2 and the 10-kΩ resistor, Rt. For timing periods over about one second, the capacitor is not needed.)

In the astable mode, the 555 timer produces positive and negative pulses timed by C1, R1, and R2. One pulser can control another by connecting the output of the first to pin 4 (pins 4 and 10 of the 556) of the second. Only when the first has a high output will the second timer operate.

Fig. 4 shows two timers, the first set for long pulses, the second for short. If the second timer is set for audio frequencies,

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we will hear a series of "beeps," that is, tones whose duration is controlled by the period of the first timer. We may also pulse lights or any other warning device. Fig. 5 shows a variation. When U1 has a high output, U2 oscillates at one tone. When the output of U1 is low, U2 shuts off, but U3 comes on because its ground (pin 1) is made low. By carefully selecting frequencies for U2 and U3, we can achieve a pleasant warbling effect.

Time After Time

We are now ready to combine four timer circuits into one station identification timer. Fig. 6 shows the circuit and the timing cycles. U1A, a monostable timer, provides the 10-minute cycle. The green LED tells us that all is well. Since 555/556 timers are dependent on capacitor quality for accurate timing, you may need to try several different electrolytics at C1 to obtain 10 minutes near the center of the range of R1. Note that S1, an spst miniature toggle switch, permits us to defeat the automatic reset pulses from U1B. In the manual mode or when power is first turned on, the timer can be triggered or reset by S2, a push-button momentary switch.

U1B, a second monostable timer, has a period of about 10 seconds. If R2 is made variable, you can alter this period to suit your taste. The output of U1B goes in three directions. First, it lights an amber LED to tell us this timer is on. Second, it returns through a 0.01-μF capacitor to the trigger of U1A for automatic reset. Third, it controls U2A, turning it on.

U2A is an astable oscillator with a one-second cycle (about 1/2-second on, 1/2-second off). Varying R3 will change the pulse durations; it operates only when U1B has a high output. U2A is the basic warning-control pulser. The output from

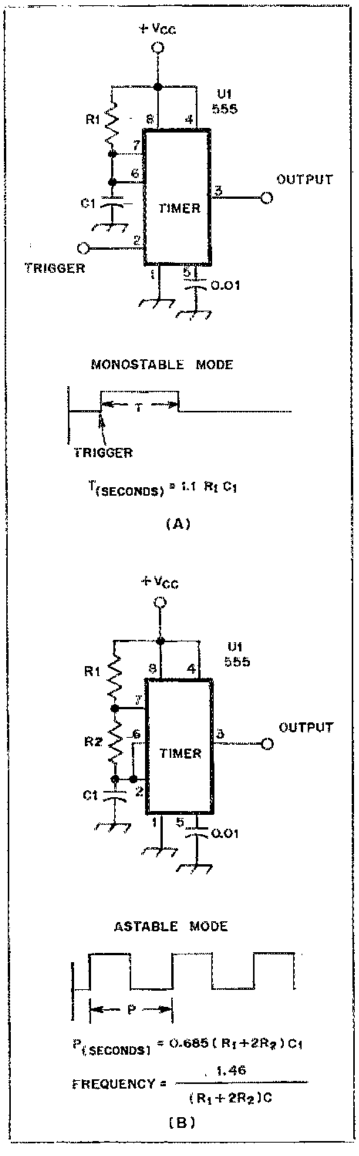

Fig. 2 — Basic circuits for the 555 timer.

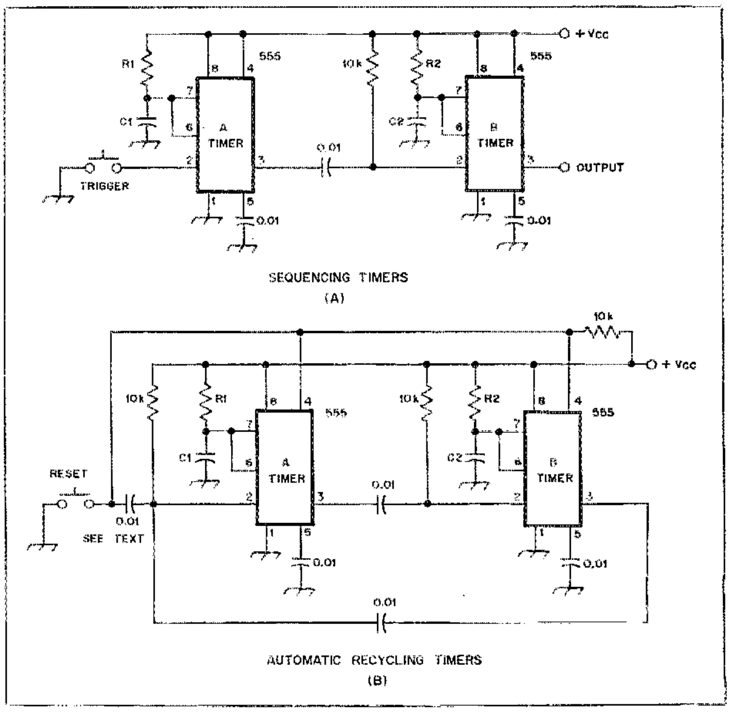

Fig. 3 — Methods for sequencing timers. The circuit at A is simply one timer being used to control a second. At B, the additional feature of automatic recycling is added by tying the output of U2 back to the trigger of U1.

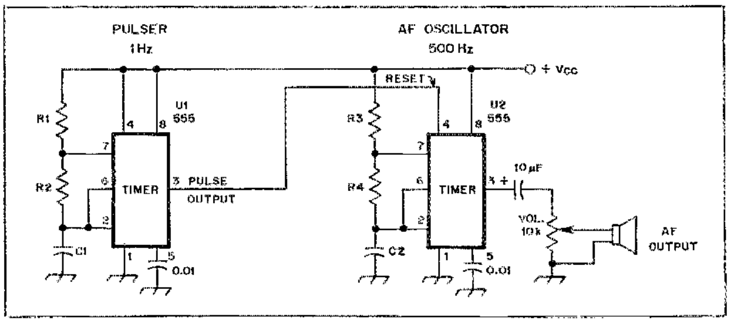

Fig. 4 — Two timers are used here to produce a pulsed audio oscillator.

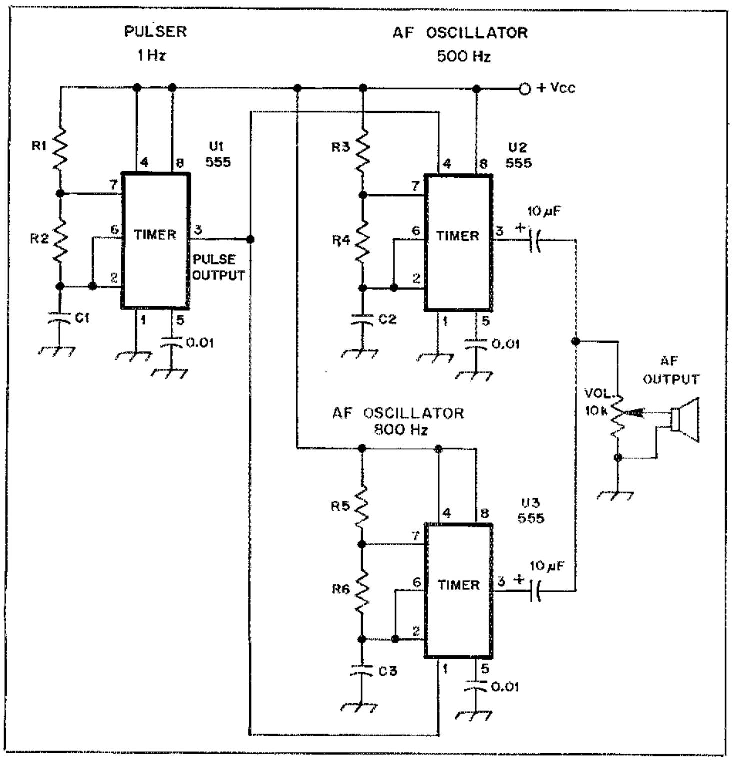

Fig. 5 — The pulsing oscillator of Fig. 4 can be modified to produce a warbling sound by adding another timer as shown here.

pin 5 controls an audio oscillator and an LED. Since the 555/556 timers have a fanout of 10 (can drive 10 standard loads) we can control many other devices. Fig. 7 shows some possibilities. In Fig. 7A, a 7404 inverter chip controls six LEDs which can be arranged in a pleasing geometric pattern. Fig. 7B shows a transistor lamp or relay driver. Fig. 7C shows the timer directly controlling a 6-volt, 400-ohm relay. The devices in Fig. 7 can also be controlled by U1B so they stay on for the entire 10-second warning period. This would permit a tape loop identification or some other continuously operating warning. The variations are nearly unlimited.

U2B (Fig. 6) is an audio-frequency oscillator with volume and tone controls. A two-inch speaker works well for warning tones, since fidelity is not a requisite. With the values shown, the tone can be varied from about 75 to 750 Hz. The volume is enough to warn even a sleeping operator!

Since the 555/556 series of timers operate from roughly 5 to 15 volts, a transistor-radio battery replacement power supply (with the components molded into the plug housing) works very well. If the timers drive ICs from the TTL series, then the supply needs to be 5 volts. A 6-volt radio supply, with a 5-volt, 1-watt Zener (as shown in Fig. 6) works best. If no lights or other heavy current loads are used with the timer, you can use batteries.

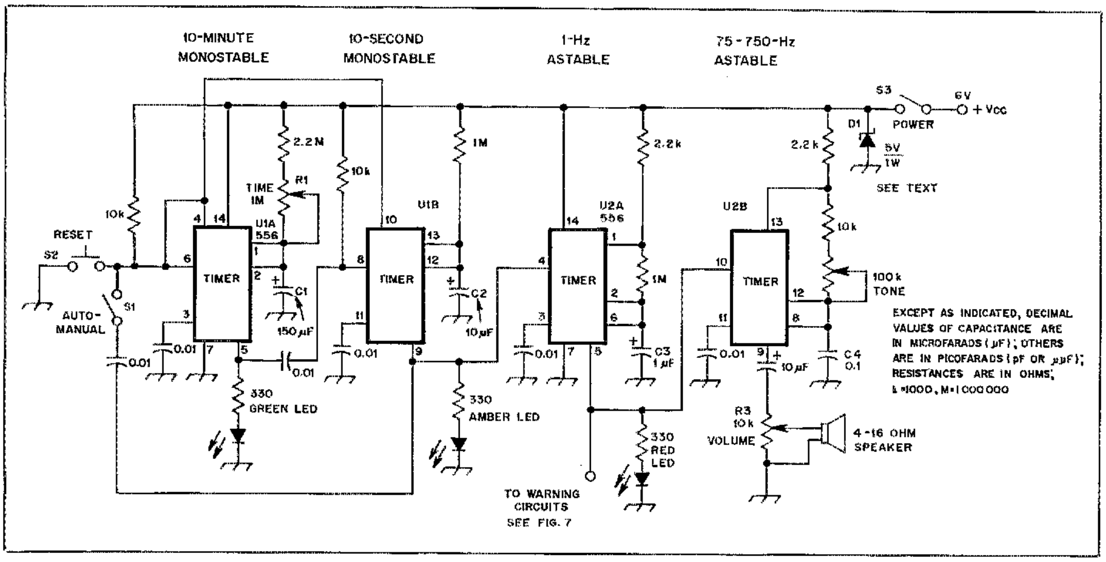

Fig. 6 — Schematic diagram of 10-minute station-identification warning timer. Fixed-value capacitors are disc ceramic unless otherwise noted. Resistors are 1/4- or 1/2-watt composition types. Parts numbers inside parentheses are Radio Shack parts suitable for use in this circuit.

C1 — 150-µF, 16-V electrolytic. Two or more capacitors paralleled to produce proper timing period. (See text.)
C2 — 10-µF, 16-V electrolytic.
C3 — 1-µF, 16-V, electrolytic. The value of this capacitor may be varied to alter the pulsing rate of the audio oscillator. A smaller value will make the pulsing faster.
R1 — 1-MΩ, thumbwheel pot (271-229).
R2 — 100-kΩ, thumbwheel pot (271-220).
R3 — 10-kΩ, thumbwheel pot (271-218).
S1, S3 — Spst toggle switch (275-612).
S2 — Spst, normally open, momentary contact (275-1547).
U1, U2 — 556, dual section timer (276-1728).

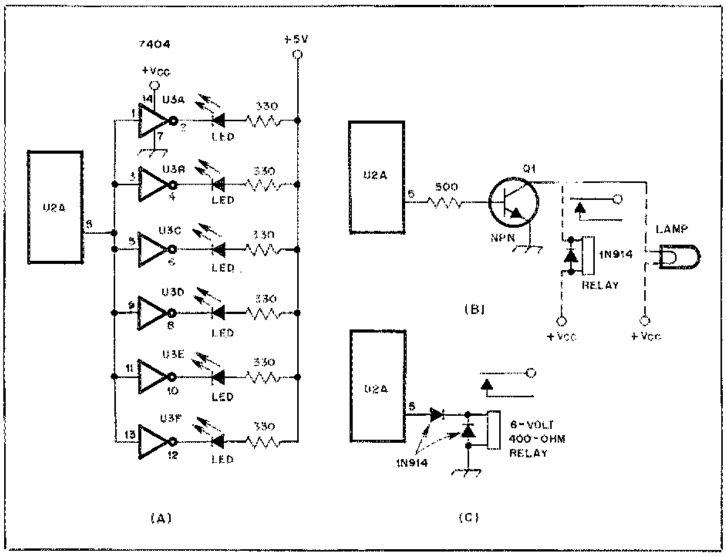

Fig. 7 — Three types of optional warning control circuits

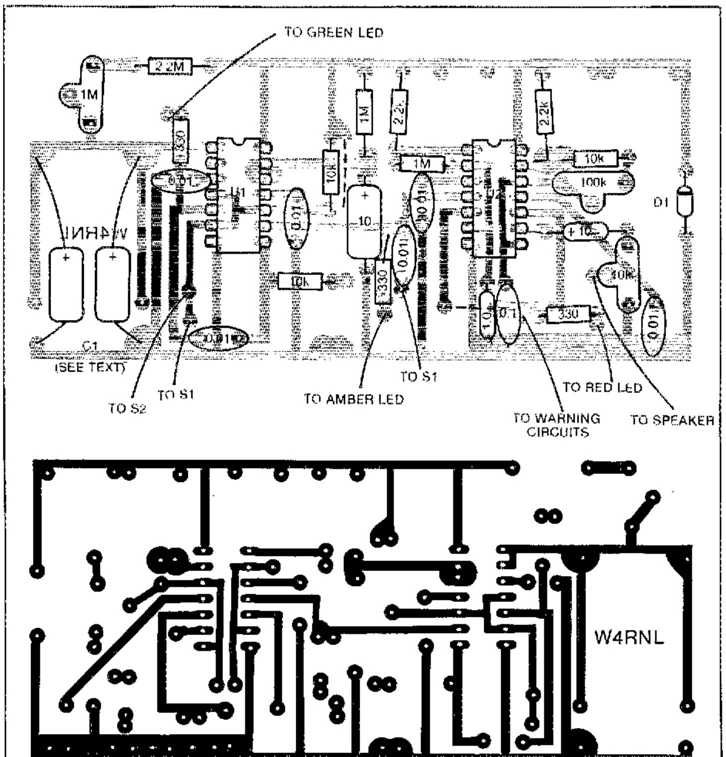

Fig. 8 — Top is parts-placement guide for the timer. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. Resistances are in ohms; k = 1000 and M = 1,000,000. All capacitances are in microfarads. Unmarked dotted lines indicate wire jumpers. Bottom is the etching pattern for the timer. Black represents copper. The pattern is shown at actual size from the foil side of the circuit board. Notice that space was left in the corner for paralleling capacitors to arrive empirically at the proper value for C1. The board was designed so that either radial- or axial-style capacitors may be used.

The entire unit (except LEDs and speaker) fits on a small etched board (Fig. 8). If the builder prefers, he can build it on a small piece of perf board; layout is not critical. A small plastic or metal box will hold everything, including a speaker and warning lights. Alternatively, the unit can be squeezed into almost any other piece of station equipment which has panel space for the speaker and warning lights (which might be blinking pilot lights for a dial readout).

Since each timer section costs about 50 cents, whether a 555 or 556 package, a few dollars will buy an endless supply of versatility. Learning to use various timing and pulsing capabilities, along with their sequencing possibilities, can be a start toward a more complex and important control circuit for the shack. This timer, which won't quit unless you make it, is a good start in that direction. QST

Strays

MOVING? UPGRADING?

☐ When you change your address or call sign, be sure to notify the Circulation Department at ARRL hq. Enclose a recent address label from a *QST* wrapper if at all possible. Address your letter to Circulation Department, ARRL, 225 Main St., Newington, CT 06111. Please allow six weeks for the change to take effect. Once we have the information, we'll make sure your records are kept up-to-date so you'll be sure to receive *QST* without interruption. If you're writing to Hq. about something else, please use a separate piece of paper for each separate request.

ATTENTION AFFILIATED CLUBS

☐ The latest copy of "Radio Club News" has been mailed to all affiliated clubs and should be in the hands of a club officer right now. This quarter's issue deals with your club and how to make it function more smoothly. Have you seen your club copy? Contact the officer in your club who receives ARRL affiliated club mail. — *Sally O'Dell, AE8P*

MEDICAL TRAFFIC STATION

☐ A station has been set up at the U.S. Public Health Service office in Cleveland, Ohio, for the purpose of handling emergency and priority medical traffic. Dr. Steven H. Posner, WB2QET/8, of Lakewood, Ohio, directs its operation (the first five minutes of each hour, 0800 to 1600 Eastern time, Monday through Friday). Frequency monitored is 28.911 MHz. The station has phone-patch capability to any medical facility in the U.S.

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood TL-922A Linear Amplifier

In compliance with the FCC 10-meter amplifier ban, Kenwood has introduced the TL-922A, a 1-kW cw, 2-kW PEP ssb, linear amplifier. The power supply is included in the 68 lb (31 kg) heavyweight package, and can be wired for a 240- or 120-volt ac input. Naturally, unless a very "stiff" 120-V service is available (that can supply 28 A peak!), connecting the '922A to 240 volts is recommended. The amplifier uses a pair of Eimac 3-500Z zero-bias triodes in the ubiquitous parallel, grounded-grid configuration. Band-switched pi-network input circuits are employed.

Cooling

An efficient system for cooling much of the circuitry (including the power supply) has been provided by the designers. Kenwood states that the amplifier will withstand a continuous key-down input of 1 kW for 10 minutes. They're right; the amplifier remained cool and unflustered throughout a 10-minute key-down test. The plates of the 3-500Z tubes hardly showed any color! In the remote event that the temperature of the high-voltage transformer rises to an unsafe value (145°C, according to Kenwood), a thermistor embedded in the transformer windings will disable the T/R relay and lock the amplifier in the standby mode. Kenwood has taken yet another measure to assure thorough cooling: When the amplifier is turned off, the fan remains on for about two minutes, then shuts off automatically. A note of caution: No screen is provided at the air outlet to prevent errant fingers from becoming entangled in the plastic fan blades. A metal rf shield is installed on the *inside* at the rear of the fan, however.

Operating and Aesthetic Considerations

The '922A is a very attractive and ruggedly built piece of equipment. The cabinet is finished in Kenwood gray, and the two side panels are heavy die castings. A metal handle is provided on each side panel, which makes it somewhat easier to move this large unit from workbench to operating table.

All the controls have a good "feel"; the plate-tuning control has a vernier drive for tuning ease. The T-R relay is rather large and seemed noisier than other linear-amplifier relays I have heard. The enclosure for the 240/120-V selection terminal block and the fan protrudes from the rear panel somewhat. Since all the connectors and terminals are below this protuberance, they were blocked from sight in my crowded station set up. I had to make all the connections to the unit by touch.

Getting the TL-922A on 10 Meters

Outside the United States, this amplifier is known as the TL-922 (no *A* suffix), and covers

*Assistant Technical Editor, *QST*

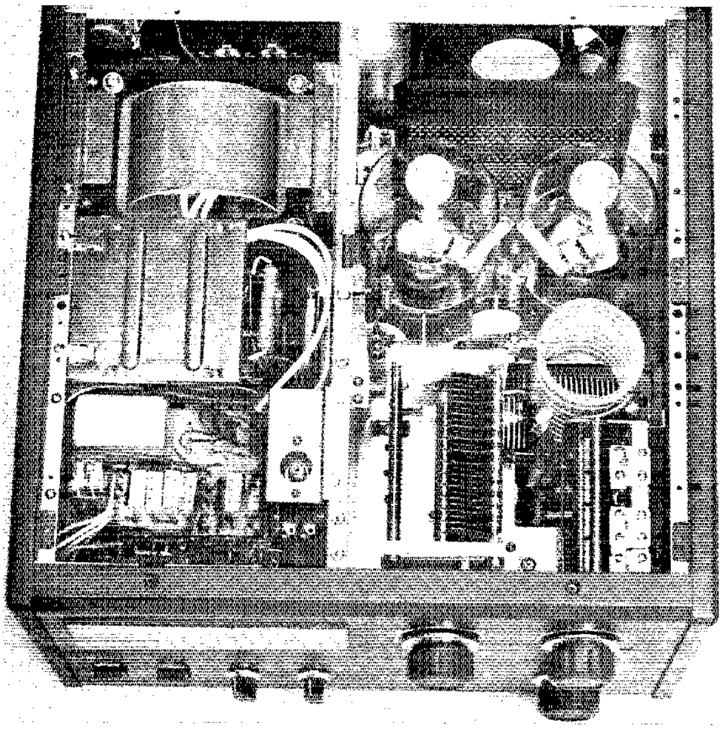

Fig. 1 — An interior view of the Kenwood TL-922A linear amplifier. In the power-supply compartment on the left, the massive high-voltage transformer is visible at the rear. A second transformer, which supplies filament, relay and lamp voltages, is located under the circuit board at the front.

the 160- through 10-meter bands. In the USA the *A* suffix means that 10-meter coverage has been deleted. Fortunately for the amateur who wants to wear his "shoes" on 10 meters too, the '922A can be restored to six-band coverage.

Kenwood engineers have cleverly "absorbed" the unneeded 10-meter input coil into the 15-meter input network. This simplifies the conversion considerably.

To begin the modification, the 10-meter coil and five capacitors are removed from the 15-meter network, and a single 120-pF, 500-V capacitor is added to complete the new 15-meter network. See Fig. 2. The newly freed 10-meter coil is now wired to the 10-meter band-switch position, and another 120-pF, 500-V capacitor is added to complete the 10-meter input network. A setscrew is removed from behind the band-switch knob to allow the switch to rotate into the 10-meter position. Last, a jumper is installed on the band switch, which allows the pi network to resonate on 10 meters. The '922A is now a 160-10 meter amplifier; it lacks only front-panel 10-meter labels for the band switch and TUNE control.

Loose Ends

The '922A has double protection against accidental contact with the high-voltage supply. Removing the upper case cover disconnects power from the primary of the high-voltage transformer. Removing an inside shield plate to gain access to the rf compartment shorts the high-voltage supply bus to ground.

An adjustable negative-going alc output is provided which, when connected to a compatible exciter (all Kenwood exciters are compatible), can prevent overdriving the amplifier. To test the usefulness of the alc output, a Kenwood TS-120S transceiver was borrowed for use with the amplifier. When carefully adjusted, the alc limited the drive from the exciter to the level just required for a 1-kW dc input. It was then no longer necessary to worry about

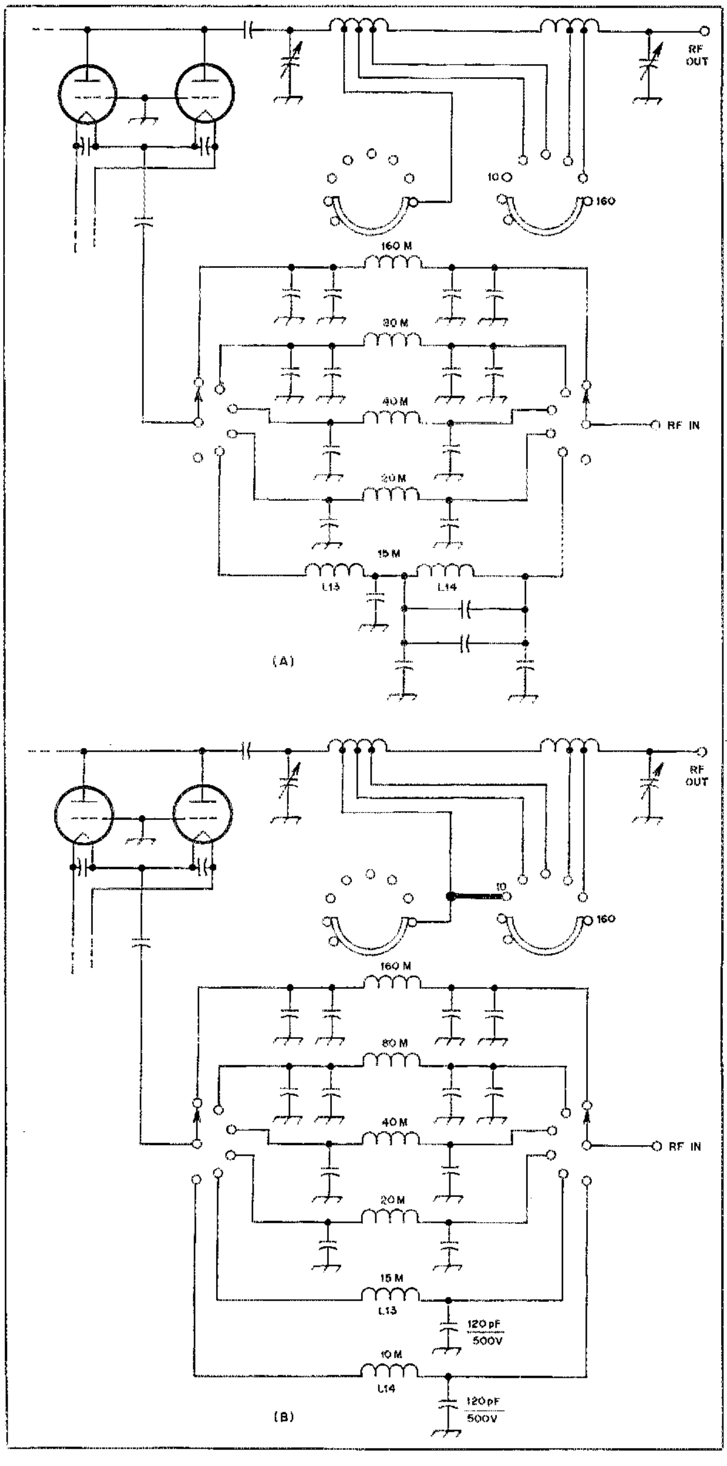

Fig. 2 — A simplified partial schematic diagram of the TL-922 amplifier band-switching arrangements. The original circuit is shown in A. The changes, to convert the '922A to a six-band amplifier, shown in B, are the addition of a jumper wire (the heavy line) in the output pi network, and modifications to the 15- and 10-meter input circuits. Part numbers shown are those assigned by Kenwood.

Kenwood TL-922A Linear Amplifier

Manufacturer's Claimed Specifications

Size (HWD): 7-1/2 × 15-3/8 × 16 inches (190 × 390 × 407 mm).
Power requirements: 120 V, 28 A; 240 V, 14 A; 50/60 Hz.
Input impedance: 50 ohms unbalanced at better than 1.5:1 SWR.*
Driving power required: 80 W nominal, 120 W maximum.*
Duty cycle: Ssb, continuous for 30 minutes. Cw and RTTY, key-down continuous for 10 minutes.
Frequency range: The 1.8- through 21-MHz amateur bands.
Price class: $1200.
Manufacturer: Trio-Kenwood Communications Inc., 1111 West Walnut, Compton, CA 90220.
*See Table 1 for results of ARRL lab measurements.

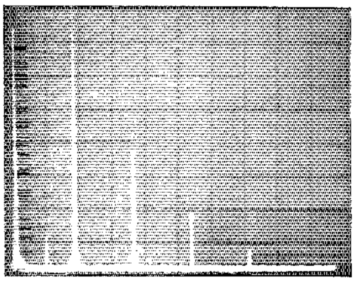

Fig. 3 — This photograph shows the spectral output of the TL-922A operating at a 1-kW dc input on 80 meters, which presented the worst case for spectral purity. The horizontal scale is 2 MHz per division and the vertical is 10 dB per division. The second harmonic is down about 43 dB, meeting FCC requirements.

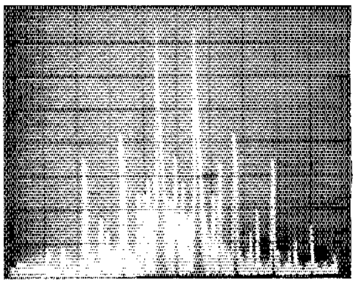

Fig. 4 — A two-tone IMD photograph of the TL-922A operating on 20 meters. The horizontal scale is 1 kHz per division and the vertical scale is 10 dB per division. Third-order products are down 37 dB; fifth-order products are down 45 dB from the PEP level.

exceeding the legal limit, or overdriving the amplifier. Unfortunately, the system gain varied slightly from band to band, so a perfect setting on one band was never optimum on another.

Speaking of loose ends, while the '922A certainly is excellent evidence that "they can still build 'em like they used to," they don't necessarily solder 'em like they used to. When the amplifier was opened for installation of the

Table 1

Results of TL-922A Tests Performed in the ARRL Laboratory

Band	Power Input (watts)	Power Output (watts)	Efficiency (%)	Drive Power Required (watts)	Input SWR
160	1000	680	68	84	1.49:1
160	2000	1300	65	100 +	
80	1000	750	75	110	1.63:1
80	2000	1490	75	100 +	
40	1000	780	78	86	1.20:1
40	2000	1550	78	100 +	
20	1000	720	72	73	1.58:1
20	2000	1480	74	100 +	
15	1000	630	63	66	1.23:1
15	2000	1540	77	100 +	
10	1000	680	68	73	1.37:1
10	2000	1500	75	100 +	

power tubes (they come packed in a separate carton), an unsoldered wire on the "meter unit" circuit board was noticed. The wire was neatly wrapped around its terminal, but was completely untouched by solder!

One evening while using the amplifier on 80-meter cw, an rf arc occurred somewhere in the final-amplifier compartment. It persisted for a few seconds, and then burned itself out. After removing the covers and poking around a bit, I discovered the cause of the undesired electrical activity: A metal strap connected to a pi-network coil tap had arced through its insulation to the chassis. Of course, I repositioned the strap to prevent further problems, but in so doing, I disturbed the coaxial cable which connects the pi-network output to the T-R relay. The center conductor had apparently been only tacked to the pi-network output, because it broke loose with only the slightest prodding. I'm glad I discovered this before any serious damage was done!

Despite the irregularities just mentioned, my overall impression of this amplifier is quite favorable. Its operation was smooth, predictable and stable. This, coupled with the relatively inexpensive cost of replacement tubes, makes it a very desirable station accessory. — *John C. Pelham, W1JA*

HEATH HM-2141 VHF WATTMETER

☐ This station accessory measures rf power in the frequency range of 50 to 175 MHz, which makes it useful on the 6- and 2-meter amateur bands. In normal operation, the left-hand meter indicates reflected power in two selectable ranges: 0 to 10 and 0 to 100 watts. The right-hand meter reads forward power in the ranges of 0 to 30 and 0 to 300 watts. Owners of efficient kilowatt amplifiers will no doubt be disappointed that a higher power range isn't included. Another mode of operation may be selected in which the '2141 will calculate the SWR: The right-hand meter indicates forward power and the left-hand meter reads reflected power on a scale calibrated from 1:1 to 3:1.

This versatile instrument can also measure peak-envelope power on ssb or a-m (or cw, for that matter). A peak-detecting and holding circuit using a quad op-amp IC is employed. This circuit is powered by a 9-volt transistor-radio battery. The battery is used only when the PEP-AVG switch is in the PEP position, so one must remember to return the switch to the AVG position when the wattmeter is not in use. If the SWR sensitivity control is rotated fully counterclockwise to an unmarked calibrate position, and the PEP-AVG switch is in the PEP position, the battery voltage may be checked on the right-hand meter. Alternatively, an ac adapter to take the place of the battery may be purchased from Heath.

Building the Kit

Following the superbly written Heathkit instructions, I completed the assembly of this kit in exactly two hours, including time to test each resistor, capacitor and diode with an ohmmeter, and calibrate the PEP circuits. (Testing components is standard procedure whenever I build a kit — defective parts are *much* easier to spot when checked apart from the rest of the circuit!) All Heathkits I had built previously used a phenolic material for all the circuit boards. I was impressed by the neat glass-epoxy circuit board used in this kit; solder resist applied to the foil side of the board made it easy to conserve solder while obtaining a good-looking result.

The remote sensor is assembled, calibrated and sealed at the factory. The instructions contain warnings that breaking the seal can void the warranty.

Using and Testing the Meter

When assembly was finished, I had one leftover nut, one lockwasher, a small amount of solder and a completed wattmeter for my efforts. The unit worked perfectly the first time it was used, and continued to function without a snag. I observed only one minor operating inconvenience: I feel that Heath should have used toggle or slide switches instead of the four push-button switches located under the meters. When the front panel is viewed from directly in front (as it should be viewed to avoid parallax error when reading the meters) it is very difficult to tell if the buttons are in or out in my dimly lighted shack. Toggle or slide switches would have obviated this difficulty.

The unit was tested in the ARRL laboratory with the aid of a Bird wattmeter and a 50-ohm dummy load. A power level of 10.0 watts (according to the Bird meter) was used on 50 and 144 MHz. The HM-2141 indicated 9.9 watts on 6 meters and 9.1 watts on 2 meters. Heath's specification of ±7.5% of the full-scale reading on the 30-, 100- and 300-watt scales translates to ±2.25 watts on the 30-watt scale that was used. The maximum 0.9-watt error on 2 meters is well within this specification. The dimensions of the meter unit (HWD) are: 4-1/8 × 7-1/2 × 6-3/8 inches (105 × 191 × 162 mm). The price class of the HM-2141 is $75. It is available from Heath Company, Benton Harbor, MI 49022 or from Heathkit retail stores. — *John C. Pelham, W1JA*

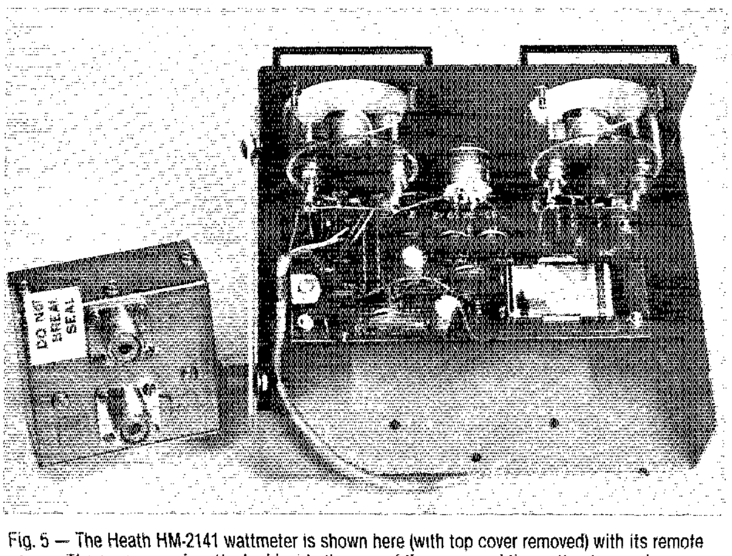

Fig. 5 — The Heath HM-2141 wattmeter is shown here (with top cover removed) with its remote sensor. The sensor can be attached inside the rear of the case, and the wattmeter used as a single, integral unit.

COMMUNICATIONS SPECIALISTS TE-64 TONE ENCODER

☐ You mention PL[1] to most hams who are active on fm and the reaction is usually negative,

[1]PL stands for Private Line; both terms are registered trade marks of Motorola. General Electric refers to a similar system as Channel Guard. The generic name is Continuous Tone Coded Squelch System, which is cumbersome, even in its abbreviated form, CTCSS. Since PL is used as the generic term in popular amateur parlance, we have chosen to use it here.

Communications Specialists TE-64 Tone Encoder

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency accuracy (subaudible) — ±0.1 Hz maximum, −40 to +85° C.	±0.1 Hz at room temperature.
Frequency stability (audible) — ±1 Hz maximum, −40 to +85° C.	±1 Hz at room temperature.
Output level — 5-V pk-pk, adjustable, flat to within 1.5 dB over range selected.	5.2-V pk-pk, adjustable, flat to within 1 dB over range selected.
Wave shape — Sine wave.	Sine wave.
Power requirement — 8 mA at 6- to 30-V dc (may be operated by adding internal 9-V transistor battery.)	
Reverse polarity protection built in.	
Off position for no tone output	
Size of case without mounting bracket — 5-1/4 × 3-1/3 × 1-2/3 inch (133 × 85 × 43 mm).	
Weight — 8 oz (0.2 kg).	
Color — Black.	
Price Class — $80.	

if not down-right hostile. A long time ago, back in the dawning ages of amateur fm operation, frequency space was not at a premium, even in southern California. A few groups picked up on PL-type operation at the time with the expressed or implied attitude of "if you ain't one of us superior, super-select, ultra-cool, noble snobs, get your crummy rig off OUR frequency and don't ever darken OUR repeater with your presence again." Nice guys, huh? These *gentlemen* soon received the contempt that they had courted and earned with their supercilious behavior. Unfortunately, in the process PL took it on the chin along with these clods. Hence, the general disdain for PL in the amateur circles.

This column is devoted to product review and not ancient history or contemporary social theory of the air waves, so what gives, you say. To appreciate the beauty of the Communications Specialists TE-64 Tone Encoder, you must look beyond how things *are* to how they *might be*. It is my belief that amateur fm-ers are now in a position where they are "cutting off their noses to spite their faces." PL may offer some cheap, practical solutions to problems resulting from the crowded spectrum — particularly 2-meter fm and 10-meter fm.

A PL tone is any one of the 32 standard tones ranging from 67.0 to 203.5 Hz. This group is generally referred to as the subaudible group — subaudible because the tones are set at a very low deviation (usually around 500 Hz in a 5 kHz system) and because the corresponding receiver generally has a high-pass filter installed in the audio chain to attenuate these low frequencies. The tone is activated when the microphone button is pressed and stays on during the entire transmission.

In a PL system, the receiver is equipped with a decoder that is set to recognize the presence or lack of the PL tone. The PL decoder controls a switch that is paralled with the standard squelch switch. Typically, in a commercial installation, the user has the option of choosing either standard or PL squelch. However, it is simple to parallel them such that either a PL signal or a non-PL signal will open the receiver. Art Reis, K9XI, described a system using this concept whereby the receiver required a non-PL signal to have 20 dB of quieting to open the receiver, while a PL signal would open it at less than 0.15 microvolt.[2] Objectively viewed, the

[2] Reis, "Should Repeaters Use Subaudible Tones?" *73 Magazine*, July 1978, p. 102.

old anti-PL argument that PL keeps the transients out doesn't hold up. It just keeps the unwanted weak signals out.

The other valid argument against PL *was* that one had to install an encoder and purchase a "reed" or similar device for each PL tone to be used. To change from one PL tone to another was time-consuming and expensive. Now, through the same magic that brings you 800 channels in the palm of your hand, there is a device that inexpensively provides you with your choice of any of the standard tones at the turn of a switch. Punch another button and you have the standard "tone-burst" or audible tones plus the tones making up the "touch-tone" system. Again, objectively viewed, the second anti-PL argument does not stand up.

Small Package, Smaller Contents

Upon first seeing the outside of the TE-64, I was struck by the complexity of the front panel. The selector knob has 32 lines extending out to 32 sets of dual tone markings — one each for subaudible and audible tones. There is also a push switch that allows the user to choose between the audible and the subaudible groups. Surely, such a small package with so much on the front panel must be jammed full of circuitry inside.

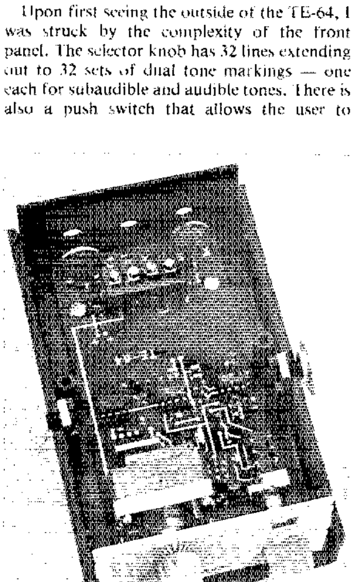

Fig. 6 — The interior view of the TE-64 reveals a rather spacious layout. External connections are made by means of the terminal board located at the rear of the unit.

After loosening the two thumbwheel retaining screws, I removed the top cover and was shocked! This small package could have been made a lot smaller! There are three 8-pin ICs (dual op amps), one 18-pin IC (a Communications Specialists' proprietary chip that does all the fancy work), a 1-MHz crystal and a handful of resistors and capacitors. The two switches are the largest components by far. I do not know of any fm radio (including portables) that does not have enough room in it for the electronics of this device to fit into.

As in most other areas of the U.S., none of the 2-meter repeaters in the Hartford area are equipped for PL operation. I did connect the TE-64 to a 10-meter fm rig and used it to access a couple of 10-meter repeaters. Although the instructions for installation are not overly detailed, anyone familiar with the workings of an fm transmitter and having the schematic diagram for the transmitter in question should have no trouble in satisfactorily attaching the TE-64 to his transmitter. If tone-burst operation (audible) is desired, the user should find it even easier to connect the TE-64 to his transmitter.

In addition to limited on-the-air tests with the unit, we ran it through its paces in the lab. An oscilloscope connected to the output showed that the TE-64 produces sine waves for both the subaudible and the audible groups. There are separate outputs for each group and separate level controls which are completely independent of each other. We did not notice distortion of the waveform at any setting of either level control. The audible group is set up as a "burst" when power is first applied. By merely clipping one jumper, the audible group becomes continuous instead of "burst." Obviously, one could replace the jumper with an spst switch. The "burst" is factory set at about one-half second, but this can be altered by changing one resistor.

I used an Optoelectronics 8010-1.3 frequency counter to check for accuracy. In all cases, the TE-64 was within 0.1 Hz of the specified frequency. It has been my experience with commercial decoders that most will "recognize" a tone that is within 1.5 Hz of the specified frequency. Unfortunately, the ARRL lab does not have facilities for checking equipment at temperature extremes, so no data is available on the amount of drift, if any, as *temperature* varies. The TE-64 was left running for over an hour with no discernable drift. It seems reasonable to conclude that the accuracy is more than adequate for general amateur use.

Do you find yourself turning off your 2-meter rig because the repeater is constantly keying up on weak signals — signals that are not intended for your repeater anyway? Are you annoyed by the noise and static that comes crashing through your repeater during marginal band openings? Dual squelch systems combined with low-cost, high-technology devices such as the TE-64 may be the answer you are looking for. We can maintain an open, friendly attitude to transients (in the best spirit of Amateur Radio) and keep 2-meter fm a noise-free, static-free, pleasant-to-listen-to, local communications medium. Of course some hams are so rigid in their thinking that they seem to take a perverse delight in "cutting off their noses to spite their faces." — *Pete O'Dell, AE8Q*

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

CONNECTORS FOR CATV "HARDLINE" AND HELIAX

□ There seems to be an abundance of surplus and sometimes free 75-ohm CATV Hardline available to amateurs at flea markets, junk yards, and who knows where. Low-loss, long-life-span line of this type is being avoided by some amateurs because the connectors for it are not only difficult to find, but they're horribly expensive. Depending on the source for these connectors we hams can pay from $10 to more than $25 for the fancy hardware.

Figs. 1 and 2 show how the writer solved the connector problem with ordinary materials. The examples at A and B (Fig. 2) show uhf-style connectors, but similar methods of construction can be used to accommodate type N connectors.

Illustration A of Fig. 2 indicates how to maintain the line impedance by using a 3/4-inch (19-mm) OD tubing slug inside a tubing section that has an ID of 3/4 inch. The solder lug on J1 is spread to accept the tapered end of the coax cable center conductor. Soldering is done through the slot in the tubing slug. Conductive grease or a thin coating of silicone grease is spread on the mating surfaces of the parts, then they are affixed firmly in position with stainless-steel hose clamps.

If a male connector is needed, the scheme at B can be applied. A piece of 1/2-inch ID (13-mm) aluminum tubing is slotted with a hack saw, then fanned at one end to provide an ID of 3/4 inch. This end clamps to the coax cable and the small end clamps to the PL-259 connector collet. The center conductor of the coax line is drilled to take a length of no. 14 bus wire. The wire is soldered into the hole in a secure manner. Stainless-steel hose clamps (2) are used to lock the assembly together.

The technique shown at B will cause a slight impedance discontinuity between the coax line and the end of the PL-259, but the magnitude of the "bump" will be of little concern at 2 meters and lower. There will be very little disruption to the line impedance when using the method shown at A.

Half-inch Hardline is simple to use when installing a PL-259 connector. The details are shown at C. The outer jacket is removed 7/8 inch (29 mm) from the end of the cable. The foam dielectric is made smaller in diameter so

*Assistant Technical Editor, *QST*

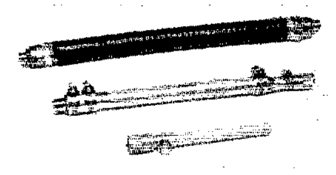

Fig. 1 — Methods of connecting coaxial couplings to Hardline cable. Pete O'Dell, AE8Q, made the adaptations for 7/8-inch Heliax shown above with the black jacket. Doug DeMaw, W1FB, developed an alternative method for use with metal-jacketed Hardline. The two samples in the foreground show his way of attaching the fittings to the cable. Detailed drawings of these are presented in Fig 2.

that it will screw into the end of the PL-258 snugly. The center conductor is drilled to accept 3/4 inch of no. 14 bus wire, which is soldered firmly into the center-conductor hole. An adaptor sleeve is made from 1/2-inch OD aluminum tubing as shown in the drawing. A 3/16-inch (4.8-mm) slot is cut in the adaptor to allow good compression when the hose clamp is tightened. The adaptor joins the rear end of the PL-259 to the outer jacket of the cable. Only one 1/2-inch hose clamp is required. This system of installing a connector does not cause a significant "bump" in the line impedance.

The cable ends can be weatherproofed by applying corrosion-resistant RTV sealant to close up the various openings in the adaptors. Alternatively, the amateur may want to retain most of the foam dielectric and use it as filler for inside the adaptors. If this is done, vinyl electrical tape will suffice for protection against moisture and air pollutants. The tape would then be wrapped around the outside of the adaptor assembly. – *Doug DeMaw, W1FB*

□ The 7/8-inch (29-mm) Heliax cable consists of an outer vinyl jacket over the corrugated copper outer conductor. The inner dielectric is foam material. Like its CATV cousins, Hardline is usually much easier to come by than the connectors!

All that is needed for the homemade-connector construction is a short piece of 1/4-inch OD copper tubing, a 7/8-inch copper sweat cap and a rear mount uhf connector (Amphenol 83-878). The 7/8-inch sweat cap can be obtained from a plumbing-supply house, or in the plumbing section of a discount store. You will need a heavy-duty soldering iron (the common 140-watt variety is not big enough). A propane torch with a soldering-tip attachment will work if reasonable care is exercised. You will also need a tubing cutter and a flaring tool.

Start by removing 3/4 inch (19 mm) of the outer vinyl jacket from one end. Using a sharp hacksaw make at least six equally spaced notches lengthwise in the exposed copper outer conductor. *Take care not to damage the center conductor.* Use a pair of small, sharp diagonal cutters to cut any remaining metal along the notches back to the vinyl. Now fan out and fold the six (at least) fingers back to the vinyl, exposing the foam dielectric. Use a sharp knife to cut away 1/8 inch (3 mm) of the dielectric.

Lay aside the coax for the moment. Use a flaring tool to spread one end of a piece of 1/4-inch OD copper tubing. Cut off the flared end of the tubing as near the end as possible (5/16 inch, [8 mm], typical). Make sure that the flared end is large enough to resist sliding inside the center conductor. This will serve as a reducer. Insert the reducer into the center conductor such that the flared end rests against the end of the inner conductor. Spread the solder pin on J1 (Fig. 3) so that it provides a tight fit inside the reducer. Using a high-wattage iron and plenty of solder, secure the reducer to the center conductor. While the solder is still flowing, insert the pin of J1 into the reducer, then shove J1 tightly against the Hardline. After the solder has set, twist J1 slightly to ensure that you have a solid connection.

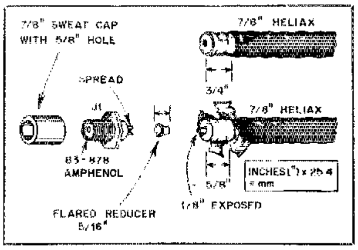

Fig. 3 — An illustration of the way that Pete O'Dell, AE8Q, suggests for fastening coaxial connectors to 7/8-inch Heliax cable.

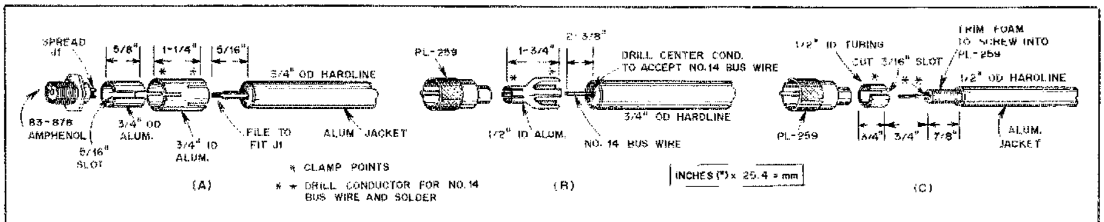

Fig. 2 — Construction details for using inexpensive connectors with 75-ohm CATV Hardline. Detail A shows a female adaptor and B illustrates how to apply a male connector to the cable. Hose clamps hold the hardware in place. J1 is an imported bulkhead-mount connector. An SO-239 can be used by cutting off the mounting flange.

Drill or punch a 5/8-inch hole in the top of the 7/8-inch sweat cap. Slide the cap down over the connector and onto the dielectric. Carefully, tighten the retaining nut. Fold the metal "fingers" down over the bottom of the sweat cap and solder. A hose clamp can be used to hold fingers in place while soldering. — *Pete O'Dell, AE8Q*

YAESU CPU-2500R MANUAL-SCAN MODIFICATION

□ The manual-scan mode of the Yaesu CPU-2500R scans continuously, ignoring any occupied channels. The installation of either of the following two modifications greatly enhances the utility and enjoyment of the CPU-2500R. The modifications provide for stopping the scan mode on channels and resuming the scan. The two diagrams show simple and proven methods to control the logic to either (1) scan continuously for an occupied or busy channel and lock on that channel, then resume scanning when the status of that channel is changed, or (2) scan continuously for an occupied or busy channel and lock on that channel for one to 10 seconds, then resume scanning.

Both schemes operate by automatically activating the scan logic in the manual mode. This causes a low on the down-scan line. The low is applied by hard-wiring it into the manual position of the AUTO/MAN switch as shown in drawing A. The down switch is used in both of these methods as it is easily accessible.

In diagram B, a 555 IC timer serves as an independent timer to periodically apply a low to the down-scan line. This is the same as pushing the down switch periodically. The period is determined by the setting of a potentiometer. By resetting the AUTO/MAN switch to the AUTO position, the logic will operate in the normal fashion and hold on the frequency desired according to the position of the SCAN-STOP-MODE switch for either busy or clear channels.

The 555 and supporting circuitry can be installed on a small perf board. This may be easily located in the area reserved for the optional tone-squelch unit on the receiver pc board. — *Robert Mielke, WB7TSG, Tucson, Arizona*

MORE THOUGHTS ON THE ACCU-KEYER

□ If you've built WA5KPG's version of the Accu-Keyer,[1] you may be interested in similar minimum-current arrangements for K8AW's trailing dot eliminator[2] and N7RT's Accu-Weight control.[3] Reversing N7RT's resistance-shunting diode, in a slightly altered "weight" circuit, discharges the small capacitor quickly. The result is that the charging rate (pulse-stretching delay) now becomes directly proportional to the potentiometer setting. The values given are widely different from the original, but work well and take up less room. You could use a 500-kΩ potentiometer and a 0.1-μF capacitor, or other similar values. Subminiature components are fine. Supply voltages in both circuits may be varied within the usual CMOS limits. Total keyer current increases with voltage, as would be expected. — *Albert H. Jackson, VE3QQ, Penetanguishene, Ontario* [QST]

[1]Hinkle, "An Accu-Keyer for QRPp Operation," January 1976 *QST*, p. 24.
[2]Hanthorn, "Eliminating the Trailing Dot," July 1978 *QST*, p. 34.
[3]Landskov, "The Accu-Weight," January 1979 *QST*, p. 50.

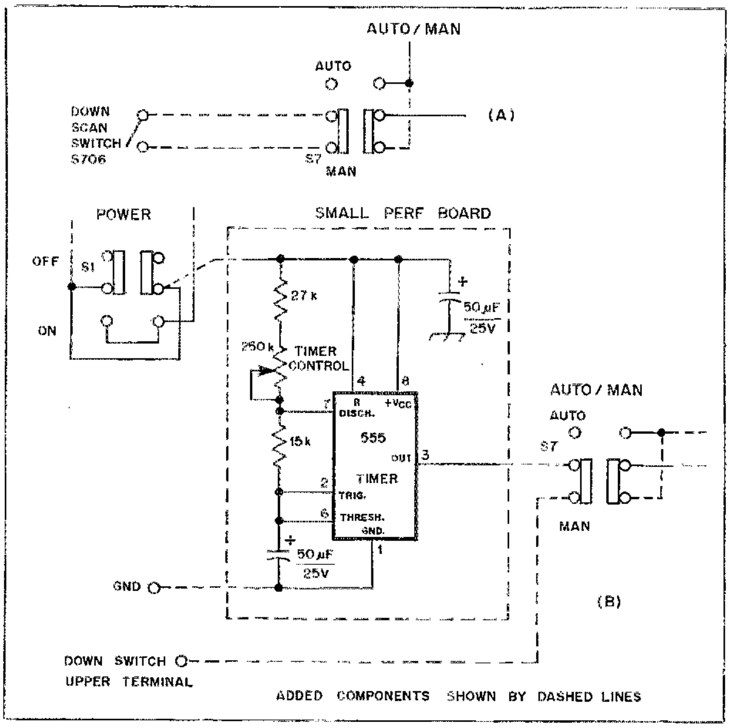

Fig. 4 — A scanning modification for the Yaesu CPU-2500R. Diagram A illustrates a modification for stopping on an active channel. The method shown in drawing B permits the scanning to resume after a selected period. These ideas are furnished by Robert Mielke, WB7TSG. Resistance values are in ohms.

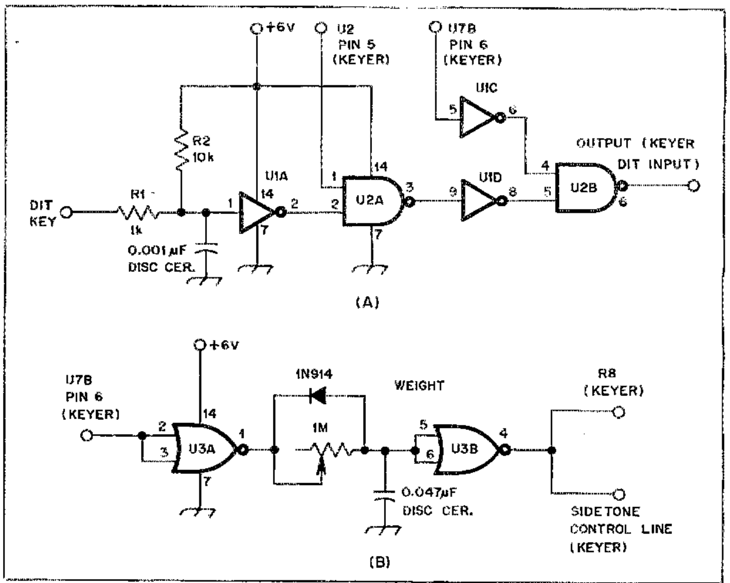

Fig. 5 — A. H. Jackson, VE3QQ, provides a circuit (A) employing a CMOS IC for eliminating the trailing dot noted on some Accu-Keyers. He has also shown his circuit (B) that uses a CMOS IC for the Accu-Weight control. In the dot-eliminator circuit, R1 and R2 are 1/4 watt. U1 (74C04) input pins 3, 11 and 13 are grounded. Spare outputs 4, 10 and 12 are left open. U2 (74C00) inputs pins 9, 10, 12 and 13 are grounded. Spare outputs 8 and 11 are left open. In the weight-control circuit, U3 (74C02) inputs pins 8, 9, 11 and 12 are grounded. Spare outputs 10 and 13 are left open. Disconnect the IC end of R8 and sidetone control line from U7B, pin 6 (keyer). Reconnect as shown.

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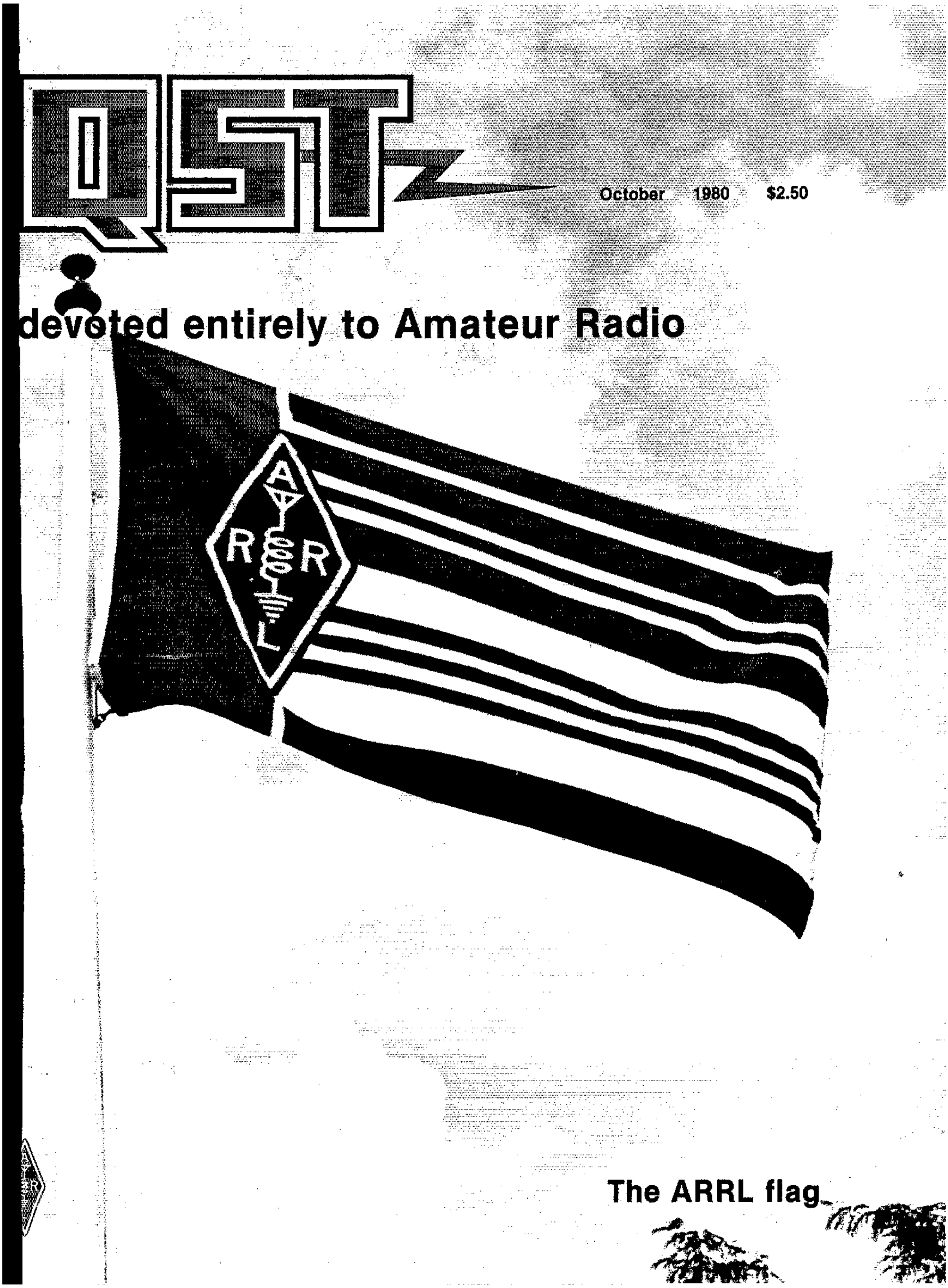

The ARRL flag

QST

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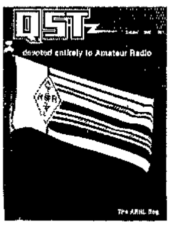
THE COVER

If you're a League member, you'll want an official flag. Several different versions of N4RX's winning design are available from League hq. See page 9.



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The Magnetospheric Echo Box — A Type of Long-Delayed Echo Explained

Radio amateurs have helped unlock the mystery of LDE signals that have puzzled scientists for over five decades. Continued observations, however, are still needed.

By O. G. Villard, Jr.,* W6QYT, D. B. Muldrew,** and F. W. Waxham, Jr.,*** K7DS

After 52 years, the mystery of one of the two types of long-delayed echoes (LDEs) reported by radio amateurs has been solved. The explanation turns out to be hf-wave trapping in occasionally occurring, tubular magnetospheric "ducts." These ducts stretch from northern to southern hemispheres along the earth's magnetic-field lines. Thanks to ionospheric-sounder satellites, the effect is now understood. In fact, the circumstances under which 80-meter operators can best access these up-to-60,000-kilometer-long magnetospheric echo boxes are set forth in this article.

Radio amateurs can be proud of the major contribution their reports have made in solving the problem of "echoes of the first type," which are characterized by delays of less than 1 second. Two explanations, based on modern plasma physics, have recently been published on the second type, which have delays of more than 1 second. Recently, Goodacre[1] has published recordings of what he believes are LDEs with delays between 1.5 and 9 seconds. Further reports of echo delays in excess of one second would be extremely helpful. Because LDEs seem to be so infrequent, both in time and space, amateurs provide perhaps the best hope of obtaining a meaningful number of reports against which to test the theories.

*Trustee, W6YX, Radioscience Laboratory, Stanford University, Stanford, CA 94305; also SRI International, Menlo Park, CA 94025
**Communications Research Centre, P. O. Box 11490, Station H, Ottawa, ON K2H 8S2
***12261 — 8th Ave., NW, Seattle, WA 98177

[1]References appear on page 14.

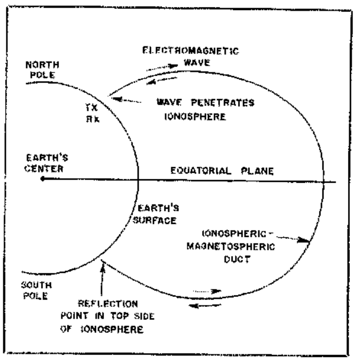

Fig. 1 — Sketch of a magnetospheric duct of the type responsible for 80-meter echoes having delays of 0.27 second. The duct length is about 40,000 kilometers and it passes over the equator at a height of 12,700 km. Diameter of the duct is only a few kilometers — too small to show on this scale.

A Noteworthy Example of How Radio Amateurs Can Help Science

On the evening of February 12, 1977, operation of a network of at least a dozen 75-meter ssb phone stations, centered in the Seattle-Tacoma area of the state of Washington, was almost totally disrupted by an echo of remarkable strength, clarity and delay. The delay was considerably in excess of the round-the-world value of 140 milliseconds. Virtually all the network stations in the Seattle area heard it, not only on their own signals, but also on each other's. Three stations in California that broke in heard the echo on the Seattle stations, but not on their own transmissions. Three other participating stations in New York, Utah and Oklahoma did not hear the echo at all.

For nearly two hours, the various stations observed the echo, marvelling at its clarity. In addition to testing it with cw and voiced bloops and bleeps, some station operators transmitted "chirps" by holding down the key and varying the frequency of their oscillators. Throughout, one of the authors, K7DS, ran his battery-operated tape recorder with the microphone held close to the speaker of his receiver.

This incident represents a noteworthy example of what radio amateurs can do to aid science. It is now virtually certain that this echo was caused by hf radio-wave trapping in a thin but enormously long magnetospheric duct, or tube, extending along the earth's magnetic-field lines high above the equator and into the southern hemisphere, as shown in Fig. 1. That something as unusual as this might occasionally occur was first proposed in 1959[2] and studied theoretically in 1962;[3] actually, radio amateurs had been observing anomalous 80-meter echoes all along,[4] but their data had never been collected. The necessary breakthrough came when the Canadian "Alouette" ionospheric-sounding satellite was launched in 1962. In exploring the topside of the ionosphere, the unexpected ducts were soon observed.[5,6,7,8] Since Alouette I actually flies through the ducts, it collects information relatively rapidly. Because the same ducts are random in occurrence and highly localized, scientific groups using ground-based sounding equipment have been unsuccessful in collecting significant information on them. It is fair to say that their ground-to-ground communication capabilities have only been revealed by Amateur Radio reports. Of these, by far the best and most comprehensive to date resulted from the February 12, 1977, episode described above.

Matters of Considerable Theoretical and Practical Interest

Fig. 2 shows a frequency-amplitude-time contour diagram of some of the manually generated "chirps" that permit especially accurate measurement of time delay. Throughout the duration of this event, the echo delay remained constant at 0.225 (±0.005) second. The calculated propagation time for a signal, trapped in a duct which terminates above Seattle, is 0.23 second. The recorded data (additional to that shown in Fig. 2) give an unparalleled feel for the size of the geographical region from which a duct can be accessed, the minute-to-minute variation of the strength of the ducted signal, the bandwidth, the multi-path, the short-term fading, the dispersion, the time delay and the attenuation. These are all matters of considerable theoretical and practical interest.

Another good example of ducted echoes is the multistation event reported by W6ONY and cited in reference 4. It took place around 0500 UTC on December 1, 1961. The delay was reported as varying between 0.1 and 0.5 second; the echo was heard by various stations in the Los Angeles area but not outside. On the basis of these and other findings, it is possible to be quite certain that the majority of the LDEs in the 80-meter band, which have been reported over the years, have been explained.

Source of the Echoes

A definable channel which guides radio waves over long distances is normally called a "duct." An example at microwave frequencies is the familiar waveguide. Hams normally transmit hf signals from place to place by reflecting them from the bottom side of ionospheric layers. As is well known, when the radio frequency becomes sufficiently high, signals penetrate completely through the ionosphere and are lost into space — unless of course, they are reflected or echoed back by something like a satellite or the moon. It now turns out that there is yet another way for penetrating hf signals to be returned to the transmitting station. If the frequency is less than or equal to about 4 MHz, waves can be trapped in column-like ducts (ionospheric waveguides, if you will) extending along the magnetic field of the earth. (See Fig. 1.) Such signals are guided over the equator and in most instances are reflected from the top of the ionosphere in the other hemisphere.

Such ducts consist of slight, localized depressions in the background electron density — perhaps one percent. They are remarkably small in diameter — perhaps a few kilometers. Their phenomenal stability — considering their size and enormous length — is explained by the magnetic field of the earth, which effectively locks them into position.

Ducts appear when irregularities in the lower ionosphere are created and moved by winds. Such moving clouds of plasma exert a drag on that portion of the magnetic field of the earth which penetrates them, thereby slightly displacing bundles of magnetic field lines. Because the lines have continuity, motion at their lower end will produce corresponding motion all along their length. It is this motion which creates the ducts even in the near vacuum far above the height of maximum ionization in the ionosphere.

Since the electron-density change is so small, it is remarkable that hf waves can be guided at all. Not surprisingly, there is a practical upper limit to the radio frequency of about 5 MHz. Fig. 3 is a recording made by Alouette of echoes resulting from ducted propagation when the source is a transmitter in orbit.

Once in a duct, a signal will travel essentially at the velocity of light, passing over the equator at a height which can be as much as 20,000 kilometers. The total one-way path length can be 60,000 km. When the signal comes close to the earth again, it can be reflected from the top side of the ionosphere; i.e., at a height above the electron-density maximum. In the northern hemisphere, winter conditions of low electron density an hour or more after sunset make it easy for 80-meter waves to penetrate the ionosphere and enter a duct. Opposite conditions exist in the southern hemisphere (where it is summer), so that the guided wave encounters a dense ionosphere and is reflected back. To an observer in the northern hemisphere, the long duct thus becomes an efficient echo box.

Brief History of LDEs — The Amateur Contribution

Long-delayed echoes were first reported in Norway in 1927 by an engineer named Jörgen Hals, not long after the beginning of shortwave broadcasting. The echoes attracted attention because their delays of 3 to 10 seconds far exceeded the delay (0.14 second) required for transmission completely around the earth. Hals described the echoes he observed as distorted replicas of the outgoing transmission.

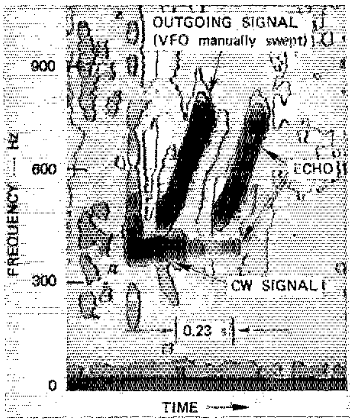

Fig. 2 — Typical frequency-amplitude-time contour plot of the echo heard in the Seattle area between 10:30 P.M., February 12, and 12:30 A.M., February 13, 1977 (local time). Relative amplitude is shown by the density of the contour lines. In this example, the transmitting station's VFO was varied manually, thus permitting exceptionally accurate measurement of delay.

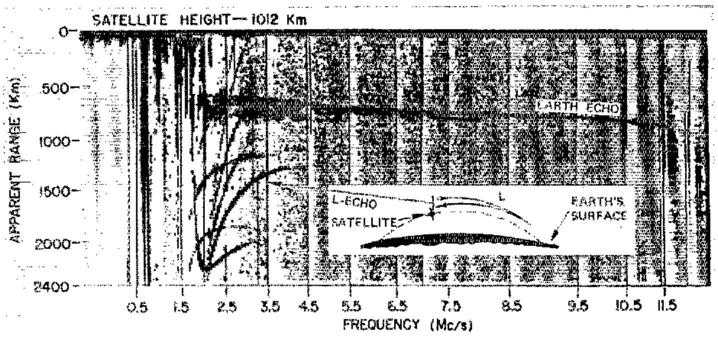

Fig. 3 — Delay-time (apparent range) versus frequency recording made by "Alouette 1" — a sounder in the topside ionosphere. The arrow in the sketch points to echo representing radio wave energy which traveled from the sounder along a duct until it was reflected from the top of the ionosphere in the southern hemisphere. The other echoes result from signals that bounce back and forth in the duct between the northern and southern hemispheres. Such ducts are responsible for the echo shown in Fig. 2. (See reference 5.)

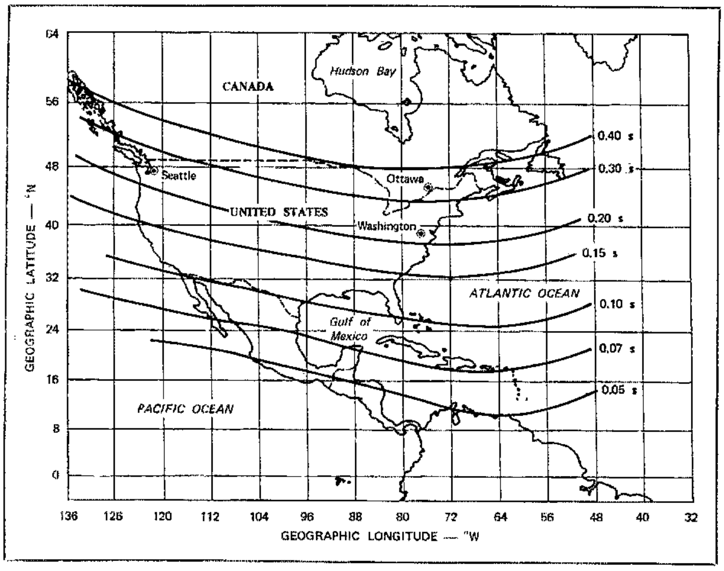

Fig. 4 — The relationship between duct location and round-trip echo delay time from Central America to Canada.

Often there would be more than one. More details can be found in a *Journal of Geophysical Research*[8] article that contains a complete review of LDE literature.

Hals communicated his findings to some of the leading radio scientists of his day — Störmer in Norway, van der Pol in Holland and Appleton in England. The first two apparently corroborated his observations. There was great difficulty in understanding why the signals didn't die away into inaudibility as round-the-world transmissions do.

In spite of many theoretical articles, scientific interest in the subject lagged during the 1930s. Just after World War II, the prestigious Cavendish Laboratory of Cambridge University started a special search for LDEs during which 27,000 signals were transmitted without one echo being heard.[9] One explanation offered was that the early observations might have been artifacts of the crude equipment of those days. A second was that the filling up of the radio spectrum that had occurred in the intervening 20 years might well have prevented further observations because of interference.

These explanations did not fully satisfy one of the authors, W6QYT, who initiated some experimental transmissions from Stanford University in 1958. He was aided by B. Dueno, KP4HF, of Mayaguez, Puerto Rico. Although some possible LDEs were recorded, it was never fully feasible to rule out alternative explanations for the observations. During the work, however, several instances of amateur observations of LDEs having both short (0.1 to 1.0 second) and long (3 to 30 seconds) delays came to light. This fact was reported in an article for *QST* and further reports were solicited.[10] A truly gratifying number of observations then poured in; they were summarized and published in two additional *QST* articles.[4,11]

These amateur reports extended over a period of years. They represent perhaps the most solid evidence of the reality and continued existence of LDEs of both kinds.

It became clear that the effect had not simply disappeared in the years since 1927; it has been present all along, although of such infrequent and sporadic occurrence that it is easy to understand why it had escaped observation by scientists and commercial users of radio alike. Only hams, it seems, are interested enough observers to catch these occasional oddities. Without their reports, it seems unlikely that the LDE phenomenon would enjoy its present credibility with the scientific community.

Fortunately, the reporting hams did not restrict themselves solely to echoes having 3- to 30-second delays, but sent in any type of echo which they thought unusual, irrespective of the actual delay. When echo delays are compared by frequency band, it becomes immediately apparent that something is unusual at 80 meters; a large percentage of the echoes at that frequency (or lower) are reported as having durations of less than 2 seconds. This finding was very encouraging because it suggested that the reports were not too badly contaminated by hoaxes. If the majority *were* hoaxes, the same spread of delays should be observed on each band, since there is little reason to expect that hoaxers would single out for special treatment any one band more than another.

It also turns out that estimating time delays accurately is very difficult when an unexpected and thus startling event such as an LDE takes place. This fact was verified in a simple test in which a group of radio amateur volunteers were asked to write down the time delays of simulated tape-recorded LDEs. Some actual one-second delays, for example, were reported as short as 0.3 and as long as 3 seconds. But the unmistakable difference between the reported 4-MHz time delays and those for higher bands shows clearly that the amateurs' estimates of time delay should, on the average, be treated with respect.

Now, what about those 80-meter echoes of relatively short delay? They, of course, turn out to be those from the magnetospheric echo box.

How to Access the Echo Boxes

The 160- and 80-meter bands are clearly the best to use. One duct, detected with satellite sounders, guided waves of frequencies up to 7 MHz, but this is very rare.

Being directly beneath the mouth of the duct is not necessary in order to have a signal trapped in the duct. However, the farther away from the mouth the transmitter is, the less the likelihood of trapping a signal.

The mouths of the ducts in the northern hemisphere exist all the way from Central America to southern Canada. Those at the lower latitudes have shorter lengths and, correspondingly, the trapped radio waves have shorter delay times. Higher latitude ducts are longer and the maximum delay time likely to be encountered is about 0.4 second. Calculated contours showing the relationship between delay time and geographical position are given in Fig. 4. At one location, ducted echoes have a time delay equal to round-the-world (RTW) propagation. RTW echoes, however, are seldom encountered at such low frequencies. Very high antennas would be required. On the other hand, the ducted echoes can be accessed with very simple antennas.

Ducts tend to be more numerous at the lower latitudes. They reach a maximum around 20° to 30° N. at American longitudes.

The Best Months

The best months for radio amateurs in North or South America for finding these ducted LDEs are December and January. In these months, the best conditions for receiving ducted echoes will be found in the northern hemisphere, as previously explained. Ducting in February and November is about half as common as ducting in December and January, but at least twice as common as from May to October.[1]

The best times are probably between 1900 and midnight (local time). One of the Seattle stations in K7DS's recording (we're not sure which one) said, "I've experienced it (the echo) three times on 80 meters in the last several years, but I've never figured out what it was."

For optimum results, an antenna that directs radiation more or less upward or in the direction of the magnetic field (30° south of vertical in the central United States) should be used. Avoid vertical antennas; a horizontal dipole or sloper is fine. If feasible, the dipole should be oriented east-west in order to direct the energy north and south. Quick transmit-receive switching or having another station do the transmitting is naturally very desirable. The radio operator's receiver should not have too long an agc time constant whenever echoes are being sought. For verification, the time delay must somehow be measured. A tape recorder is almost indispensable.

Current Theories of the Second Type of LDE and the Need for More Reports

LDEs having time delays in the 0.5- to 30-second range cannot be explained by the ducting phenomenon. Ducts of sufficient length do not exist. Several theories have been offered to explain the echoes having longer delays. One of these is by Crawford and his students.[12] A more recent theory is by one of the present authors.[8] Both theories overcome the central problem of explaining signal decay with time by postulating an amplifying interaction between waves and streams of electrons in the ionosphere or magnetosphere. In the Crawford theory, the electrons stengthen waves directly; in the new theory, there is an intermediate step. This step enables LDEs at vhf and uhf, such as the one reported by Rasmussen,[13] to be explained.

Both theories depend on various assumptions about the physical state of the ionosphere or magnetosphere that are difficult to check. The best way to decide between explanations is to see how well they explain actual occurrences. The authors would be very grateful for additional reports of unusual echoes occurring in any frequency band. Of particular interest will be any echoes which have been Doppler shifted slightly from the original frequency and LDEs that indicate distortion. Distortion could include acquisition of a modulation not present in the original signal such as hum, voice sidebands or on-off keying. Frequency shifts and distortion, however, will make recognition much more difficult.

The assistance of E. L. Hagg, A. C. Fraser-Smith and D. M. Mandelkern, WA4BAX, is gratefully acknowledged.

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[13]Rasmusen, "Ghost Echoes on 1296 MHz," Technical Correspondence, *QST*, June 1976 p. 36.

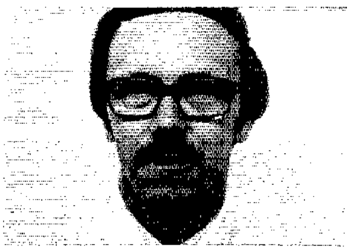
Strays

TA PROFILES

We express our sincere thanks to ARRL Technical Advisor David L. Ingram, K4TWJ, of Birmingham, Alabama, for his professional expertise in SSTV. Being involved in electronics since the age of seven, Dave received his Amateur Radio license at age 14. His primary interests in Amateur Radio are SSTV, DXing, OSCAR, 10-meter fm, QRP and evaluating/studying new gear. He holds an Extra Class license and a Radar-endorsed "First Phone" commercial license.

Dave is an instructor of comprehensive courses in electronics technology at United Electronics Institute. He has authored five books, each relating to a specialized area of Amateur Radio, coauthored a sixth book, and has published over 250 articles.

In his leisure time, Dave enjoys collecting and constructing antique ham equipment. He is also enthusiastic about sports cars and photography. — *Marian Anderson, WB1FSB*



K4TWJ, Technical Advisor for SSTV

QST congratulates . . .

Leonard R. Kahn, WB2SSP, of Freeport, New York, who has been selected to receive the Radio Club of America's Armstrong Medal in recognition of his developments in the fields of ssb, independent sideband, voice processing, low-distortion and high-efficiency modulation techniques, diversity, and time-diversity communications techniques and, most recently, a-m stereo broadcasting.

MORE THAN JUST THE TIME

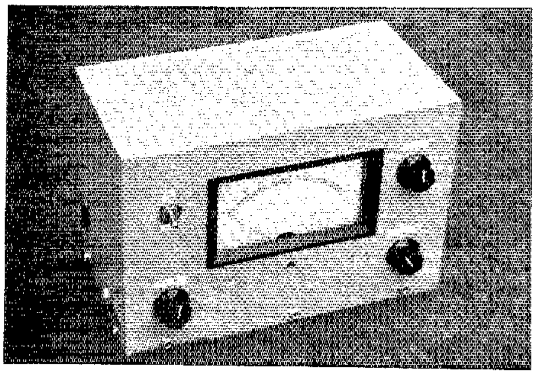
A complete description of WWV, WWVH and WWVB services is available from the Superintendent of Documents, Washington, DC 20402. The 16-page illustrated booklet costs $1.50 (ask for S/N 003-003-02105-9). — *Tom Frenaye, K1KI*

DOTS AND DASHES

If you enjoy telegraphy, be it American Morse (landline) or continental (international) radio code, you might find the Morse Telegraph Club of interest. A quarterly publication, "Dots and Dashes," edited by Cecil Combs, WØVZH, is sent to all members. The publication covers news of interest to code operators and has an Amateur Radio section. For more information write Mr. A. J. Long, Secretary, Morse Telegraph Club, Inc., 520 W. Schwartz St., Salem, IL 62881. — *Jim Romelfanger, K9ZZ, Baraboo, Wisconsin*

A Reflectometer for Twin-Lead

This instrument measures SWR directly on 300-ohm transmission lines from 3.5 to 450 MHz.



By Fred Brown,* W6HPH

Despite its unpopularity, twin-lead is not really bad stuff. Compared to almost any kind of flexible coaxial line, twin-lead has lower loss per unit length (when dry) and is also considerably cheaper. It is an obvious first choice for connection to a balanced antenna or for tuned-feeder antenna systems.

Amateur literature abounds with descriptions of reflectometers for 50-ohm coaxial cable, both of the bridge type and the directional-coupler version. But the user of 300-ohm twin-lead has been neglected when it comes to accurate measurement of SWR. Although measuring twin-lead SWR through a balun is possible, two problems are usually associated with such an approach. Unless the balun is perfect, it will introduce some reflection of its own, which may add to or subtract from the reflection from the load, and thereby give a misleading result. Second, most baluns have a 4:1 transformation ratio, whereas a transformation from 300 to 50 ohms requires a 6:1 ratio.

The instrument described here is a parallel-wire directional-coupler reflectometer for 300-ohm balanced line. It works on the same principle as the old twin-lamp SWR indicator (Fig. 1A). With a low standing-wave ratio, only the lamp closest to the transmitter would light. If the twin-lamp is replaced with a properly terminated directional coupler, it will be possible to determine standing-wave ratios

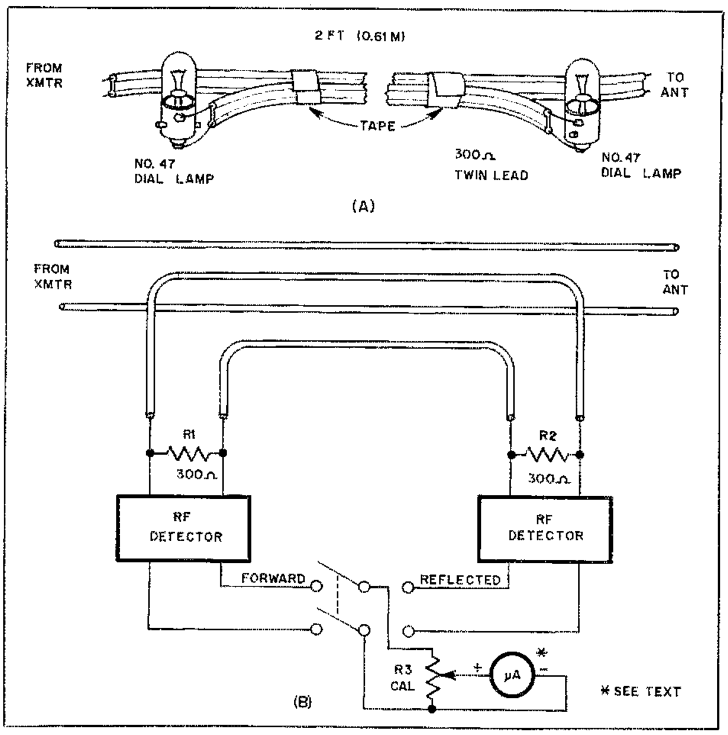


Fig. 1 — The twin-lamp SWR indicator, shown at A, is a crude form of reflectometer. With a high SWR, both lamps will light with equal brightness. With low SWR, only the lamp on the left side will be illuminated. A laboratory-type reflectometer, such as illustrated at B, is similar in principle to the twin-lamp arrangement, but yields accurate, quantitative results. The twin-lead ribbon and dial lamps have been replaced with a properly terminated directional coupler. The meter can be calibrated to read SWR directly.

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accurately by measuring the rf voltage across the 300-ohm termination (Fig. 1B). If properly constructed, the rf detector on the left will respond only to energy on the transmission line flowing from left to right. The detector on the right will give a dc output proportional to the energy propagating in the opposite direction. If the sensitivity control is adjusted for full scale reading with the switch in the *forward* position, the meter scale can be calibrated to read SWR directly with the switch in the *reverse* position, as with any reflectometer.

The Circuit

The complete schematic diagram is shown in Fig. 2. Originally it was hoped that a completely passive instrument could be built, but the 0 to 100 microammeter did not provide sufficient sensitivity for low-power measurements. Accordingly, a dc amplifier (Q1 and Q2) was incorporated. If a 0 to 10 microammeter is available (they *do* make them), the dc amplifier can be omitted. Fig. 2 shows connections for such an alternative.

In Fig. 2 the forward and reflected signals are detected by D1 and D2, respectively. The resulting dc voltage is transferred through S1 to the 500-kΩ sensitivity control. These two dc voltages are also made available to an external voltmeter by means of test-prod jacks (J1, J2 and J3) located on the side of the cabinet. A digital millivoltmeter will permit measurements with a very small amount of rf power in the transmission line, as little as 50 mW at 10 meters. Furthermore, two external meters, or one external meter in conjunction with the internal meter, will permit simultaneous observation of both forward and reflected power.

C1 and C2 in Fig. 2 are dc blocking capacitors to prevent the dc voltage from D1 reverse biasing D2. Only one of these capacitors is really needed, but two are used to maintain symmetry and balance. The two 150-ohm, quarter-watt resistors (5% tolerance) terminate the coupled line section and transfer the detected dc voltage to the isolating resistors, R1 and R2.

The dc voltage from the sensitivity control is applied to the gate of JFET Q1, a source follower, which drives the base of the common-emitter stage, Q2. This transistor is one arm of a bridge; the other arms are R3, R4 and R5 in conjunction with the three diodes, D6, D7 and D8. The diode strings, D3 through D5 and D6 through D8, are each made up of three germanium diodes in series and are used for temperature compensation. Although the resulting compensation seems nearly perfect, it was deemed prudent to locate the zero-adjustment potentiometer, R5, on the front panel for easy access.

Construction

The directional coupler should be less

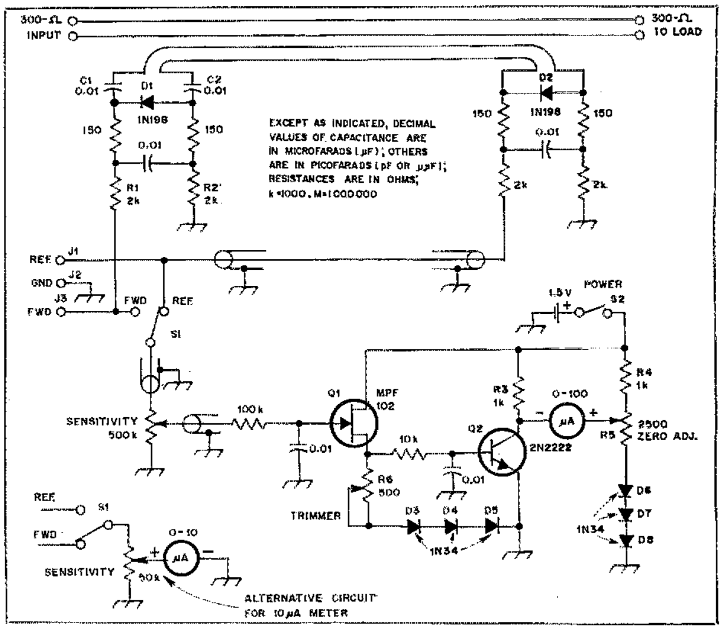


Fig. 2 — Complete circuit of the reflectometer. The dc amplifier (Q1 and Q2) is powered by a single 1.5-V cell. Current drain is about 1 mA. If a 0- to 10-μA meter is available, the dc amplifier can be omitted, as shown at the lower left.

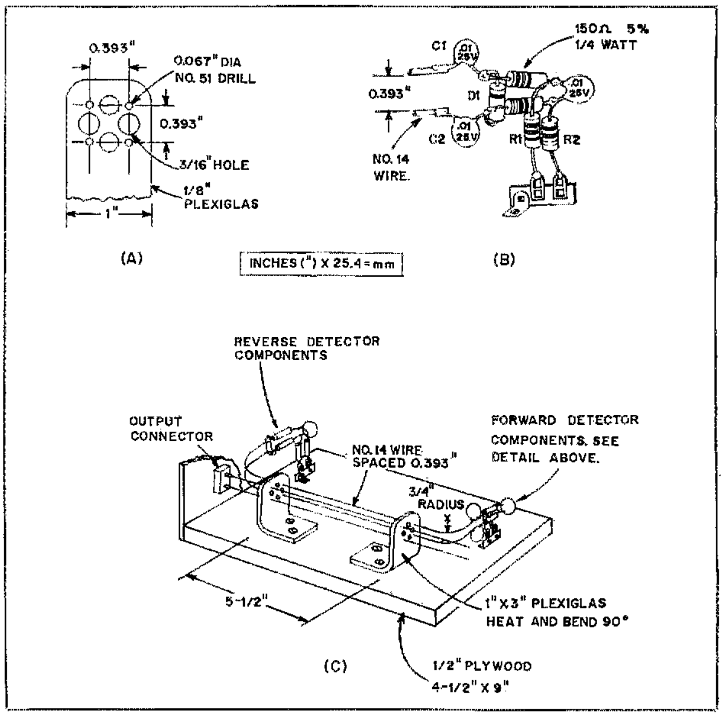


Fig. 3 — Construction details of the parallel-wire directional coupler. Drilling dimensions for the directional coupler wire-holder bracket are at A. Detail of the directional coupler at the "forward" termination end is presented at B. The "reverse" termination is identical, except for the omission of C1 and C2. With the exception of R1 and R2, all components have the shortest possible leads. The drawing at C shows the parts layout.

than a quarter-wavelength long at the highest desired operating frequency. A length of 6 inches permits operation up to 450 MHz, although a longer length would give greater sensitivity at the lower frequencies. Construction details of the directional coupler are given in Fig. 3. A wire spacing of 6.13 times the wire diameter will give the desired 300-ohm impedance. The dimensions shown are correct for no. 14 bare wire (0.064 inch or 1.63 mm dia). The four wires are held in place with brackets formed from 1/8-inch (3.18-mm) Plexiglas. The amount of dielectric material between the wires is reduced by drilling 3/16-inch (4.76-mm) holes midway between the wire holes.

Minimizing stray coupling is important. Therefore, all wiring and components should be kept at least 1 inch (25 mm) away from the directional coupler lines.

For proper termination, the detector components must have the shortest possible leads, as shown in Fig. 3. No tie points are used to mount these components. They are supported in air by the ends of the coupled line section and by resistors R1 and R2. Germanium diodes are said to be subject to damage by soldering temperatures, but the 1N198s suffered no apparent ill effects even though the 1/8-inch leads were soldered without heat sinks.

The base of the instrument is a 4-1/2- × 9-inch (115- × 230-mm) piece of 1/2-inch (13-mm) plywood. The sides and top are cut from 1/8-inch (3-mm) Plexiglas and stuck together with Super Glue. Overall height is 6 inches (152 mm). The dc amplifier components are all mounted on a 2-inch (50-mm) square piece of perfboard.

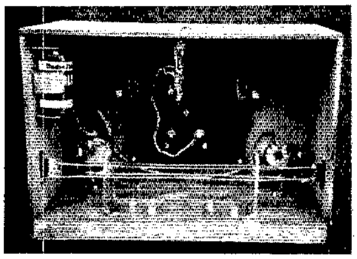
Input and output connectors are Radio Shack no. 274-342. They are not 300-ohm connectors, with the result that there is a slight impedance bump on the line. Reflection is negligible at hf, but not at 450 MHz. Uhf performance can be improved by drilling holes through the plastic between the conductors of these connectors to remove as much dielectric material as possible. A better connector combination would be the James Millen no. 37412 plug and no. 33102 socket, which are compatible with Mosley 300-ohm connectors.

Checkout and Operation

To prevent possible meter damage, a wise precaution is to disconnect the meter when the dc amplifier is first tried. Trimmer potentiometer R6 should be adjusted for a potential (with respect to ground) of about 0.8 volt on the collector of Q2. R5 should then be adjusted to give the same voltage at the wiper that existed before the meter was connected.

If the dc amplifier is working properly, a low-power source of rf can be applied to the 300-ohm input through a suitable balun. The rf coupling to the detectors is directly proportional to frequency, which means that every time the frequency is halved, *four* times as much rf power is required for full-scale deflection. The minimum power requirement per band is as follows: 80 meters, 12 watts; 40 meters, 3 watts; 20 meters, 0.75 watt; 10 meters, 200 milliwatts; and 2 meters, about 10 milliwatts.

With the reflectometer terminated in either an open or short circuit (infinite SWR), practically the same meter reading should be obtained with S1 in either the FORWARD or REVERSE position. A pair of 150-ohm, 2-watt resistors connected in series with short leads will make a fairly good matched load, usable from 40 through 6 meters. With such a load, the reflected meter reading should be less than one tenth the forward reading.



This inside view shows the parallel-wire directional coupler built on the plywood base. The dc amplifier circuit board is located at the top center for easy access. Power for the dc amplifier is provided by the 1.5-V "C" cell held in the clip on the left sidewall. A penlight cell would be entirely adequate.

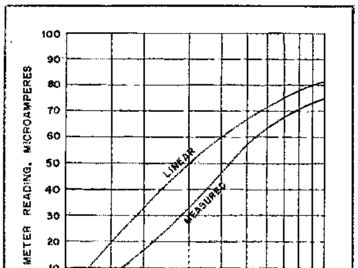


Fig. 4 — Standing-wave ratio vs. meter reading, assuming the sensitivity control is first adjusted for full-scale reading with S1 in the *forward* position. The "measured" curve was determined for the maximum sensitivity setting of the author's unit, which resulted in full-scale deflection with 115 mV dc at J3. The "linear" curve will apply if this dc potential is greater than about 0.5 V.

Linearity

The detector response to rf input voltage will be almost perfectly "square law" for detector outputs below 50 mV dc. This means the dc output will be proportional to the *square* of the rf input voltage. For dc output voltages greater than 0.5 V, the relationship between rf input and dc output will be nearly linear.

Accordingly, to measure SWR accurately, it will be necessary to know whether the detectors are operating in accordance with the square law, linearly or something in between. Usually it will be in between.

In the author's unit, full-scale deflection occurs with a dc input to Q1 of 115 mV (measured at J3). At this level, the detectors are operating near their square-law region.

The graph of Fig. 4 shows the measured value of SWR vs. meter reading for a detected output voltage from the *forward* detector of 115 mV dc. For comparison, a curve of SWR is shown, assuming the detectors are perfectly linear. Where the instrument is operating at less than full gain, the actual SWR will lie somewhere between these two curves. At detector output levels greater than 0.5 V, the linear curve should be quite accurate. The experimental curve should be accurate for a level near 100 to 120 mV, measured at J3. At lower detector output voltages, the actual SWR will be slightly higher than that shown by the experimental curve. QST

RALPH M. HEINTZ, W6RH

□ *QST* sadly announces the passing of Ralph M. Heintz, W6RH, who was 88 years old when he died in May. The firm of Heintz and (Jack) Kaufman was famous for transmitter design and transmitting vacuum tubes. In its lobby W1AW proudly displays an "H & K" TPTG transmitter, featuring a pair of 204As, that was used at W1MK until a flood messed it up and prompted the building of W1AW in Newington. Heintz and Kaufman were also the founders of the commercial wireless company Globe Wireless.

A leader in the scientific world, Ralph was the genius behind many of the electronic developments we now take for granted. His expert talents, however, were not limited to just radio and electronics — he patented a stratified-charge automobile engine that featured greater gas economy and cleaner combustion. Honda presently uses an engine based on these principles. A keen insight and understanding of the needs of surgeons led him to the development of specialized instruments for use in eye surgery. This outstanding man, with over 200 patents to his credit, was honored in 1976 when the San Francisco Patent Law association named Ralph Heintz "The Inventor of the Year."

Modifications to a Microprocessor-Based Keyboard

Here are some changes and improvements to the original information — other offerings, too.

By John A. Donaldson,* WB5DGQ

After reading Mr. Eubanks' article, I decided to write a similar program for an 8080A-based microprocessor.[1] While studying the flow charts he presented, I discovered some errors and made some changes, which I would like to pass along to others who wish to use the program.

Making It Simple

Use of a debounced keyboard can greatly simplify both the main program and the keyboard routine. That portion of the main program dealing with the programmable timer may be eliminated; this change is shown in Fig. 1. The altered keyboard routine may be seen in Fig. 2.

Five errors exist in the original record routine.

1) No provision is made to decode a period, comma or slant bar while decoding 2X characters.

2) If the 2X character is not \$20 (20_{16}), then \$10 is added to it. This will cause any 2X character (except \$20) to be recorded as a number.

3) Should the 2X character be \$20, \$5 is used instead.

4) No provision is made for special cw characters such as $\overline{SK}$, $\overline{AS}$, $\overline{BT}$, $\overline{CT}$ or the ERROR signal.

5) Finally, the blank block in the record routine should read: SET BRA = BOTTOM OF BUFFER. [A printing goof. — Ed.]

The changes which correct for all of these errors may be seen in Fig. 3 and are summarized below.

1) All characters are used to index the look-up table.

2) If the character is \$20, space bar, the decoded cw character stored at BRA is \$FF, word space, as in the original program.

3) Lower-case letters can be decoded as upper case, thus eliminating the necessity to disable the shift key. This is done by coding the lower-case letters as upper case in the look-up table.

4) Any unused key can be used to decode the special cw characters.

5) All other unused keys are coded as \$00.

6) If the routine decodes a \$00 from the look-up table, it can exit there instead of being stored in the buffer. This avoids unnecessary recording of unused keys.

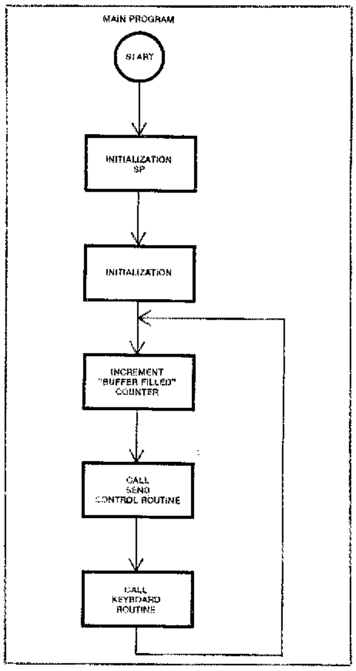


Fig. 1 — The programmable-timer portion of the original main program has been omitted.

Buffer-Filled and Speed-Routine Changes

Instead of using the flashing display as a buffer-capacity indicator, I felt that an audible tone would be better. As such, it would be an aid should the keyboard be operated by a blind amateur. I employed a spare output port on the microprocessor to turn an NE555 tone oscillator on and off. The flow diagram for this routine is shown in Fig. 4. Additionally, the speed routine was altered to allow keyboard speed selection by assigning different keys

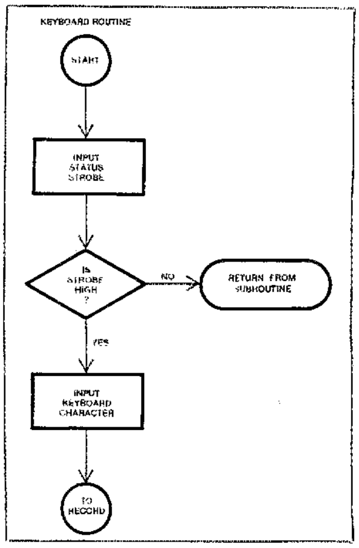


Fig. 2 — The use of a debounced keyboard results in a simplified keyboard routine.

*1808 Cardinal, League City, TX 77573

[1]Notes appear on page 19.

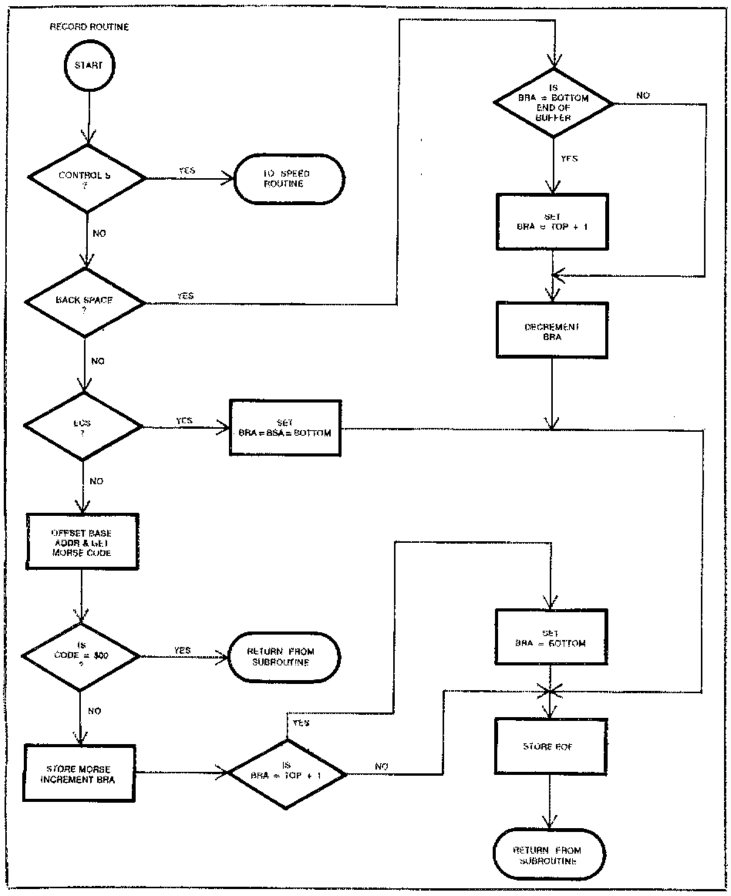


Fig. 3 — The altered and corrected record routine.

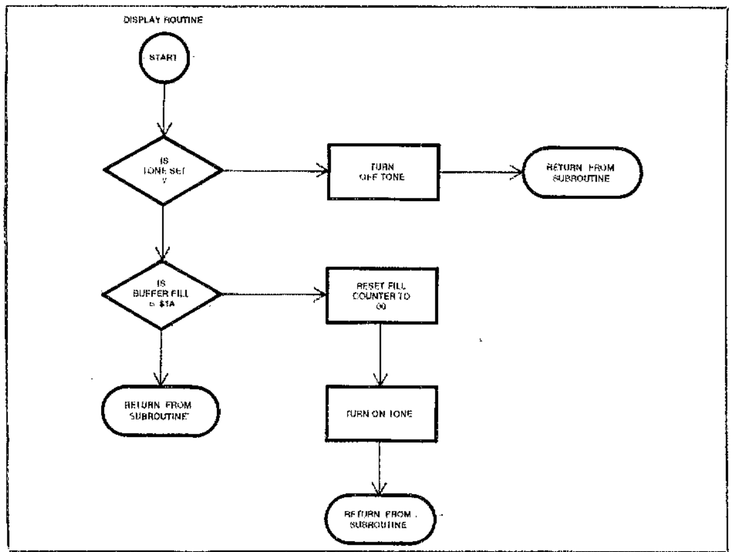


Fig. 4 — The modified display routine is programmed to trigger and reset an audio oscillator instead of a flashing display.

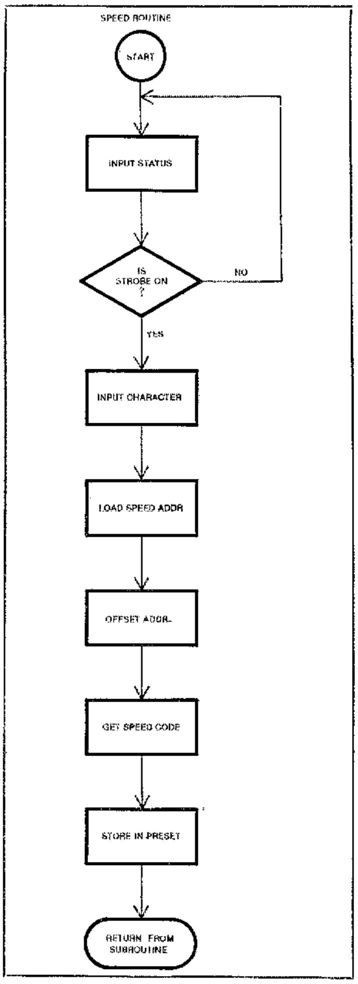


Fig. 5 — This speed routine provides for a more flexible keyboard selection of speed.

for the various speeds. Thus, any number of speed codes can be used. This flow diagram is shown in Fig. 5. No changes were made to either the send-control or letter-preparation routines.

Additional Programs

In my program, I have made other changes as well, but I've mentioned only those I felt were of most importance. Copies of my revised program and flow charts for an 8080A-based microprocessor are available for an s.a.s.e. I also have copies of a simple program and flow chart for those who wish to use the Morse code-to-Alphanumeric Converter that appeared in previous issues of *QST*.[2] QST

Notes

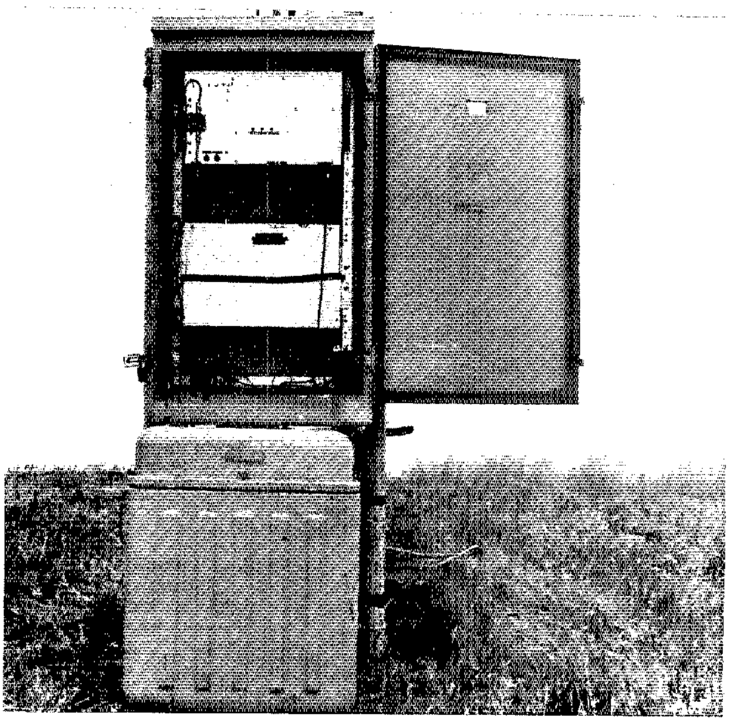
[1] Eubanks, "A Microprocessor-Based Keyboard," *QST*, October 1979.
[2] Riley, "A Morse Code to Alphanumeric Converter and Display," *QST*, October, November and December 1975.

A CMOS Command Decoder for Repeaters and Remote Bases

Need a remote-control system for your repeater? Here's a flexible unit that also features power-saving CMOS circuitry.

By M. P. (Jug) Jogoleff,* WA6MBZ

Ever since acquiring an understanding of the TTL command decoder by Bensinger, W5PCX, I had an obsession to build one.[1] I decided to redesign the original presentation using CMOS logic.[2] The many features of this circuit include the following: nanowatt power consumption in the static state (99% of the time), 32 functions (including both on and off for each function), a command sequence that normalizes all the output latches and a power-up reset generator for the output latches. Also employed are anti-falsing integration networks on the reset and execute lines and another network that is used to prevent more than one output latch from changing state per single given command. There's also a pre-addressing strapping network and provision for preventing key audio command tones from being retransmitted by the system. This circuit is intended to be used as part of a radio-operated, remote-control system for a repeater or remote base. The circuitry accepts a series of tone voltages from a Touch-Tone decoder and translates them into latched-logic outputs, which remain at supply voltage (high) or ground (low) levels until commanded to the opposite state. The system is connected to the



The CMOS command decoder installed at the bottom of the repeater cabinet. The unit at the top is the repeater.

*1324 Panchita Pl., Santa Barbara, CA 93103

[1]References appear on page 24.

controlled functions via transistors and relays.

Circuit Description

Figs. 1 through 5 show the circuitry of the decoder. Instead of giving a blow-by-blow description of what each IC does, only several of the important aspects will be mentioned. U1, U3 and U5 accept the signals, in sequence, from the Touch-Tone decoder.

The data from U2, U4 and U6 are presented to U7 and U8 in parallel. The output of U7 or U8 provides the clock signals that drive the output latch circuitry, U11 through U26.

The major differences between this circuit and the TTL version mentioned earlier are these: Touch-Tones A, B, C and D drive the pre-addressing network in the CMOS version. Touch-Tone 3 determines which half of the circuit will be activated and Touch-Tone 5 determines whether a function is to be turned off or on. Anti-falsing networks, as well as the audio-muting control, have been added. A normalizing function on the output

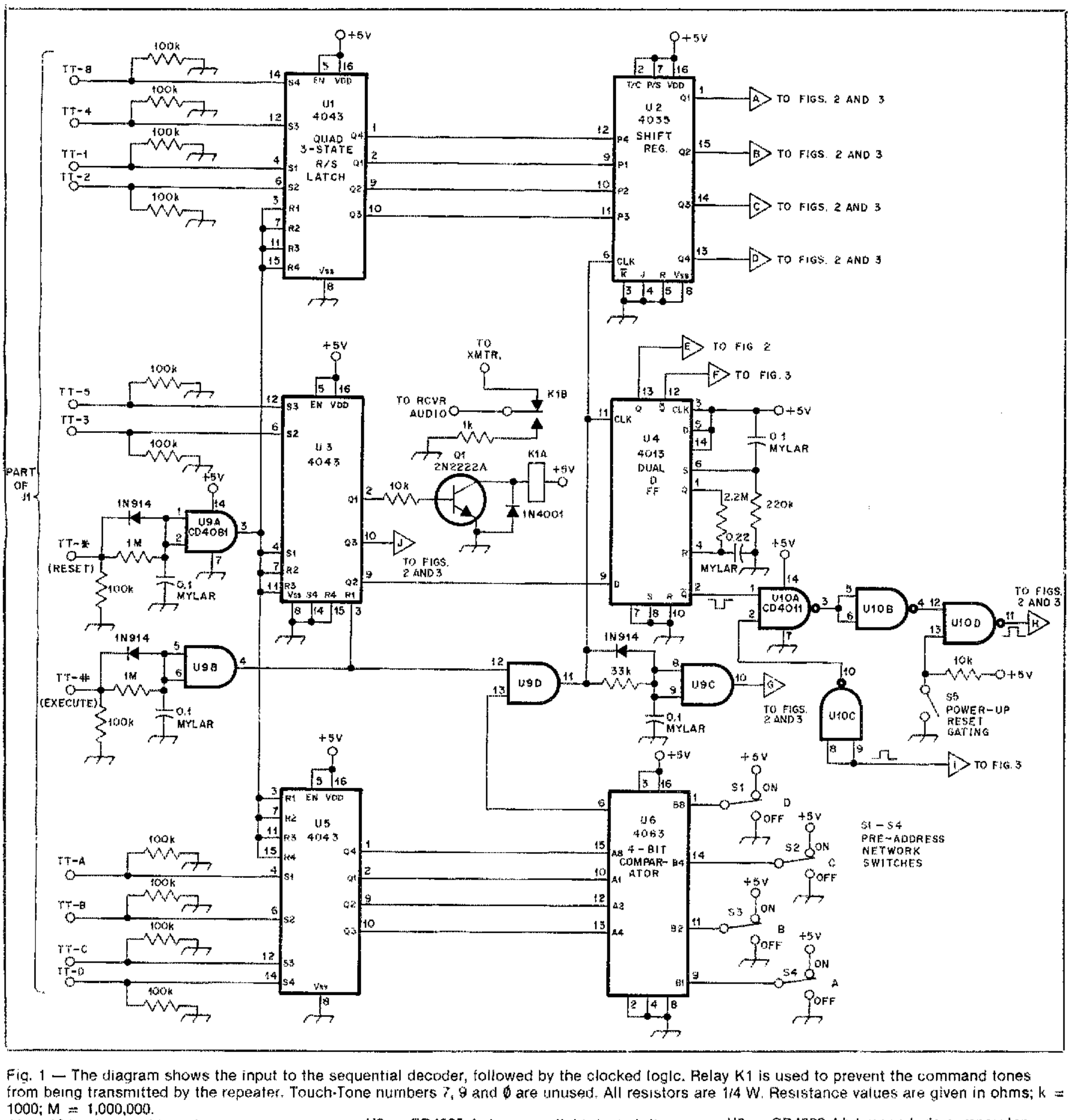


Fig. 1 — The diagram shows the input to the sequential decoder, followed by the clocked logic. Relay K1 is used to prevent the command tones from being transmitted by the repeater. Touch-Tone numbers 7, 9 and Ø are unused. All resistors are 1/4 W. Resistance values are given in ohms; k = 1000; M = 1,000,000.

J1 — 18-lug terminal board.
K1 — 12-V, spdt relay, low-current type.
U1, U3, U5 — CD4043 quad, 3-state R-S latch.
U2 — CD4035 4-stage parallel in/out shift register.
U4 — CD4013 dual D-type flip-flop.
U6 — CD4063 4-bit magnitude comparator.
U9 — CD4081 quad 2-input AND gate.
U10 — CD4011 quad 2-input NAND gate.

latching circuits has also been included.

Power-Saving Output Latch Circuit

Fig. 5 shows a dual-D flip-flop (U25) wired as two monostable circuits and tied to the Q and Q̄ of any of the flip-flop output latches. When Q goes high, it triggers the first monostable and closes the coil of the latching relay. When Q goes low, the monostable is reset. But that also means Q̄ has been driven high, with the result that the second monostable has been triggered and the other side of the coil energized, thus resetting the latching relay. Power is saved since the coil remains energized only during the active period of either monostable and not continuously while one or the other function is engaged.

A Summary of Command Sequences

Always begin the command sequence with an asterisk (*). If a mistake is made during the process of encoding a command, begin the command sequence again with the asterisk. Choose the command number by keying the proper tones — 1, 2, 4 or 8. Decide if the command is to be a number or its prime (1 or 1′). Tone 3 selects the number and the lack of it provides the prime. Tone 5 gives the output latches D line a sense of direction. The presence of tone 5 forces D high and (eventually) Q high. The absence of tone 5 drives D low and Q low. Next, tones A, B, C or D are inserted as desired to match the data that the toggle switches have encoded on the B line of U6. Finally, activate the pound sign (#), which is the execute signal. If command 1 prime (1′) or 2 (2′) were chosen, tone 6 should be activated. Note that U3, FF1, serves as the audio muting control. When the * tone is keyed, the audio output is removed (via K1) from the repeater transmitter. When the # tone is transmitted, the audio is restored. This

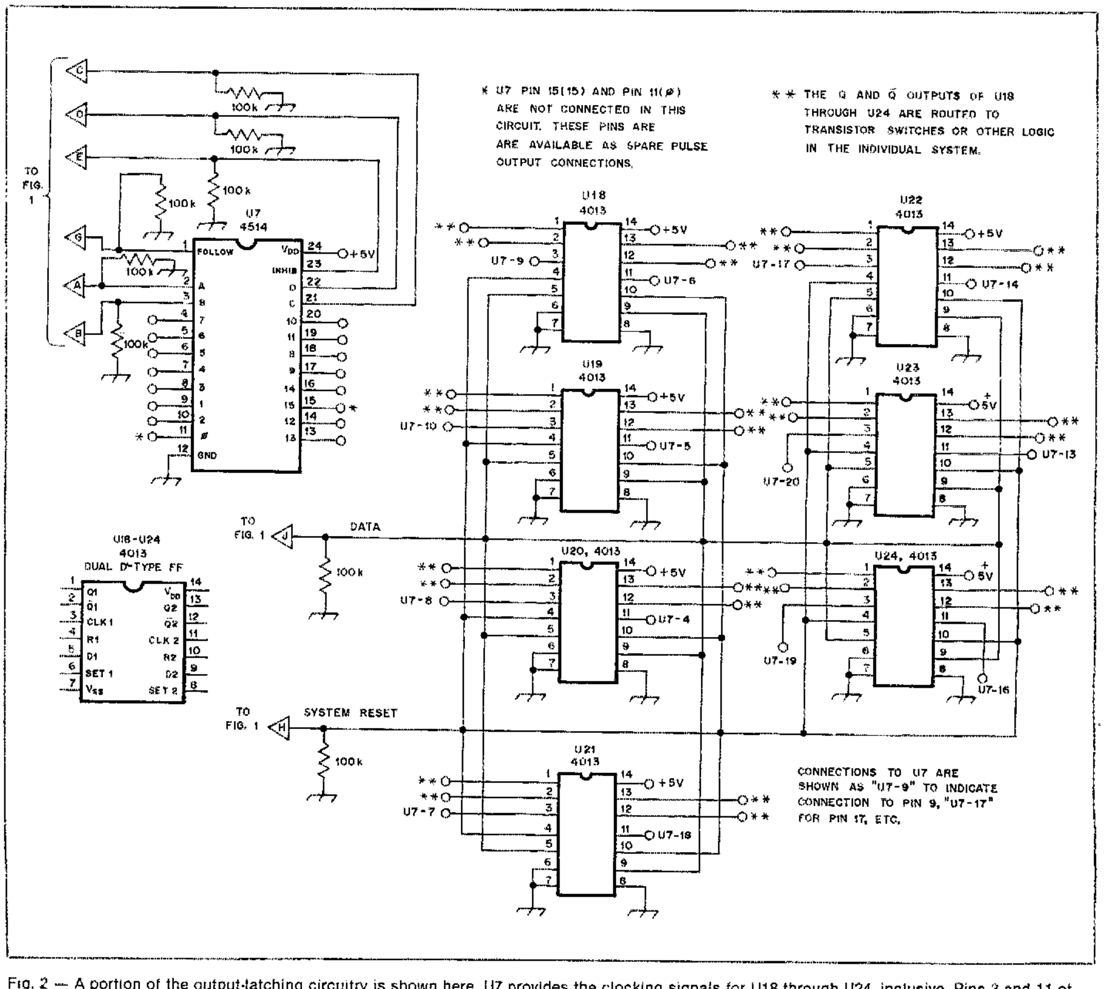


Fig. 2 — A portion of the output-latching circuitry is shown here. U7 provides the clocking signals for U18 through U24, inclusive. Pins 3 and 11 of U18 through U24 are connected to the appropriate pin of U7; e.g., U18 pin 3 connects to U7 pin 9. All resistors are 1/4 W. Resistances are in ohms; k = 1000, M = 1,000,000.
U7 — CD4514 4-bit latch/4-line to 16-line decoder.
U18-U24, incl. — CD4013 dual D-type flip-flop.

means that the only control tones repeated on the air in a valid command sequence would be the *, # and 6.

Toubleshooting

The key to understanding this circuit in theory or practice centers on U7 and U8, the 4-to-16 decoders. In this regard, Table 1 should be of assistance. The command train can be followed easily by tracing the circuit from the inputs toward the Touch-Tone decoder and before the outputs at the output latching. The circuit contains no oscillators, PROMS or RAMS, which would require the use of an oscilloscope for troubleshooting. A high-impedance VTVM and milliammeter, along with several LEDs with 1-kΩ resistors in series, are the only pieces of test equipment necessary for circuit checking. If a low-impedance multimeter is used, ICs may be damaged. If appreciable current is measured (other than the static current of the tone decoder) there's probably a floating input in the circuit.

Construction Notes

It is probably best to lay out the subsystems on separate cards: tone decoder, command decoder (U1 through U6, U9 and U10), first bank of output latches (U13 through U19 and U7), second bank of output latches (U20 through U26 and U8) and last, the other cards for special functions such as those provided for by U11 and U12. When using long runs of wire, bypass the input ports with 100-kΩ resistors to protect the ICs from static charges. Bypass the power supply leads with 0.01-μF disc-ceramic capacitors, using one capacitor for every six ICs or less.

The unit shown in the photograph was built in a metal box 4 in. (102 mm) deep, 17 in. (432 mm) long and 11 in. (279 mm) wide.

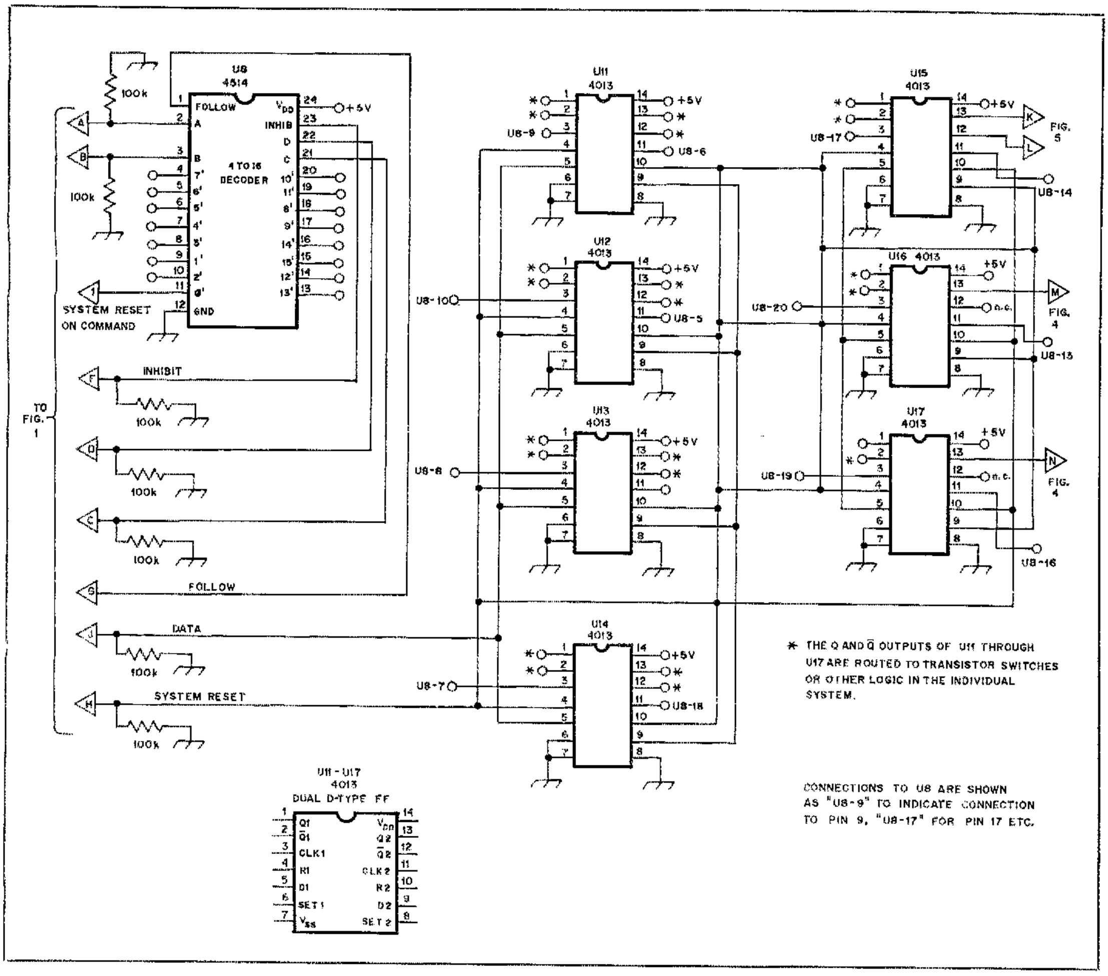


Fig. 3 — The second half of the output-latching circuitry is shown here. U8 provides the clocking signals for U11 through U17 inclusive. Pins 3 and 11 of U11 through U17 are connected to the appropriate pin of U8; e.g., U11 pin 3 connects to U8 pin 9. All resistors are 1/4 W. Resistances are in ohms; k = 1000; M = 1,000,000.

U8 — CD4514 4-bit latch/4-line to 16-line decoder.

U11-U17, incl. — CD4013 dual D-type flip-flop.

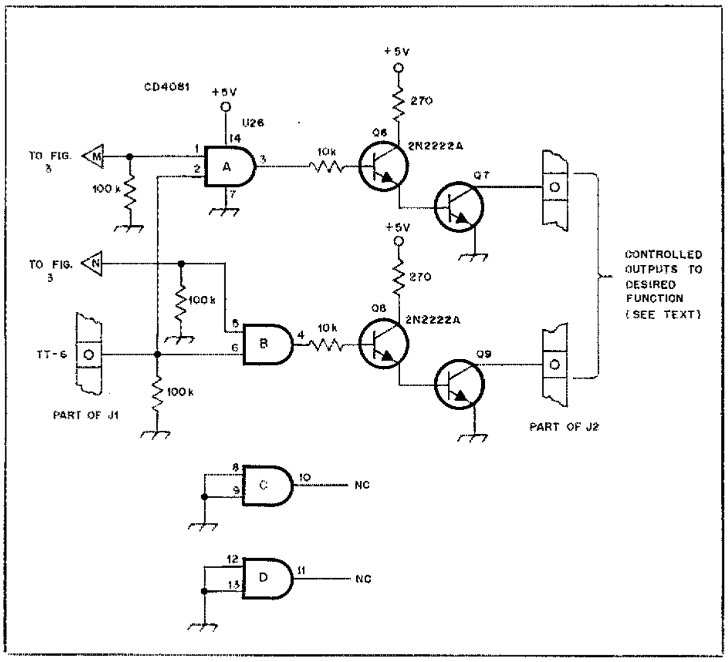


Fig. 4 — These two circuits will provide a controllable function. After being commanded ON through the decoder, the function is ruled by Touch-Tone 6 for any designated purpose. In the original system, it is used to reset the time-out timer. All resistors are 1/4 W. Resistances are given in ohms, k = 1000.
J2 — 18-lug terminal board.
Q7, Q9 — Any suitable npn transistor.
U26 — CD4081 quad 2-input AND gate.

Table 1

Truth Table for U7 and U8

Parallel Inputs DCBA	*Serial Output No.*	*Pin No.*
LLLL	∅	11
LLLH	1	9
LLHL	2	10
LLHH	3	8
LHLL	4	7
LHLH	5	6
LHHL	6	5
LHHH	7	4
HLLL	8	18
HLLH	9	17
HLHL	10	20
HLHH	11	19
HHLL	12	14
HHLH	13	13
HHHL	14	16
HHHH	15	15

The above data assume the *inhibit* line is low and the *follow* line is high. Otherwise, no output will occur.

The completed unit was installed at a repeater site on Santa Cruz Island. As can be seen, either unit is easily removed from the cabinet for transportation back to the mainland for servicing, if necessary. QST

References

[1] *FM And Repeaters For The Radio Amateur*, ARRL, first edition, pp. 121-125.

[2] Texts recommended by the author are: Lancaster, *CMOS Cookbook*, Howard W. Sams & Co., Inc., 4300 West 62nd St., Indianapolis, IN 46268 and *CMOS Databook*, National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051.

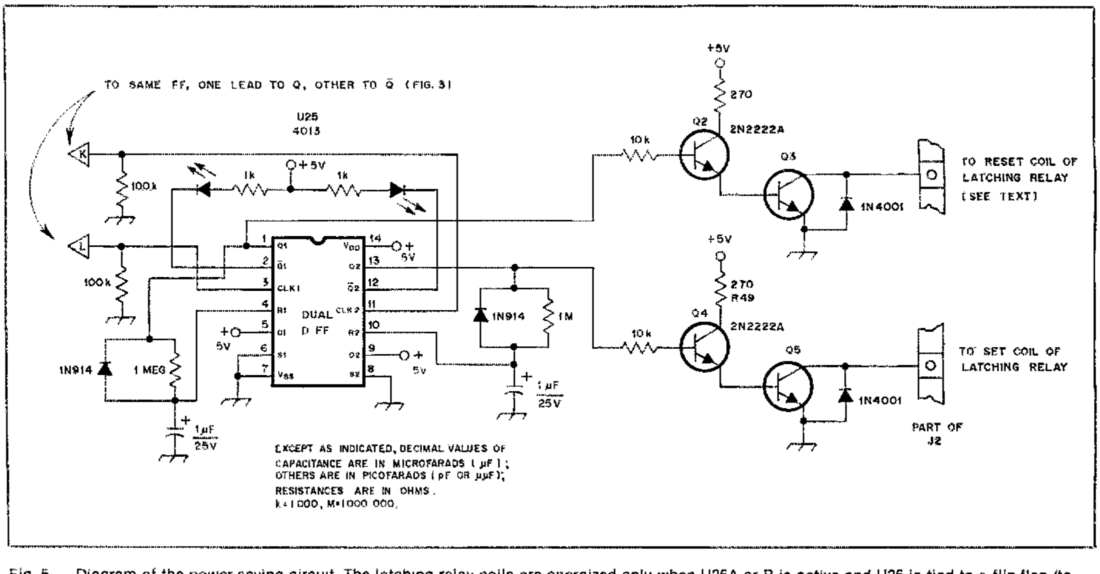


Fig. 5 — Diagram of the power-saving circuit. The latching relay coils are energized only when U25A or B is active and U25 is tied to a flip-flop (to the Q and Q̄ of any one of the output latches). The LEDs are used as monitors of the status of U25. All resistors are 1/4 W. Resistance values are given in ohms, k = 1000; M = 1,000,000.
Q3, Q5 — Any suitable npn transistor.
U25 — CD4013 dual D-type flip-flop.

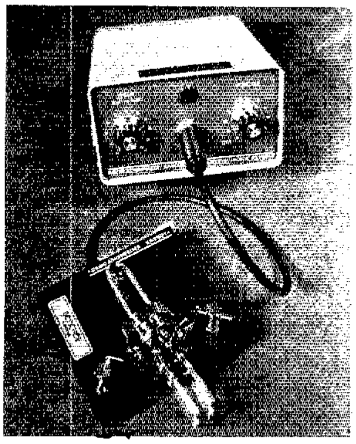
External Paddles for the Heath HD-1410 Keyer

Been yearning to try a different set of paddles with your '1410? It's as simple as one, two, three-circuit jack and plug!

By David L. Ashenfelter,* KA8DDT

The Heath HD-1410 is a popular electronic keyer, but cw purists who own this dandy little gadget sometimes complain about the quality of the internally mounted paddles. I had my heart set on acquiring Bencher paddles for quite a long time, but repeatedly postponed their purchase because I figured I would have to buy a new keyer, too. Then George Bullard, KA8APE, suggested I modify the HD-1410 to accept external paddles. Finding no such existing modification, I devised two simple and inexpensive ways to modify the keyer for that purpose.

All that is needed for the project are a three-circuit (stereo) phone jack, a matching plug, a length of three-conductor cable and a few inches of wire. The three-circuit jack can be mounted in either of two locations: the front panel (by removing the internal paddles and installing a new panel), or on the rear panel, by replacing the existing two-circuit PHONES jack. The latter method will render the PHONES and adjacent RCVR AUDIO jacks useless, but the headphones may just as easily be plugged into the station receiver. Another option that remains is to remove the internal paddles *and* utilize the rear-mounted key jack. This, too, requires installation of a new panel.



The author's modified Heath keyer and favorite set of paddles. Rub-on lettering adds a professional touch to the homemade panel. *(photo by Thomas Harm)*

Rear-Panel Jack Installation

Disconnect the two brown wires that connect the PHONES jack to the speaker and volume control. Solder these two wires together to remake the speaker connection and insulate the joint with tape or sleeving. Remove the single wire connecting the PHONES jack to the adjacent RCVR AUDIO jack. Remove the PHONES jack and replace it with the three-circuit jack. Refer to Fig. 1. Wire the jack lugs to the internal paddle assembly as follows: The dit wire is connected to circuit board hole A, the dah wire to hole B, and the ground lug to the small nut and screw that fasten the paddle assembly to the circuit board. The screw grounds the paddle assembly to the circuit board and chassis (the nut and screw are labeled H on page 32 of the HD-1410 assembly manual).

Internal Paddle Removal

Extracting the internal paddles from the keyer requires removal of the front panel; this exposes the two flathead screws that hold the paddle assembly to the chassis front. Remove these screws. Then loosen — but do not remove — screw H. Cut wires A and B at the paddle terminals. (Don't discard the paddles or hardware. You may need them to restore the keyer to its original state should you decide later to sell the keyer or return it to the factory for repairs.) Removing the paddles results in two unsightly holes being left in the front panel, but this can be remedied by cutting a new panel from a piece of aluminum of similar thickness. Using the original panel as a guide, drill holes for the neon lamp and the speed and volume controls. An additional hole (in the center of the panel) will be required if the external paddles are to be plugged into the front of the keyer. To obtain a truly professional look, spray the new panel with a few coats of paint and apply rub-on lettering. One or two coats of clear acrylic lacquer will protect the lettering and paint.

The Finishing Touches

Connect the three-conductor cable to the three-circuit plug and insert the plug into the key jack. Using an ohmmeter, locate the ground wire, which is connected via the plug and jack to screw H. Attach this wire to the center post of the external paddles. Identify and attach the remaining two wires to the dit and dah paddles. That does it! Happy keying! QST

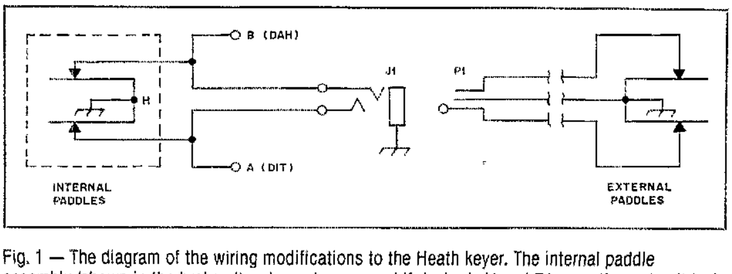


Fig. 1 — The diagram of the wiring modifications to the Heath keyer. The internal paddle assembly (shown in the broken lines) may be removed if desired. J1 and P1 are a three-circuit jack and plug combination.

*23612 Coach House Ct., T.H. 204, Southfield, MI 48075

A CW ASCII Keyboard

Care to key by ASCII? Let your fingers do the talking with this low-cost keyboard.

By Brooks Carter,* W4FQ

The following presentation is not a step-by-step construction project. Rather, it is a brief description of a simple and inexpensive cw-only ASCII keyboard which was built for use with a microprocessor-based keyer requiring an ASCII-encoded input. Many other uses for such a keyboard will probably come to the reader's mind, too. The basic circuit is derived from portions of the *TTL Cookbook*.[1] The keyboard requires no shift or control keys and costs less than $25 to build. Surplus keyboard assemblies may be purchased from Meshna[2] or elsewhere and the rest of the parts are available from your local Radio Shack outlet.

Circuit Description

The ASCII encoding circuitry and diode matrix are shown in Fig. 1. Initial contact closure of the key is noisy and erratic and might result in skipping a character or doubling it. Therefore, a 10-ms delay is created to allow for firm closure of the contacts. This delay is provided by the combination of C1 and R1, which prevents the timer, U5, from releasing the required positive latch-loading pulse. Following the delay sequence, the latch outputs are fed to the inverting buffers, U3 and U4. Do not attempt to eliminate the buffers by using the inverting outputs of U1 and U2; it won't work.

The Diode Matrix

Table 1 shows the matrix arrangement; the complete matrix requires a total of 161 diodes. It may be necessary to change the special-character diode sequences (such as $\overline{AS}$, $\overline{BT}$) if those in the table do not conform to your requirements. All the other characters use standard ASCII encoding.

You may wish to use the diode/transistor matrix presented in an earlier issue of *QST*.[3] However, the circuit will not operate reliably with a 5-volt supply; a 12- or 15-volt supply would be required and the 74LS175s must be replaced by 40175s. Pinouts for both IC types are given in Fig. 1. The buffers will still require a 5-volt supply to keep their outputs compatible with 5-volt ASCII code-level inputs.

Table 1

Matrix Connections

All diodes are connected from the appropriate character key-switch matrix line to the designated vertical matrix line.

From	*To*	*From*	*To*	*From*	*To*
A	6,Ø	Q	6,4,Ø	7	5,4,2,1,Ø
B	6,1	R	6,4,1	8	5,4,3
C	6,1,Ø	S	6,4,1,Ø	9	5,4,3,Ø
D	6,2	T	6,4,2	Ø	5,4
E	6,2,Ø	U	6,4,2,Ø	$\overline{AS}$	4,3,1,Ø
F	6,2,1	V	6,4,2,1	$\overline{AR}$	1,Ø
G	6,2,1,Ø	W	6,4,2,1,Ø	$\overline{SK}$	2
H	6,3	X	6,4,3	$\overline{KN}$	Ø
I	6,3,Ø	Y	6,4,3,Ø	BK	1
J	6,3,1	Z	6,4,3,1	Space	5
K	6,3,1,Ø	1	5,4,Ø	$\overline{BT}$	5,4,3,2,Ø
L	6,3,2	2	5,4,1	?	5,4,3,2,1,Ø
M	6,3,2,Ø	3	5,4,1,Ø	/	5,3,2,1,Ø
N	6,3,2,1	4	5,4,2	.	5,3,2,1
O	6,3,2,1,Ø	5	5,4,2,Ø	,	5,3,2
P	6,4	6	5,4,2,1		

*Rte. 2, Box 407, Irmo, SC 29063

Notes

[1] Lancaster, *TTL Cookbook*, first edition, Howard W. Sams and Co., Inc.
[2] John J. Meshna, Jr., Inc., P. O. Box 62, 19 Allerton St., E. Lynn, MA 01904.
[3] Isley, "A Static Morse Keyboard," *QST*, January 1980.

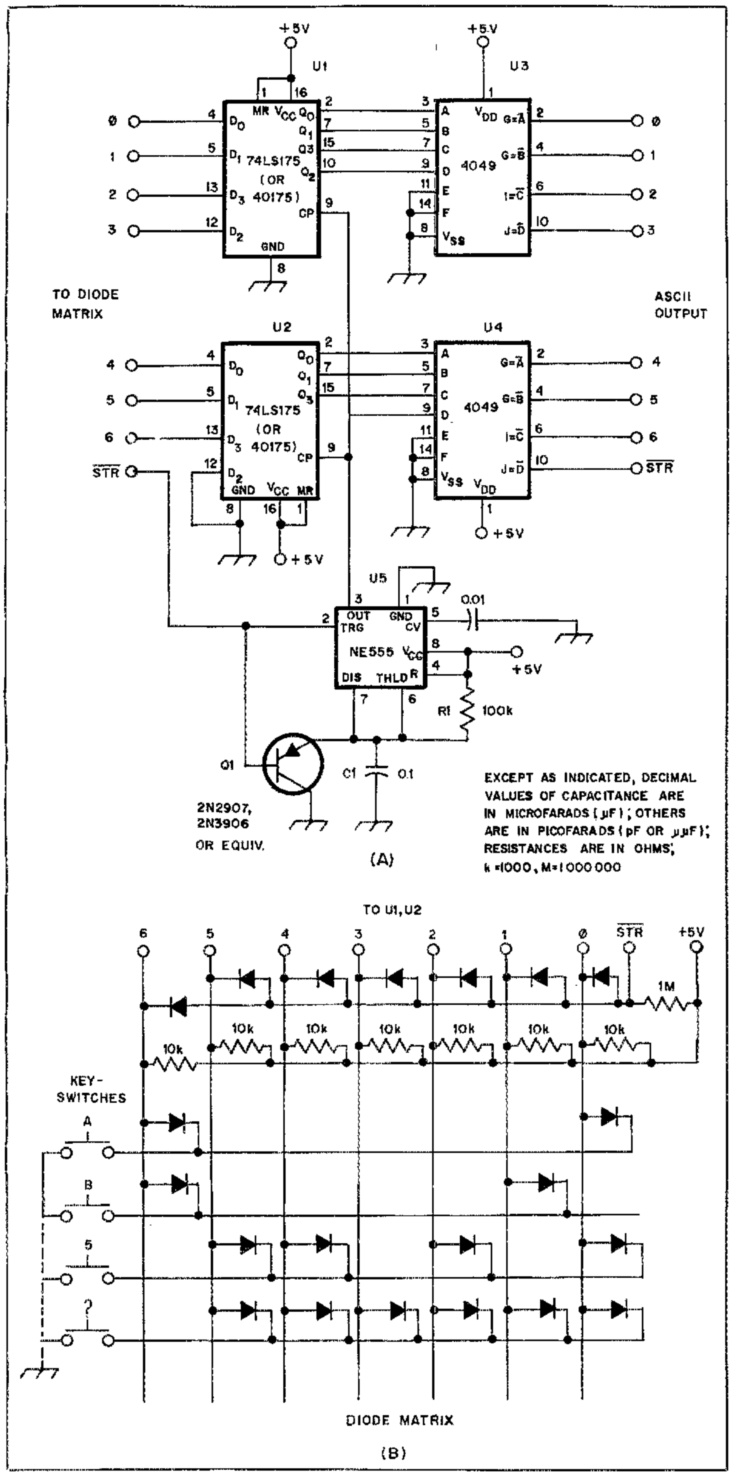


Fig. 1 — Schematic diagram for the ASCII cw keyboard. Only a portion of the diode matrix is shown; all other keyswitch and diode connections may be found in Table 1. All diodes are 1N914 or equivalent; resistors are 1/4-watt, carbon-composition type.

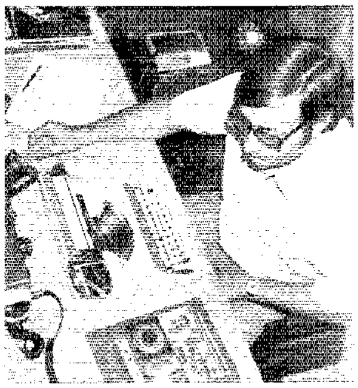
Strays

TA PROFILES

☐ We acknowledge with gratitude the services of Richard K. Olsen, N6NR, who at age 30 is completing his second term as an ARRL Technical Advisor (TA). Rick was one of our first TAs, having been appointed, along with Wes Hayward, W7ZOI, in 1976. His field of expertise is microwave circuits.

Rick was first licensed in 1964 as WN7CNP in Scottsdale, Arizona. He has an Extra Class license. His principal interests in Amateur Radio include being a TA, cw (40-wpm CPA), vhf/uhf weak-signal work and remote bases. Besides being a *QST* author and a life member of the League, Rick is a member of the Point Loma Radio Club, Convair Radio Club, ARES and IEEE.

Employed at the General Dynamics Electronics Division in San Diego, his primary responsibility is that of coordinator of Manufacturing Technology. He also acts as principal investigator of the Microelectronics IR&D program and is the Advanced Manufacturing Technology department staff engineer on microwave theory and techniques. He received a BSBA and MBA from La Jolla University, and is currently working on his Ph.d. in Human Behavior, with emphasis on engineering management. — *Marian Anderson, WB1FSB*



TA Rick Olsen, N6NR, at his operating position. *(photo courtesy of Dronk Radio & TV News Agency)*

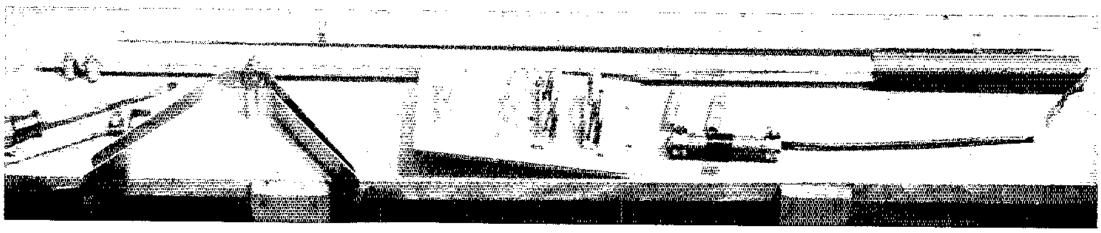
I would like to get in touch with . . .

☐ teenagers interested in forming an ssb Advanced class study group. Greg Whitman, KA1DEU, 165 Woodruff Ave., Watertown, CT 06795, Tel. 203-274-4025.

A Traveling Ham's Trap Vertical

If you're a wayfarer, you should be interested in this two-band trap vertical, which collapses to 39 inches for easy transport.

By Doug DeMaw,* W1FB



The traveling ham's trap vertical ready for final assembly. At the left foreground are two wing-shaped pieces of aluminum used experimentally during development of the antenna; they are not required for the model described in the text.

How effective is a trap type of antenna? That's a question the ARRL staff is asked repeatedly. Unfortunately, there is no simple answer we can offer. This is because the term "effective" is rather subjective. Effectiveness for one operator might mean the ability to work rare DX. Conversely, another amateur might consider the antenna effective if it helped him to break into pileups quickly. Some other operator might think of antenna effectiveness as a quality that would permit maintaining reliable communications over a specified ground-wave path.

Perhaps a better question to ask would be, "How *efficient* is a trap style of antenna?" But even that query is a tough one to address. The efficiency depends on many factors, such as the quality of the ground system, the Q of the traps (minimum losses) and the tuning of the system. The antenna performance also will depend on its height above nearby conductive or absorptive objects.

The best response to questions about trap-antenna performance is probably something like, "In theory, a full-size antenna will perform better than a short antenna with lumped constants." In other words, there is a certain trade-off to be expected in any "compromise" antenna. The performance degradation of a compromise antenna may, in some instances, be so minor that the operator would never recognize the difference between it and a full-size antenna. On the other hand, the performance difference can be startling. An example of the latter was seen during a DXpedition by W8JUY/8P6WM and W1FB/8P6EU. The two stations had equal transmitter power and were situated 100 feet (30.5 m) apart. The antennas of each station were erected over the ocean shore. W8JUY used a 4-band trap vertical at a height of 40 feet (12 m) above the sea shore. A complete radial system (factory specified) was erected for the vertical antenna. W1FB used a center-fed sloping dipole over the sea shore. It was approximately 25 feet (7.6 m) above the shoreline. During 20-meter operation over a two-week period, comparative signal reports from the USA and DX stations revealed that the sloping dipole of W1FB was consistently two to three S units better than the trap vertical. It is fair to say that at another time, and from some new QTH, the situation might be reversed. The inferior performance of the trap vertical did not, however, impair the ability of W8JUY to hold regular schedules or work DX, which brings us to the focal point of this discussion: Irrespective of the actual performance, a trap beam or trap vertical can be (and usually is) a suitable all-around amateur hf-band antenna.

Table 1

Dimensions for Various Frequency Pairings

Tubing (Fig. 1)	*Band (MHz)*	*A*	*B*	*C*	*D*	*E*	*F*	*C1 (pF)***	*L1 (Approx. µH)*
Tubing Length	21/28	25	16	25	25	25	33	18	1.70
(inches)	14/21	38	33	37	37	37	33	25	2.25
	10/14*	42	42	54	54	54	49	39	3.25
Tubing Length	21/28	20	16	21.5	21.5	21.5	33	—	—
at Resonance	14/21	33	33	33	33	33	33	—	—
(approx. inches)***	10/14*	37	37	49.6	49.6	49.6	49	—	—

in. × 25.4 = mm
*New WARC-79 band.
**See text.
***Midband dimensions. X_{C1}, $X_{L1} \approx 300\ \Omega$

*Senior Technical Editor, ARRL

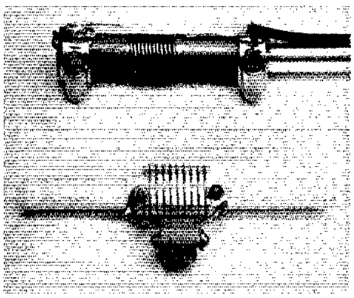


Fig. 1 — Photograph of two styles of traps. PVC tubing is used for the lower one (see text) and Teflon rod is used as the coil form for the other. The ends of the Teflon rod have been reduced on a lathe to fit inside the tubing sections above and below the trap. Teflon is too flexible for large verticals, but phenolic or fiberglass rod would be satisfactory. Miniductor stock comprises the coil in the upper trap. A ceramic transmitting capacitor is used in parallel with the coil.

Separate single-band, full-size vertical antennas would probably work slightly better than a multiband trap vertical, but the latter would cost less, occupy less space, be more convenient and do a pretty good job for the operator.

How do Traps Work?

A *trap* is pretty much what the name implies: It "traps" rf energy by blocking its passage to portions of the antenna that aren't used during operation in a specified band. A trap is a high-impedance device at the selected operating frequency, which enables it to block the passage of rf energy on the band for which it is a parallel-resonant circuit. At some lower frequency it becomes part of the antenna, and responds somewhat as a loading coil. Thus, if we were to build a two-band trap beam or vertical for, say, 40 and 20 meters, the part of the antenna from the feed point to the bottom of the trap would constitute the 20-meter radiator. The trap (tuned for 20 meters) would effectively "divorce" the portion of the antenna above the trap during 20-meter operation. When changing operations to 40 meters, all of the antenna would become a functional part of the system. The trap acts as a loading coil on 40 meters, which results in the overall antenna length being somewhat less than that of a full electrical quarter wavelength.

If the trap antenna were designed for more than two amateur bands, additional traps and antenna sections would be used, but the principle of operation would remain the same. The highest frequency section of the antenna is always nearest the feed point and progresses outward until all of the antenna is used for the lowest operating frequency.

Trap Design

There is no rigid formula for selecting a best L/C ratio for an antenna trap. Generally, the X_L and X_C values can range between 100 and 300 ohms, and since $X_L = X_C$ at resonance, they will be the same value in a trap.[1] We often select a standard capacitor value in that reactance range and "tailor" the coil X_L to equal it.

It is important to keep the trap losses as low as possible (high Q). This requires the use of a coil form with high dielectric quality, such as polystyrene, phenolic, fiberglass, ceramic, Teflon or Plexiglas. The material chosen should be capable of withstanding antenna stress during periods of wind and ice loading. Brittle materials should not be used in cold climates in order to prevent the coil form from shattering under stress.

For power levels below 200 watts dc input to the PA stage of the transmitter, it is okay to use PVC tubing. At high rf-power levels, the PVC may heat, melt and burn. Nylon insulating forms are subject to the same failure, and the condition worsens as the operating frequency is increased.

The coil conductor should be of large cross-sectional area to minimize trap loses. No. 14 AWG or heavier copper wire is recommended. For high-power work, it is helpful to use copper tubing as the coil.

The Q and voltage rating of the trap capacitor also is an important consideration. If a fixed-value capacitor is used, it should be a ceramic transmitting type of capacitor (Centralab 800 series or equivalent). These units are available with working voltages up to 20 kV. This style of capacitor is shown in Fig. 1.

A suitable length of 50- or 75-ohm coaxial cable can be used as a trap capacitor. RG-58/U and RG-59/U cable is suggested for rf power levels below 150 watts. RG-8/U or RG-11/U will handle a few hundred watts without arcing or overheating. The advantage in using coaxial line as the trap capacitor is that the trap can be adjusted to resonance by selecting a length of cable that is too long, then trimming it until the trap is resonant. This is possible because each type of coax exhibits a specific amount of capacitance between the conductors. *The Radio Amateur's Handbook* contains a table that lists the capacitance per foot for popular coaxial cables. For example, RG-58/U has approximately 25 pF per foot, whereas RG-8/U cable has approximately 30 pF per foot. A coax-cable capacitor is also shown in Fig. 1.

Additional Band Capability

Assuming that we have built a trap vertical for two or three bands, what might we do to obtain capability for one additional band without using the trap concept? The simple way to achieve this is to place a coil and capacitance hat on the top of the trap vertical. This is equivalent to "top loading" any vertical antenna. Suppose we had a trap vertical for 20, 15 and 10 meters, but also wanted to use the system on 40 meters. The popular way to do this is to construct a 40-meter loading coil which can be installed as shown in Fig. 2. A number of commercial trap verticals use this technique. The loading coil is called a "resonator" because it makes the complete antenna resonant at the lowest chosen operating frequency (40 meters in our example). The coil turns must be adjusted while the antenna is assembled and installed in its final location. The remainder of the antenna has to be adjusted for proper operation on all of the bands *before* the resonator is trimmed for 40-meter resonance. If the capacitance-hat wires are short (approximately 12 inches or 300 mm), we can assume a capacitance of roughly 10 pF, which gives us an X_C of 2275 ohms. Therefore, the resonator will also have an X_L of 2275 ohms. This becomes 51 μH for operation at 7.1 MHz, since $L_{\mu H} = X_L/2\pi f$. The resonator coil should be wound for roughly 10% more inductance than needed to allow some leeway for trimming it to resonance. Alternatively, the resonator can be wound for 51 μH and the capacitance-hat wires shortened or lengthened until resonance in the selected part of the 40-meter band is achieved.

As was true of the traps, the resonator should be wound on a low-loss form. The

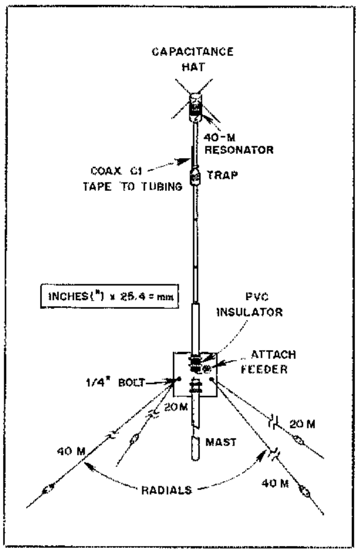


Fig. 2 — The assembled trap vertical, showing how a resonator can be placed at the top of the radiator to provide operation on an additional band (see text).

[1][Editor's Note: This is true only for one frequency band. All other dimensions being held equal, the lower the L/C ratio, the higher the resonant frequency will be on a lower frequency band. Of course the length of the outside end section can be adjusted for desired resonance on the lowest frequency band with a fixed L/C ratio.]

largest conductor size practical should be used to minimize losses and elevate the power-handling capability of the coil. Details of how a homemade resonator might be built are provided in Fig. 3. The drawing in Fig. 2 shows how the antenna would look with the resonator in place.

A Practical Two-Band Trap Vertical

The author needed a 20/15-meter antenna for use on his RV camper and to carry to the Caribbean for DXpeditions. Therefore, it seemed prudent to design an antenna that could be broken down into a small package for carrying or storage. The best approach seemed to be that of using short lengths of aluminum tubing that would telescope into one another. The longest of these is 39 inches (991 mm).

The ends of the sections are cut with a hacksaw to permit securing the joints by means of stainless-steel hose clamps. The trap is held in place by two hose clamps that compress the PVC coil form and the 1/2-inch (13-mm) tubing sections onto 1/2-inch dowel-rod plugs (Fig. 4). Strips of flashing copper (parts "G" of Fig. 4) slide inside sections B and C of the vertical. The opposite ends are placed under the hose clamps, which compress the PVC coil form. This provides an electrical contact between the trap coil and the tubing sections. The ends of the coil winding are soldered to the copper strips. Silicone grease should be put on the ends of straps "G" where they enter tubing sections B and C. This will retard corrosion. Grease can be applied to all mating surfaces of the telescoping sections for the same reason.

The trap (after final adjustment) should be protected against weather conditions. A plastic drinking glass can be inverted and mounted above the trap, or several coats of high-dielectric glue (Polystyrene Q-Dope) can be applied to the coil winding. If a coaxial-cable trap capacitor is used, it should be sealed at each end by applying noncorrosive RTV compound.

The trap is tuned to resonance prior to installing it in the antenna. It should be resonant in the center of the desired operating range, i.e., at 21,050 kHz if you prefer to operate from 21,000 to 21,100 kHz. Tuning can be done while using an accurately calibrated dip meter. If the dial isn't accurate, locate the dipper signal using a calibrated receiver *while the dipper is coupled to the coil and is set for the dip.*

A word of caution is in order here: Once the trap is installed in the antenna, it will not yield a dip at the same frequency as before. This is because it becomes absorbed in the overall antenna system and will appear to have shifted much lower in frequency. For the 20/15-meter vertical, the apparent resonance will drop some 5 MHz. Ignore this condition and proceed with the installation.

The Tubing Sections

An illustration of the assembled two-band trap vertical is shown in Fig. 5. The tubing diameters indicated are suitable for 15- and 20-meter use. The longer the overall antenna, the larger should be the tubing diameter to ensure adequate strength.

A short length of test-lead wire is used at the base of the antenna to join it to the coaxial connector on the mounting plate. A banana plug is attached to the end of the wire to permit connection to a uhf style of bulkhead connector. This method aids in easy breakdown of the antenna. A piece of PVC tubing slips over the bottom of section "F" to serve as an insulator between the antenna and the mounting plate.

If portable operation isn't planned, fewer tubing sections will be required. Only two sections need be used below the trap, and two sections will be sufficient above the trap. Two telescoping sections are necessary in each half of the antenna to permit resonating the system during final adjustment.

Other Bands

It's unlikely that everyone would want to build this antenna for 20 and 15 meters. Those who are interested in other frequency pairings will find pertinent data in Table 1. We have included information on building a trap vertical for the new 10-MHz WARC-79-sanctioned band, plus 20 meters. One additional band can be accommodated for any of the combinations shown by using a top resonator.

A Universal Mounting Plate

Field operation requires a variety of antenna-mounting schemes such as porch-rail attachment, window-sill mounting,

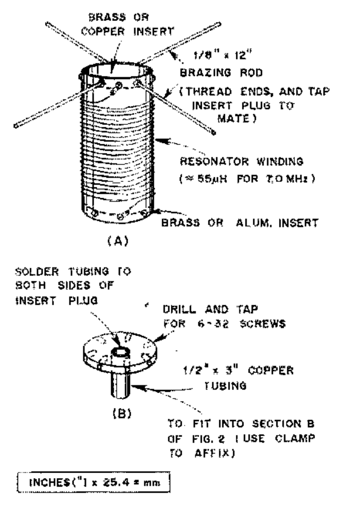


Fig. 3 — Details for building a homemade top-loading coil and capacitance hat. The completed resonator should be protected against the weather to prevent detuning and deterioration.

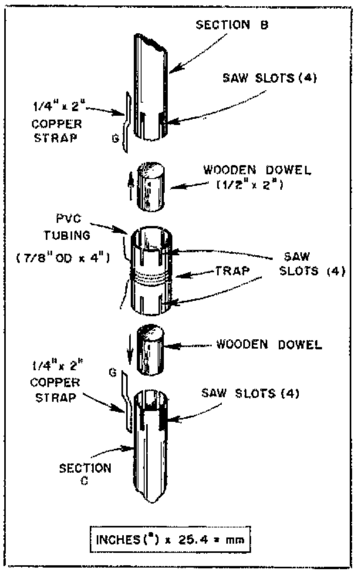


Fig. 4 — Break-down view of the PVC trap. The hose clamps that go on the ends of the PVC coil form are not shown.

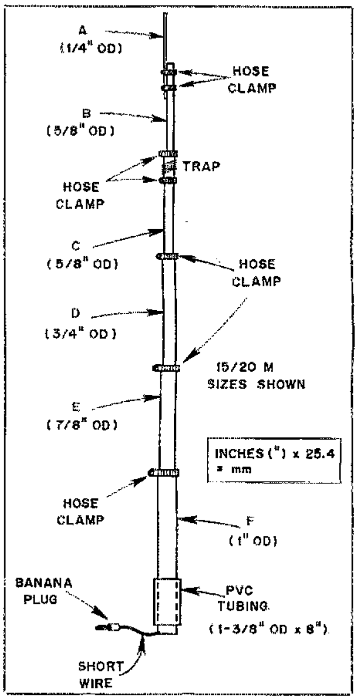


Fig. 5 — Assembly details for the two-band trap vertical. The coaxial-cable trap capacitor is taped to the lower end of section "B."

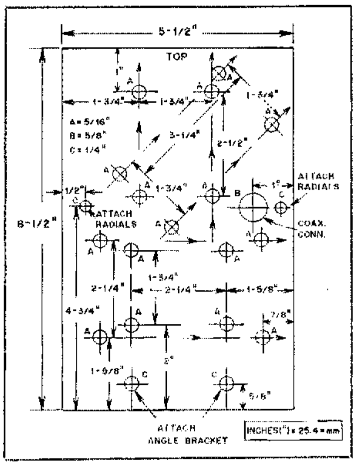


Fig. 6 — Suggested layout for a universal mounting plate. U bolts or muffler clamps can be used to attach the vertical to the plate, and to affix the supporting mast to the antenna. The arrows show the angles at which the antenna and the mast can be mounted to meet a host of mechanical conditions. Hole "B" is for a uhf bulkhead coax connector.

etc. For this reason it is helpful to have a mounting plate which will satisfy many unknown conditions. Fig. 6 shows the layout for a plate that is made from 1/4 inch (6.3 mm) thick aluminum plate. Steel, copper or brass plate is also suitable. The top half of the plate contains two sets of U-bolt holes for mounting the radiator vertically. A second set of holes permits 45-degree mounting from a window sill.

The lower half of the plate has two sets of U-bolt holes for attaching a mast vertically. A second set of holes permits horizontal mast mounting, should that format be necessary.

The bottom two holes in the plate are for attaching a length of angle stock. There is a second piece of angle stock the same length. The angle brackets can be used with a pair of C clamps to attach the antenna to a variety of foundations.

Hole "B" is for the uhf female-to-female coaxial bulkhead connector. Holes "C" at the left and right center of the plate are for attaching the radials by means of large bolts and washers. The holes marked "A" are for the U bolts or muffler clamps. The hole diameters and spacings will depend upon the size and brand of U bolts used. The arrows indicate the mounting angle of the antenna element and the mast. A photograph of the base plate and related hardware is given in Fig. 7.

Ground System

There's nothing as rewarding as a *big* ground system. That is, the more radials the better, up to the point of diminishing returns. Some manufacturers of multiband trap verticals specify two radial wires for each band of operation. Admittedly, an impedance match can be had that way, and performance will be reasonably good. So during temporary operations where space for radial wires is at a premium, use two wires for each band. We prefer a minimum of four wires for each band, and generally use that many. The slope of the wires will affect the feed-point impedance. The greater the downward slope, the higher the impedance. This can be used to advantage when adjusting for the lowest VSWR. When the radials are perfectly horizontal, the feed impedance will be on the order of 30 ohms. This suggests the use of a 1.6:1 broadband transformer at the feed point to assure a good match — assuming horizontal radials must be used in a particular installation.

The radial wires are cut to an electrical quarter wavelength for the band of operation. Some operators argue that making the radials 5% longer will increase the antenna bandwidth. The author has not found this to be true, but did observe some changes in feed-point impedance when that was done.

If the antenna is to be ground-mounted, make certain that the lower end of section "F" is only a few inches above ground. Bury as many radials in the earth as practical, using no less than 20 wires that are the length of the overall vertical antenna, or longer.

Tune-up

An SWR indicator will be necessary when adjusting the antenna. Apply rf

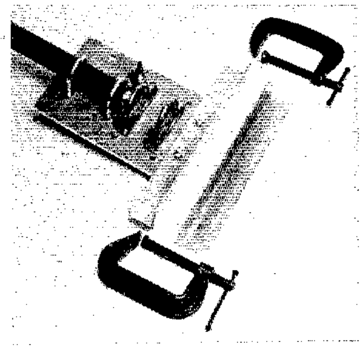


Fig. 7 — Photograph of the mounting plate showing two angle brackets and C clamps, which provide additional mounting possibilities.

energy at the center of the desired operating range of the highest operating band of the antenna. Adjust the length of the section below the trap for the lowest VSWR.

Next, set the transmitter for a frequency in the center of the lowest frequency operating range. Adjust the length of the section above the trap for the lowest obtainable VSWR. Repeat both adjustments to compensate for interaction of the adjustments. If a top resonator is used for a third band, it should be adjusted last for the lowest attainable VSWR.

Summary Comments

The antenna can be broken down to form a compact assembly for transport. A heavy-duty cardboard mailing tube, or a 2-inch (51-mm) ID piece of aluminum tubing will serve nicely as a container for shipping or carrying. Iron-pipe thread protectors can be used as plugs for the ends of the carrying tube. The trap, mounting plate and coaxial feed line should fit easily into a suitcase with the operator's personal effects.

If you haven't been a radio-operating wayfarer thus far, perhaps this antenna will inspire you to become one! If you want to hear this antenna in operation, look for W1FB on 20 and 15 meters from the camp site, or from Tortola, British Virgin Islands during late October and early November of 1980.

Strays

NOVICE DX NET

☐ A Novice DX net is being formed. Planned starting date is October 11 at 1430 UTC on 28.103 MHz. Write Al Fetzer, WD9EJE, 1444 Wilmette Ave., Wilmette, IL 60091, for details.

LIBRARY OF CONGRESS WANTS AMATEUR TV PUBLICATION

☐ Henry B. Ruh, K2VCU, assistant chief engineer for Indiana University Radio and Television Services, has been asked to provide a copy of *Amateur Television Magazine*, which he publishes, to the permanent collection of the Library of Congress. Ruh has been publisher of the magazine, which has an international circulation of 2100, since 1975.

I would like to get in touch with . . .

☐ amateurs who practice the Transcendental Meditation technique or who are interested in TM. A net meets on 14.340 MHz Sundays at 1630 UTC, or contact Barbara Sweet, WA2KCL.

☐ anyone who could donate some old DX *Callbooks*, dating back to 1945. Carl Mitchell, K1JDJ, Box 1003, Fairfield, CT 06430.

• *Basic Amateur Radio*

Designing and Bending Metal Enclosures

Do you get all bent out of shape when bending metal? Do lids that don't fit give you fits? This article will help you gain an understanding of metal bending — without fatigue!

By Dave Smith,* K3LHD

Home construction is still the name of the game for many amateurs. Most devotees build the electronic part of a project and then put it into a manufactured enclosure so it doesn't look so homemade. Unfortunately, these enclosures are becoming increasingly expensive.

Many who do try to make their own enclosures are usually less than satisfied with the results. My own experiences produced enclosures that just didn't come out right, no matter how carefully I measured the pieces. Usually I had to trim edges or put up with wide gaps where the lid and bottom joined together. It was only after I got into metal aircraft building that I learned a few simple tricks to ensure that my parts came out to be the correct size after bending.

A Gain Problem

Metal shows gain in one dimension when bent. This unexpected gain was making my earlier pieces come out too large. A piece of metal will gain length in the direction away from the portion held firmly in the brake. This is graphically depicted in Fig. 1.

The amount of gain has to be taken into consideration and allowed for by subtracting from the piece that is to be bent. The amount to be subtracted is called the *bend allowance*. Bend allowances will differ for each brake and for each gauge of metal. Table 1 is provided as an illustration.

Bend allowances can be individually determined for any brake simply by placing a piece of known dimension in the brake, bending it by 90° and measuring the gain. An example is shown in Fig. 2. As you can see from the figure, the bent

Table 1
Bend Allowances for the Author's Brake

Metal Thickness	*Bend Allowance*
0.025 in.	0.10 in.
0.040 in.	0.12 in.
0.063 in.	0.22 in.

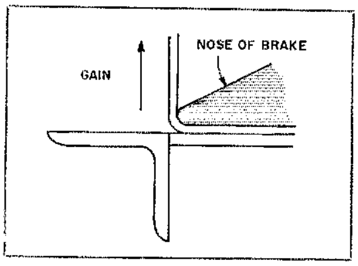


Fig. 1 — Gain occurs in the portion not held firmly in the brake or vise.

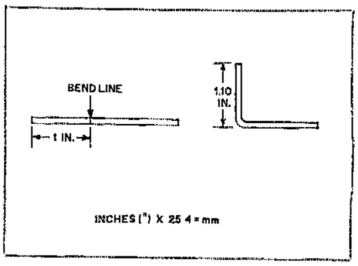


Fig. 2 — Portion not held in the brake gained 0.1 inch in the process of being bent.

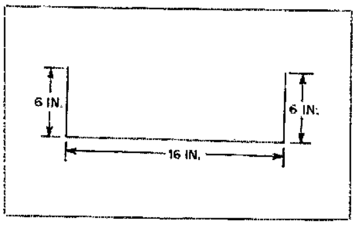


Fig. 3 — The dimensions desired in the finished product.

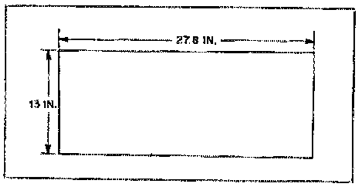


Fig. 4 — After allowing for the gain to be attained during the bending process, these are the dimensions of the piece of metal before bending.

*RD 1, Box 366A, Carlisle, PA 17013

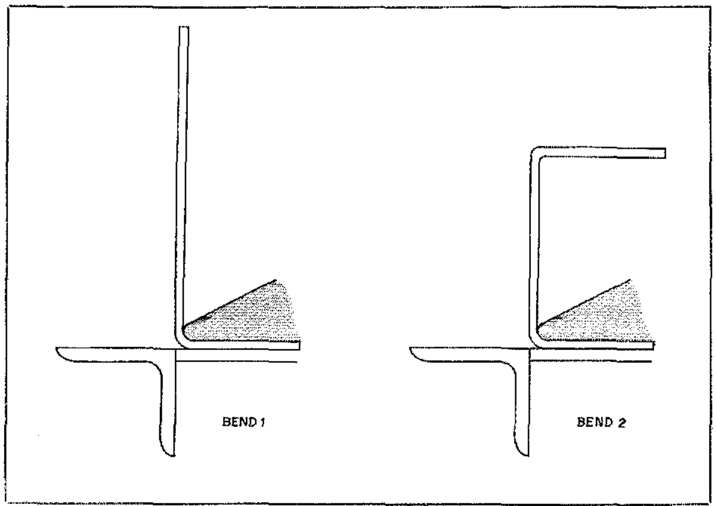


Fig. 5 — Correct bending sequence.

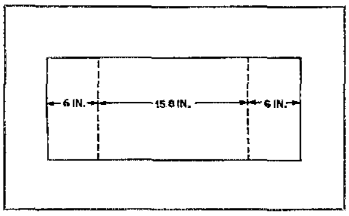


Fig. 6 — Correct position of bend lines.

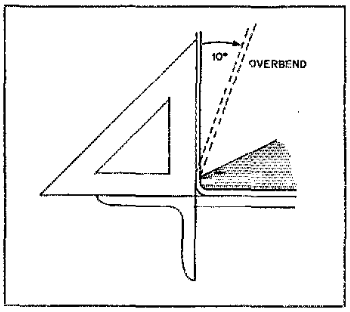


Fig. 7 — Using a protractor to ensure the bend is a perfect 90° angle.

piece has gained 0.10 in., meaning the bend allowance is 0.10. Now let's apply this to the making of a Transmatch chassis bottom, whose dimensions are to be 16 × 13 × 6 inches (406 × 330 × 152 mm) finished.

1) First, calculate the total outer dimensions of the finished channel as shown in Fig. 3. The finished dimension totals 28 inches.

2) Now determine the number of bends, two in this case.

3) Multiply the number of bends times the bend allowance; 2 × 0.10 = 0.20 in. (5 mm). This is the amount that must be subtracted from the total outside dimension for the piece to come out correctly; 28 − 0.20 = 27.8 in. (706 mm). The piece must then measure 13 × 27.8 in. (330 × 706 mm) before bending (Fig. 4).

The next thing to consider is where to draw the bend lines and in what order to make the bends; if you use the wrong bend sequence, more-complicated pieces can come out wrong or get trapped in the brake. Remember, *gain occurs in the free part*, not the held-down part of the piece. Therefore, the U channel should be bent with the sides held firmly in the brake. See Fig. 5 for a pictorial description of the sequence. You can see that the gain will occur in the center and not on the ends, so you simply draw the bend lines 6 in. from the ends, which is the desired finished dimension (Fig. 6).

One other thing that I might mention: Metal has a natural tendency to spring back when bent. So in order to get a 90° bend, you will have to overbend it by about 10° or so. By placing a square or draftsman's triangle on the piece while in the brake, you can finger-work the piece to the angle desired (Fig. 7). When bending to an angle other than 90°, I usually just make a simple cardboard protractor to measure the angle while in the brake.

The same techniques apply to making the top of the unit. With a little ingenuity, tabs can be included or added later to connect the top and bottom. Add components, rubber feet, a fancy paint job and lettering, and you have a homebuilt project in an enclosure that doesn't look homemade. Good luck, and happy bending!

Strays

TA PROFILES

☐ We are grateful for the services rendered by David T. Geiser, WA2ANU, who has been an ARRL Technical Advisor (TA) for vhf/uhf microwave components since 1977. First licensed in 1939 as W3IOA, Dave has held appointments as Assistant EC, OO, OBS and occasional NCS for the Kansas and Massachusetts Phone nets. He received the ARRL Public Service Award for his work in the 1951 floods. Dave's interests in Amateur Radio include experimenting, ragchewing and traffic. He holds a Radiotelephone First Class license with a Radar endorsement. He is a life member of the ARRL and a member of QCWA, the Utica (New York) Amateur Radio Club and the IEEE.

Dave received his BSEE degree from Southern Methodist University in 1947. He has published over 100 articles in amateur and professional journals, and has been granted six patents. Employed as a Components Engineer for one of the larger U.S. companies, Dave professionally writes specifications for these commodities. He lives in New Hartford, New York. — *Marian Anderson, WB1FSB*

TA WA2ANU, with one of his homemade projects in hand.

ATTENTION AFFILIATED CLUBS

☐ If your club is *actively* affiliated with the ARRL, one of your officers has already received a coupon redeemable for a review copy of the new *ARRL Operating Manual*. If your club has not received a copy of the July *Radio Club News*, you did not receive this coupon. Why not update your club records so that your club can participate in future giveaways? Contact the Club and Training Department at ARRL hq. for the status of your club. — *Sally O'Dell, AE8P, Club Programs Manager*

• *Basic Amateur Radio*

Rewinding Transformers

Turned off by the high cost of power supplies? Wouldn't you like to turn a junked transformer into a custom-wound unit in less than two hours? It is easy; here's how.

By Peter O'Dell,* AE8Q and Bob Shriner,** WAØUZO

A few years back Lew McCoy, W1ICP, stated that his motivation for writing an article similar to this was that he was "a noted cheapskate."[1] We believe that such a quality is an admirable characteristic! Laziness may be pretty good, too. Therefore, any resemblance between this article and McCoy's is less than accidental. Our younger readers should take note of this, as it can be of benefit in their formal education. Depending on whether one is taking or giving the course, this process is either referred to as plagiarism or research. Once you have departed the nest of academia, the laws of the real world take over. The one that applies here is, "don't reinvent the wheel."

Winding your own secondary on a transformer can provide several benefits. For instance a quick check of an industrial supply catalog revealed that a 24-V, 12-ampere transformer costs approximately $30. You can rewind the secondary of a discarded transformer for less than $6 (including the cost of the wire). Additionally, suppose that you want to build a 12-V regulated power supply capable of delivering 6 to 8 amperes: You may have to resort to using a 24-V 12-ampere transformer. That would mean that your heat sink and regulator circuit would have to be capable of dissipating nearly 100 W. If you custom design the transformer, you can choose your values such that the heat dissipation is reduced by as much as 75% without any detrimental effects on regulation. Add personal satisfaction to the other benefits and you have a strong mandate for winding your own.

Choosing a Transformer

The first step in this process is selecting a transformer. This can be easier than you think, as the sources are many. Some

*Basic Radio Editor
**Box 969, Pueblo, CO 81002

[1]McCoy, "The Ugly Duckling," *QST*, November, 1976, p. 29.

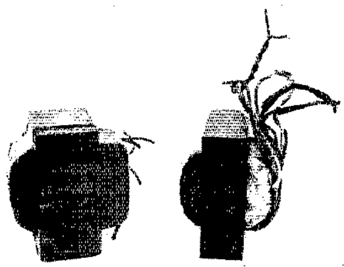


Fig. 1 — Two transformers: One suitable for rewinding, one not. The transformer on the left has been soaked in tar and will prove to be quite messy should you try to remove the windings. Notice the "caked" appearance on the outside of the laminations; this should tip you off before removing the bell housing. This transformer also has a copper strap wrapped around the outside of the laminations. Its function is to shield nearby ac-sensitive circuits from the field of the transformer. For our purposes, this shield may be cut off and discarded. The transformer on the right has not been soaked in tar; however, note that the laminations have been coated with shellac, which gives them a dark appearance and bonds them together. *(all photos courtesy of W1JA)*

surplus houses sell transformers that can be rewound without difficulty. Transformers are usually abundant at flea markets. Of course, a popular source has been the carcass of a defunct TV set. There are a few things to be aware of: The primary should be designed for 117 V if you are to avoid the cumbersome task of rewinding it. Some transformers are potted in tar (Fig. 1); most of you will probably want to avoid the mess of removing the tar. Sealed transformers may possibly contain oil that has been impregnated with PCBs — *avoid these*!

The size of the core is the chief limiting factor in the power-handling capability of the transformer. Fig. 2 depicts the "E" and "I" shapes of the laminations and how they are stacked together. Each piece has a thin coating of varnish or glyptol, which acts as an insulator and helps pre-

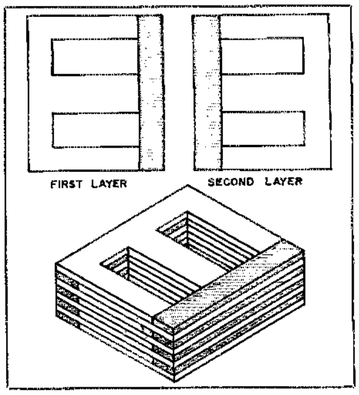


Fig. 2 — How the core is assembled. Alternate layers have the E laminations facing oppositely. Sometimes two or more laminations of the same kind are grouped together and handled as a single lamination to save assembly time.

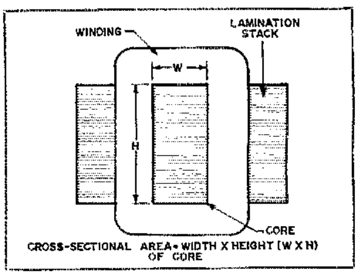


Fig. 3 — This is a cross-sectional drawing of a typical power transformer. The cross-sectional area referred to in Fig. 4 is determined by multiplying the tongue width by the height of the center core.

vent losses in the core. Lamination sizes for U.S. transformers are standardized. For the typical TV transformer, the width and length are commonly 3-3/4 by 4-1/2 inches (95 × 114 mm), with the tongue of the "E" laminations always 1-1/2 inches

(38 mm) wide. To determine the cross-sectional area, all that is needed is the height of the stack (Fig. 3). Once you have determined the cross-sectional area by multiplying the height by the width of the "E" tongue, refer to the graph in Fig. 4 to determine the power-handling capability. If the transformer is an odd size, we can estimate its capability by using the rule of thumb that it will handle about 40 W for each pound (about 88 W per kg) of iron in the core.

Quite a variety of alloys are employed as core material in transformers. Silicon, cobalt and nickel are the most frequently used additives. These alloys are sold under a wide range of trade names such as Hypersil and Permalloy. If you are dealing with a used transformer, chances are that you will have no idea of the precise composition of the core material. Various core materials display some difference in power-handling capability; therefore, keep in mind that any estimate of power-handling capability based on mass is just that — an estimate. For instance, some of the imported transformers sold in popular consumer-oriented electronic parts stores have enough mass *to suggest* to the casual observer that their power-ratings are reasonable. These transformers tend to "run hot," however, even under a no-load condition, indicating an inferior core material.

The power-handling capability needed can be determined by multiplying the highest current to be drawn from the supply times the maximum voltage across the secondary under full load. If we wanted to build a 13.8-V regulated supply capable of delivering 20 amperes, we would calculate the needed capability as follows. To function properly most regulator circuits require more voltage (2 V or greater) at the input of the regulator than that which is to be delivered at the output. To be on the safe side, we will add another volt to this figure for a total of 17 V. (Since we are custom-winding the transformer, we will make sure that the voltage does not go any higher, because increased input voltage beyond this point means increased heat dissipation and decreased efficiency.) We multiply 17 V times 20 A and get 340 W. Fig. 4 indicates that we need a transformer whose core has a cross-sectional area of about 3.5 square inches (2200 square mm). If we are dealing with a standard size TV transformer, then we are looking for one with a stack at least 2.3 inches (58 mm) high.

Once the transformer has been decided upon, the next step is to measure the voltage of one of the low-voltage windings with an ac voltmeter. If the transformer is being removed from some tube type of equipment, it will probably have a 6.3-V winding. Without a load, this winding will read slightly higher on the meter. Cut off the excess leads from the transformer; make sure that enough of the colored in-

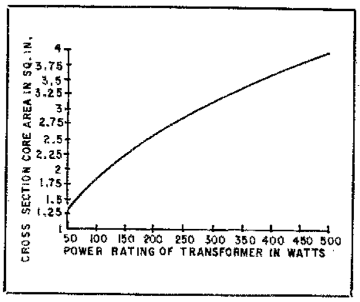


Fig. 4 — This graph provides a simple means for determining the power capabilities of an unknown transformer. First determine the cross-sectional area of the core. Find your cross-sectional area figure on the vertical axis and then go across the graph to the curve. Drop from intersection point vertically to the bottom of the chart to find the power in watts.

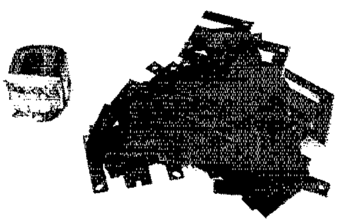


Fig. 5 — Old windings with pile of laminations next to it. After you remove the laminations from the windings, you may doubt that you will ever get them back in. Fear not; they usually go back in much easier than they came out.

Fig. 6 — Old winding stripped down to the original primary, which was then wrapped with fiberglass-reinforced tape. If the enamel insulation of the wire has been damaged during the process of removing the other windings, use a small amount of Q-dope or fast-setting epoxy to restore the integrity of the winding before wrapping with the tape.

sulation remains to allow identification of the primary and the secondary with the known voltage. If the insulation has "lost its color" over the years, tag the leads to the above-mentioned windings with different types of tape. If it has not already been done, remove the nuts, bolts and bell housing.

Sack the Stack

If you examine the winding and the core closely, you may find a small piece of wood wedged between the windings and the core. If so, remove this wedge and save it for reassembly. Place a knife blade in the groove between the first and second laminations at one end. Gently tap the knife blade with a hammer until it separates the two laminations. Using the same method, work your way around the core until the first and second laminations are completely separated. With a small flat-bladed screw driver or similar device, tap the E lamination out of the winding. This is usually the hardest lamination to get out. Proceed in a similar manner with the remaining laminations. To simplify things, if you notice that there are some substacks (two or three Es in a row oriented in the same direction), just remove the subassembly without breaking it into individual laminations. When you are finished you will have a pile similar to that shown in Fig. 5.

Carefully remove the brittle paper that surrounds the windings. If the secondary winding that was measured earlier is the outermost winding, unwind it and count the turns. It is important that you count the number of turns precisely to be able to calculate the amount of wire needed for the new secondary. If the known-value secondary is not the outermost, remove the outer secondaries down to the known-value one and then count the turns. Write down the number of turns and the voltage for future reference. Remove the other secondaries. We have assumed that the primary is the innermost winding; this may not always be the case, but the chances seem remote that you would find it otherwise. If, in fact, the primary is not the innermost winding you have some options: (1) you may want to rewind the whole transformer, including the primary, (2) you could cut and tape the ends of any secondaries that lie beneath the primary and wind the new secondaries around the primary, or (3) you may elect to find another transformer and start over. If you have the transformers available, starting from scratch may be the best course. Whatever, the final product of this stage should appear similar to the winding shown in Fig. 6.

One Good Turn Deserves Another

Using the known-value secondary voltage and number of turns, calculate the turns-per-volt ratio by dividing the number of turns by the known voltage of the secondary. For example, suppose we have measured one of the secondaries and found that it produces an ac voltmeter indication of 6.5 under no-load conditions. We will assume that it is, in fact, a 6.3-V winding. Suppose we count the turns and find that this secondary has 19 turns. Dividing 19 turns by 6.3 volts, we find that we have a 3 to 1 turns-per-volt ratio, three turns for every volt at the secondary output. Now multiply the desired secondary voltage by the turns-per-volt ratio to find out how many turns you will need. Next, measure the circumference of the winding and multiply that times the number of turns needed in the secondary to find out how much wire is needed for this winding. It is wise to allow some additional footage for "slop" — say 10% to 25% depending on your confidence in your ability to wind. Refer to charts in *The Radio Amateur's Handbook* or *ARRL Electronics Data Book* giving information on the current-carrying capability of various-size wires and determine the gauge of wire needed for the new secondary. If you do not have wire large enough to carry the desired current, you may parallel two or more smaller gauge pieces to provide a larger effective cross-sectional area. The limiting factor is keeping the windings thin enough so that the core can be reassembled.

Before going further, the choice of insulation between layers of the winding should be explained. The industry standard is varnished cambric, but we can not recommend any source for it. McCoy was fond of using wax paper for this purpose, but it is prone to sliding around. At times we have heard others suggest plastic electrical tape. Most tapes have a tendency to separate from their sticky backing and unravel after a few months. We prefer masking tape, which does not separate from the backing and tends to mold itself to the shape of whatever it is attached to after a few months.

Masking tape is perfectly adequate for a low-voltage transformer that will *not* be running hot. If you decide to rewind a high-voltage transformer that will be operating close to its power-handling-capability limits, then some other material should be used. Commercially oriented electronics distributors usually stock cloth based, fiberglass tape that is both heat and shrink resistant; it should be acceptable for the more demanding applications. (It is more expensive, too.) One further note is that we are using ordinary fiberglass-reinforced packing tape (because of its strength) to hold the end windings in place on each layer.

Once the desired length of wire has been determined, measure and cut it (including the amount as a safety factor). If you are doing this as a one-person job, secure one end in a vise. Cut off five pieces of fiberglass-reinforced tape, each about 10 inches (250 mm) long. Place one end of one piece of tape on the center of the windings (parallel to the wire in the winding). Making sure that the end of the tape is sticking to the winding, place another piece of the tape at the first corner, perpendicular to the first piece of tape, with the *sticky side of the tape facing out.* Press the first piece of tape down over the second and move on to the next corner. Repeat the process until you have one piece of tape at each of the four corners, with the sticky side out (see Fig. 7).

Position the free end of the previously prepared wire so it will exit the winding properly when the transformer is reassembled. Carefully start the first turn of the secondary near the edge of the primary. As you wrap the wire around the first corner of the windings, fold that end piece of tape back over the wire and cut off the excess (see Fig. 7).

Repeat this process at each corner of the first turn of the secondary until the turn is tightly secured to the windings. The four unused ends of tape will be used in a similar manner for the last turn of the first layer. As you wrap the other turns on the first layer keep the wire taut; this will ensure that the turns are straight and that you get a maximum number of turns per layer. Also keep track of the number of turns. Once the last turn of the first layer has been secured with the four pieces of tape, it will be necessary to add a layer of insulation before winding the next layer of the secondary (Fig. 8).

After you have finished the first layer, repeat the process if more turns are needed. First, prepare five strips of the fiberglass-reinforced tape. Use one strip

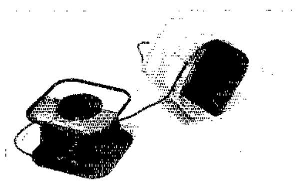


Fig. 7 — The first turn of the new secondary. Notice that the end of the wire making up the secondary has been positioned such that it will be properly aligned when the transformer housing is put back together. Note also that one end of each piece of tape is now folded over. The other four ends will be used on the last turn of this layer.

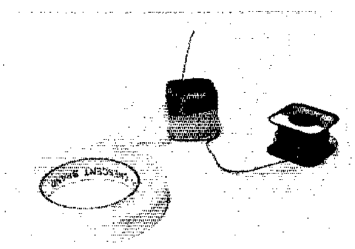


Fig. 8 — Masking tape is applied between layers of the secondary.

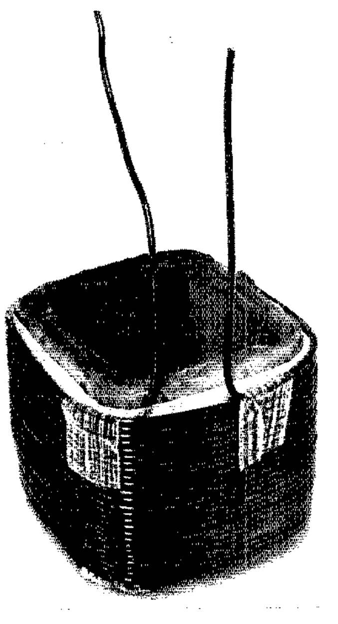


Fig. 9 — Completed windings. Notice that the secondary leads enter and exit on the same side as the primary leads (which have been folded inside the windings out of the way).

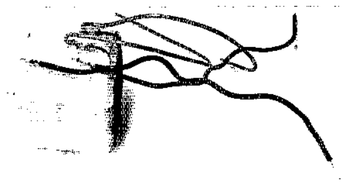


Fig. 10 — Completed windings ready for reassembly of the core. Color-coded-insulated wires have been attached to the leads from the windings. Electrical tape or heat-shrink tubing may be added to the solder joints or any other place that might need the added protection.

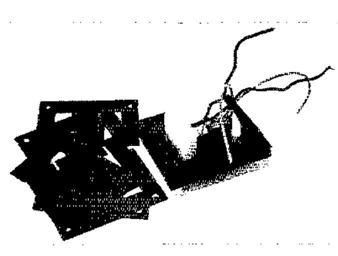


Fig. 11 — Partially reassembled core. Reassembly can usually be accomplished quite a bit quicker than disassembly. If it is likely that enough shellac was scraped off during disassembly to cause shorting between laminations, add a thin coat of shellac or glyptol as you put the core back together again.

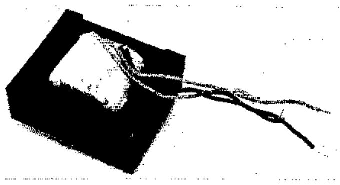


Fig. 12 — Transformer reassembled and awaiting the bell housing.

to attach the other four (sticky side out) to the windings, as you did for the first layer. Bring the wire up onto the edge of the masking tape from the position where it exited the first layer. Wind and secure the first turn of the second layer. Repeat the other steps until the desired number of turns have been wound. If additional layers are required, repeat the "between-layers" process until the desired number of turns has been wound. When the secondary is completed, it should look something like the one pictured in Fig. 9. Make sure that the leads are oriented properly for reassembly of the transformer.

Final Wrap-Up

Wrap the windings with a few layers of masking tape. Cut off the excess leads and solder color-coded insulated leads (adequate gauge to handle current available) to the primary and secondary (Fig. 10). Position the leads as necessary for the reassembly of the unit. Reassemble the laminations into and around the windings. It is probably best to start with any "sub-assemblies" of more than one lamination that were removed as one piece earlier. Make sure that each "E" is matched with an "I" and that the holes are aligned. Fig. 11 shows a transformer with the laminations partially reassembled. Once the laminations have all been reinstalled and aligned, use a small hammer to tap the wooden wedge back between the windings and the laminations. The wedge will prevent vibration and noise when the transformer is operating. If disassembly required a great deal of scraping and prying, there may be danger of one lamination shorting to another. Should this seem possible, it might be wise to give each lamination a thin coating of varnish or glyptol as the core is being reassembled. If it is not likely that bare metal will be touching bare metal, however, this is a bit messy and probably isn't worth the effort.

The only thing left to do is to reassemble the bell housing and tighten the nuts and bolts. Your custom-wound transformer is now ready for use in your power supply. You may not relish the idea of referring to yourself as a "cheapskate"; you may not wish to engage in plagiarism. But isn't it nice to save money on that power supply by doing a little "research" while avoiding reinventing the wheel?

Strays

LOW-COST CODE-PRACTICE RECEIVER

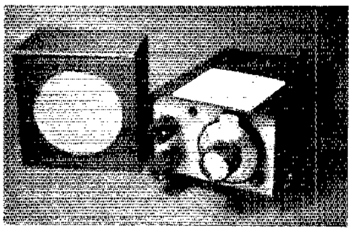
☐ Dick McIntyre, K4BNI, who has distinguished himself over the years as an inveterate builder of neat ham gear, was stimulated recently by K4MD concerning the building of a simple, inexpensive receiver for beginners. The challenge was to build a code receiver that would enable the beginner or would-be amateur to practice copying cw, or to become familiar with the amateur bands and operating procedures.

The end product is shown in the accompanying photograph. Dick chose the Radio Shack no. 28-222 a-m radio kit as the foundation. He obtained the kit, a cabinet and some assorted hardware for approximately $20. The vernier dial and tuning capacitor were already on hand in his parts cache at home.

A simple BFO (455 kHz) was added to the a-m detector, and a "bare bones" 40-meter converter was built and connected to the input of the a-m receiver. Coverage of the entire 40-meter band allows reception in the cw and ssb segments. Stability and sensitivity are good, but Dick says, "Admittedly, the receiver does not match the latest factory job's dynamic range."

The speaker is from the a-m radio kit. It is housed in a homemade enclosure that he made from scraps of "framing cardboard." These were obtained from a local frame shop for 25 cents a bundle!

A project of this type seems worthwhile for club groups as part of a training program. There is no reason why a factory-built pocket-size a-m radio could not be used as the heart of such a receiver. Used radios of that type are commonly found at yard sales and flea markets for two or three dollars! — *Doug DeMaw, W1FB*



This neat little package is the latest from Dick McIntyre, K4BNI, of Cape Coral, Florida. A Radio Shack a-m radio kit, cabinet and some inexpensive parts were the basis for this beginners project.

Harry A. "Connie Mac" McConaghy, W3SW (center), was recently presented an album of signatures and pictures as a token of appreciation for his long service as ARRL Atlantic Division Director. The presentation was made by Tony Maugeri, W2SDO, at a Delaware Valley Chapter QCWA luncheon. Current Atlantic Division Director Jesse Bieberman, W3KT, looks on.

RADIO ASTRONOMY NET

☐ The International Union of Radio Astronomers has an active Radio Astronomy Commission which offers a forum to exchange ideas, data and computer information. An Amateur Radio net is being formed and check ins are welcome. For more information send an s.a.s.e. to Communications Net Officer Jack Chancellor, W9SON, RR 1, Box 23, Timber Ridge, Freeport, IL 61032. — *Bob Patterson, K5DZE, North Little Rock, Arkansas*

VERY LARGE ARRAY OPERATION

☐ A special event station will be activated at the National Radio Astronomy Observatory's Very Large Array (VLA) project on Saturday, October 25, to commemorate the dedication and open house of the world's largest radio telescope. The VLA is located about 50 miles west of Socorro, New Mexico, and consists of 28 dish antennas, each having a diameter of 82 feet and weighing 215 tons. Listen for W5FZ and W7LHO on ssb in the lower portion of the General phone bands, and KA5CNE on cw 30 kHz up from the band edges and on some Novice frequencies calling CQ VLA. Other calls may be used also. Special event QSL cards for s.a.s.e. to NRAO, VLA Project, c/o Paul Harden, KA5CNE, P. O. Box O, Socorro, NM 87801.

A Deluxe RV 5-Band Antenna

Better'n ham and eggs . . . ham and RV!

By Charles W. Schecter,* W8UCG

The development of this RV[1] antenna system came about from my desire to "marry" two hobbies I've enjoyed for 40 years — hamming and RVing. My antenna requirements called for a 5-band system that could be raised to a vertical operating position in just a few seconds, exhibit extremely low VSWR (below 1.5:1 on all bands), cover the individual bands entirely without tuning, and require no radials or ground systems other than the RV itself. The antenna must also present a neat appearance whether raised or lowered, so as not to detract from the RV appearance (or cause the XYL concern), and yet be able to withstand winds of reasonable force.

Although my RV is a 31-ft. (9.4-m) Airstream, the same basic design may be applied to any RV by changing some of the dimensions. The installation involves the use of a Hustler 4BTV vertical with the normal installation dimensions radically changed. See Fig. 1. This particular antenna is rugged, neat in appearance and well suited for the required application. The modified antenna is mounted on a special mast that is hinged near the top to allow it to rest on the RV roof during travel. In the traveling position, the raising handle is removed and stored. This makes for a neater package, thwarts the curiosity of onlookers and prevents unauthorized use.

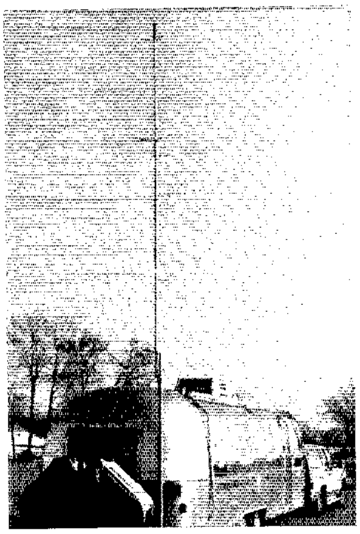
From the Bottom Up

The secret of the neat appearance of this installation is the unusual mast material used to support the antenna. Commonly known as Unistrut, it is often used by electrical contractors to build switching and control panels for industrial and commercial installations. The size selected is 1-5/8 in. (41 mm) square 12-gauge U channel. The open edges of the U are folded in for greater strength; the material is an extremely tough steel which resists bending (as well as drilling and cutting!). The U channel is available with a zinc-plated, galvanized or painted finish to prevent rust and corrosion; it may be repainted to match any RV color scheme.

The supporting mast is secured to the rear frame or bumper of the RV by means of 3/8-in. (10-mm) diameter bolts. Although the mast is actually strong enough to be self-supporting, I have attached a 3/4-in. (19 mm) wrap-around strap at the RV center trim line. Any brackets mounted higher detract from the neat appearance and will necessitate a complete change of dimensions for proper tuning. I chose to have my particular installation located on the curb side of the vehicle to hide the lowered antenna behind the awning and provide greater safety to the person raising the antenna. This precaution is taken primarily for situations involving stopping alongside a highway to meet a schedule. (Caution — beware of overhead power lines!)

Mounting the Hustler

The 4BTV base is U bolted to a 19-in.



Ready to go! The W8UCG deluxe RV antenna is shown mounted at the rear of the author's 31-ft. (9.4-m) Airstream.

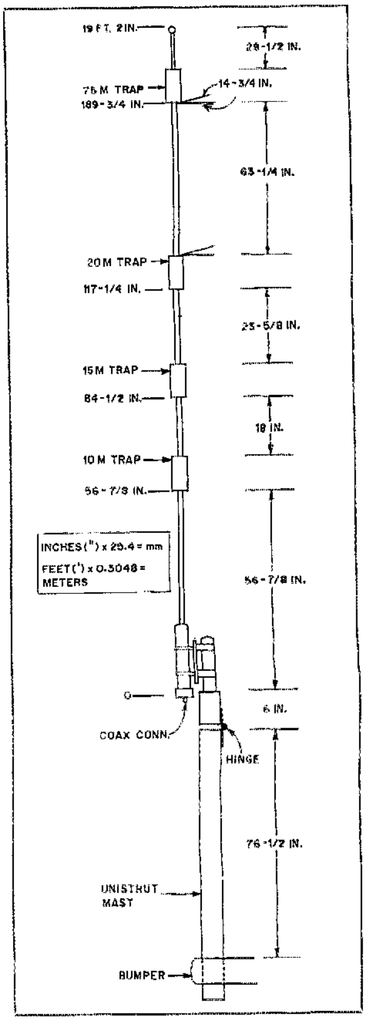
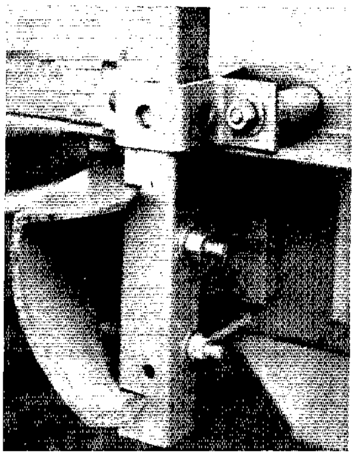


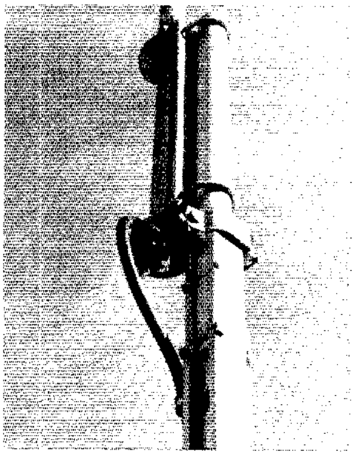
Fig. 1 — The dimensions of the modified Hustler 4BTV antenna as used by the author on his RV. Table 1 shows the resultant SWR vs. frequency figures obtained with the antenna. Refer to the text concerning the SWR bandwidth of the antenna on 75 meters.

*630 Glenwood Ave., Muskegon, MI 49445

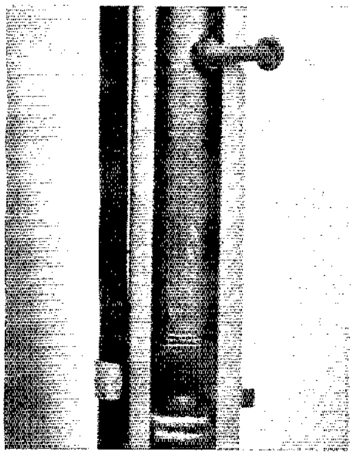
[1]Recreational vehicle.



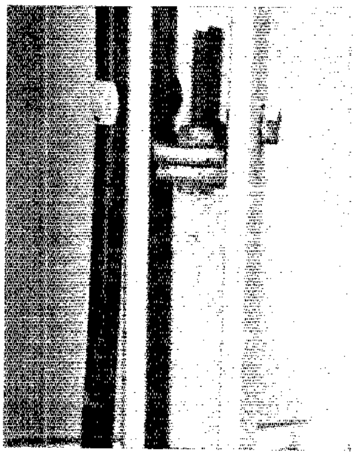
Sturdy looking, isn't it? The supporting mast is secured to the rear frame of the RV by means of 3/8-in. (10-mm) diameter bolts.



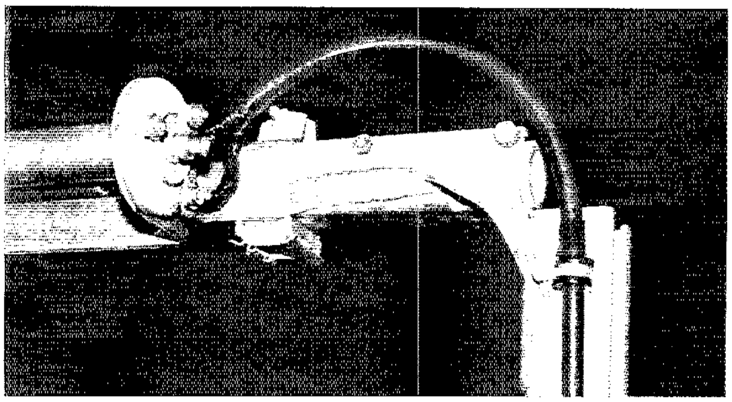
A close-up photo of the mounting arrangement of the Hustler 4BTV vertical antenna. The clamp and bolt in the photo were subsequently replaced by a weld.



The handle and raising fixture, seated on the lock pin.



In this photo the open edges of the Unistrut channel are facing the viewer. The lock pin may be seen in the middle of the channel.



Heavy braid is used to ensure a good ground connection across the hinge section of the antenna support.

(480-mm) piece of 1-5/16 in. (33-mm) OD galvanized steel pipe (1-in. water pipe). This is inserted into and welded along the edges of a short piece of Unistrut, which is attached to the lower portion of the mast by means of a heavy-duty, welded-on hinge. It is not feasible to bolt these pieces together, as the inside of the pipe must be completely clear to accept the end of a 54-in. (1.37-m) piece of 1/2-in. water pipe (7/8 in. or 22 mm OD) that is used as a removable raising fixture and handle. This handle is wrapped with vinyl tape at the top end and also about 12 inches (300 mm) back to form a loose-fitting shim that provides a better fit inside the 1-in. water pipe. At 15 inches (380 mm) from the top end, a thicker wrap of tape acts as a stop to allow the handle to be inserted the same distance into the base support pipe in every instance. A short projecting bolt near the bottom end of the handle provides a means of lifting it off the lock pin (a bolt) which is mounted inside the Unistrut on an L-shaped bracket.

The top-hat spider rods should be installed only on one side of the antenna so as not to poke holes in the top of the trailer. No effect on antenna performance will be noted. Bring the coaxial cable into the trailer at a point close to the antenna. This is preferable to running it beneath the trailer, where it can be more easily damaged and where ground-loop paths for rf current may be created. RG-8X cable is easy to install. Be sure to use drip loops both at the antenna and at the point of entry into the RV. Silicone rubber sealant should be used at the outside connector end and at the RV entry hole. Clear acrylic spray will provide corrosion protection for any hardware used. Lock washers and locknuts should be used on all bolts; good workmanship will result in first-class appearance and long, trouble-free service.

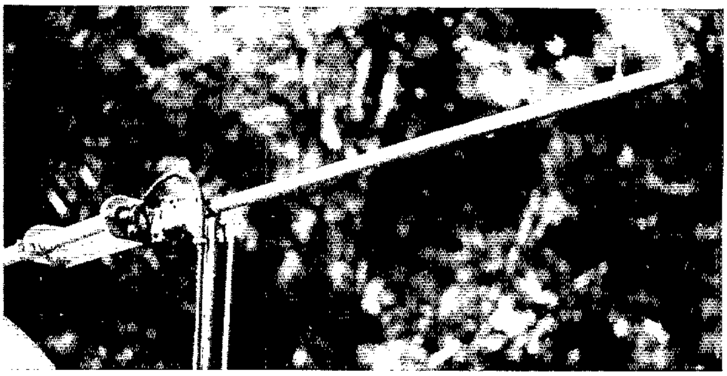
To ensure optimum results, great care should be taken to obtain an extremely good ground return from the antenna all the way back to the transceiver. Clean, tight connections, together with heavy-duty tinned copper braid, should be used across the mast hinge, the mast-to-RV frame and to bond the frame to the equipment chassis. This is a *must* if the vertical quarter-wave antenna is to work properly. With such connections, this installation requires no radials or ground connections of any kind!

Antenna Pruning and Tuning

The antenna must be carefully tuned to resonance on each band starting with 10 meters. The most radical departure from the manufacturer's antenna dimensions (for home use) takes place with the 10-meter section. There, 30 in. (760 mm) of tubing is cut off. Only 3 in. (76 mm) need be removed from the 15-meter section. The 40-meter (top) section has to be lengthened, however, because of the

Table 1
SWR Chart

Freq., kHz	*SWR*
3990	1.0:1
7000	1.0
7150	1.0
7200	1.1
7250	1.2
7300	1.35
14,150	1.0
14,250	1.0
14,300	1.05
14,350	1.15
21,270	1.0
21,350	1.1
21,400	1.3
21,450	1.6
28,000	1.1
28,500	1.05
29,000	1.1
29,500	1.9


The lifting handle has been placed into position prior to erecting the antenna. During travel, this handle is removed and stored in a convenient place.

radical shortening of the 10-meter section. The easiest way to do this, short of buying a longer piece of 1-1/4-in. (32-mm) OD aluminum tubing, is merely to lengthen one of the top-hat spider rods. A 15-1/2-in. length (394-mm) of 1/2-in. (13-mm) diameter aluminum tubing (with one end flattened and properly drilled) can be held in place under the RM-75S resonator. It is a good idea to start with a longer piece of tubing and trim as necessary to obtain resonance at 7150 kHz.

The described method of installation, grounding and tuning of the antenna resulted in an SWR of 1.0:1 at resonance on the 75-, 40-, 20- and 15-meter bands. At the lower end of the 10-meter band, the SWR is 1.05:1. These low SWR values remain exactly the same regardless of the length of coax used and whether or not the RV is grounded externally.

This system design also provides full band coverage on the 40- through 10-meter bands with an SWR of less than 2:1. (My antenna was adjusted to favor the low ends of the 10-, 15- and 40-meter bands, but it can as easily be tuned for the high ends of the bands if desired.) Band coverage on 75 meters is limited to approximately 100 kHz because of the short overall length of the resonator coil/whip. The tip rod is adjustable to enable you to select your favorite 100-kHz band segment.

Proof of the Pudding

On-the-air signal reports have been phenomenal, even though the output power was generally between 25 and 50 watts, and never exceeded 100 watts. No antenna matching network is needed, nor has one ever been used. In fact, the rig I use (a Ten-Tec Triton IV) does not even have any tuning or loading controls! A regular schedule with our home (in Michigan) was maintained each day during a 10-week, 7500-mile trip through the South — often from the side of the road — using whatever band was required at the time. These schedules, including many phone patches, were maintained in spite of the competition from many DX chasers using high-powered transmitters and large antennas. Casual contacts were also made easily with Hawaii and Australia. Hamming from an RV can be great fun — with a good antenna system! QST

Strays

DAVID CROCKETT TAVERN OPERATION

☐ The Lakeway ARC will operate from the David Crockett Tavern in Morristown, Tennessee, on Saturday, November 1, from 1300 until 2200 UTC. This tavern is the boyhood home of Davy Crockett, pioneer, frontiersman and congressman. The call sign WD4PEQ will be used for ssb-only operation on 7.235, 14.280, 21.360 and 28.560 MHz, plus or minus QRM. A handsome commemorative certificate will be available for $1 or 3 IRCs plus a legal-size s.a.s.e., from Davy Crockett DXpedition, Rte. 11, Box 28, Morristown, TN 37814. Visitors are invited to visit the Tavern and site during regular operating hours, weekdays 9 A.M. to 5 P.M. and Sundays 2 to 5 P.M.


Michigan Governor William G. Milliken (seated) recently signed an executive declaration in observance of Michigan Amateur Radio Weeks, June 15 to 29. Also at the signing were (left to right) Senator James DeSana, Jack Kesterman, K8OLG and Great Lakes Division Director Leonard M. Nathanson, W8RC.

QST congratulates . . .

☐ Charles Dibrell, W5BLW, of Ardmore, Oklahoma, who was recently honored by Ardmore area amateurs for his more than 50 years of outstanding service to Amateur Radio.

I would like to get in touch with . . .

☐ hams in Long Island interested in working in the 10-GHz band. Charles M. Doby, WA2EUS, 110 Lafayette St., Copiague, NY 11726.

☐ other severely disabled war veterans to form a group to discuss common interests and problems. Robert Hibberd, 21 War-Memorial-Homes, Castle-Lane, Bournemouth, Dorsett BH8 9TP, England.

Technical Correspondence

Conducted By
John C. Pelham, W1JA

The publishers of QST assume no responsibility for statements made herein by correspondents.

IMPROVING THE "BASIC RADIO" POWER SUPPLY

☐ Doug DeMaw (W1FB) and Bob Shriner (WAØUZO) did an excellent job with "Basic Power Supplies" in the November 1979 issue of *QST*. However, I suggest C2 (10 µF) should be at the output with C3. In its present location across R1 it will slow down the transient response. Since R1 is part of a divider that senses any output voltage change and compares it with an internal reference, the R-C time constant will slow down the response. Across the output, C2 will support transient loads. — *Walt Omdal, W83GHS, 24 Old Orchard Ct., Cedar Grove, NJ 07009*

A 4:1 "UNUN"

☐ Doug DeMaw's article in April 1979 *QST*, "The Whys and Hows of Bifilar Filament Chokes," arrived just in time when I was constructing an 811A grounded-grid linear amplifier. What interested me was the 1:4 broadband input matching transformer shown in Fig. 2 of Doug's article ("Feedback," May 1979 *QST*). This simple device, used to match the 50-ohm output impedance of a typical grounded-grid linear amplifier, had totally escaped my attention until I noticed it in W1FB's article. I immediately set about designing *this* black box. Since I could not obtain a toroid core, I decided to stay with a ferrite rod.

My broadband 1:4 matching transformer follows the same design pattern as DeMaw's bifilar filament choke except that it uses no. 14 AWG wire. This should be more than adequate to handle 100-watt transceivers. See Fig. 1A. The "rule of four" was applied; each leg of the bifilar winding should have a reactance of 4 × 50 or 200 ohms. At 1.8 MHz this works out to an inductance of 17.7 µH.

I had a 10-mm (0.39-in.) diameter × 7-inch (178-mm) long ferrite rod at hand which was rated for 2 to 30 MHz. Onto it I wound 23 bifilar turns of wire. Centered on the rod, each leg of the winding measured 18.5 µH. Since my own amplifier was designed to operate no lower in frequency than 3.5 MHz, I could probably have made the grade with a five-inch (127-m) rod (only 9.1 µH is required at 3.5 MHz) and walked away with a more compact unit. I have called this device an "unun" (*un*-balanced to *un*balanced). A thin coating of moisture-resistant varnish secured the turns in place.

I wondered whether a ferrite rod originally intended for use as a transistor-radio antenna could handle 100 watts of rf power. To test this, the transmitter was connected to the 50-ohm input of the unun, and a 100-watt lamp was connected to the 200-ohm terminals. Lo and behold, after I tuned the transmitter, the lamp lighted to full brilliance. For normal cw and ssb input, the ferrite rod was absolutely cool to the touch.

I think the unun, with modifications in connections (see Fig. 3B), can also be used as a low-power 4:1 balun either for feeding a beam antenna or with a homemade antenna tuner. High-frequency toroid cores are hard to get in this area, whereas the 10-mm receiving-type ferrite rod can be had 'round the corner. It is indeed an efficient poor man's impedance matcher. It also matches the very low impedance of his pocket. — *Vasant Bhatt, VU2RX, 5 B, Suresh Colony, Swami Vivekanand Road, Vile Parle (West), Bombay 400 056, India*

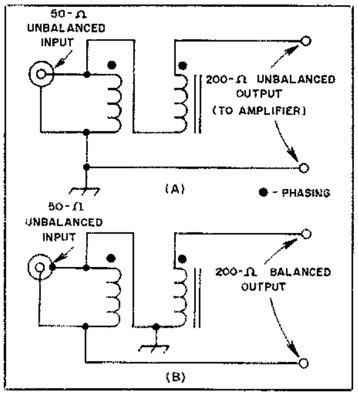


Fig. 1 — The schematic diagram of the "unun" is shown at A. At B, the connections to the unun can be changed to the more familiar balun configuration.

MORE ON COUPLING TWO LOW-VOLTAGE POWER SUPPLIES

☐ The following refers to the "Hints and Kinks" entry by W2DKH in January 1980 *QST*. These points may help some amateurs get that circuit working.

The author apparently did not take into account the forward-voltage drop across D1 and D2, which will vary with both forward current and junction temperature. I have successfully paralleled regulated power supplies for various applications for years and found that the diodes must be identical to ensure true "sharing" operation, since the current density through the silicon junctions will vary from one diode design to another.

Proper procedure, therefore, would be to adjust supply A and supply B for a higher voltage than actually desired (before the load is applied), since the forward voltage drop (V_F) of any silicon junction is a function of current density, or I_O. For example, if one desired to set up the paralleled supplies to deliver 13.8 V dc, such as is required by most mobile transceivers, the correct output voltage setting for each supply before the load is applied would be 13.8 V + V_F, where V_F is the forward drop per diode. V_F at load current can either be measured via individual bench test or estimated by studying the rectifier manufacturer's data sheet plotting V_F vs. I_O. For high-current applications, V_F can be as high as 1.5 V for many diode designs. V_F will be much lower at reduced load current, dramatically affecting the dynamic regulation of the system. If this parameter is taken into account, however, and the system is designed to accommodate the unique properties of the silicon junction, the experimenter is less likely to be upset by the results obtained.

A significant improvement in dynamic regulation may be obtained by the use of power rectifiers which are rated for considerably higher forward current than will ever be drawn through them; e.g., use a 50-A rectifier for 5-A application. This will keep V_F reasonably low while helping to assure long operating life via lower junction temperatures.

I mention this primarily to alert experimenters to the pitfalls of operating power supplies in parallel. While many mobile transceivers would not be adversely affected by a change of plus or minus 1.5 V in the supplied voltage, TTL or ECL systems might be. — *Steven D. Katz, WB2WIK, 24 Louis Dr., Budd Lake, NJ 07828.*

ASCII STANDARDS PROPOSAL

☐ Now that ASCII has been legalized for use on the amateur bands, I believe many amateurs like myself are interested in using ASCII for computer communications. Unfortunately, there are currently no standards for using ASCII on the amateur bands, which makes it difficult for people to get started using this new mode. The purpose of this letter is to propose a set of preliminary standards for ASCII communications on the low-frequency bands to facilitate using this new mode.

What I propose is that we adopt standard Bell 103 modem signaling frequencies and format for use on 80 through 10 meters. Specifically, I recommend using the high-group frequencies of 2025 Hz for space and 2225 Hz for mark at standard rates of 110 and 300 baud. Adopting the above standards will have the following significant advantages:

1) Availability of equipment. Standard Bell 103 style modems and circuits are widely available both new and surplus at reasonable prices.

2) Ease of implementation. Standard answer/originate modems could be connected directly to the microphone input and speaker output of most typical ssb equipment to transmit and receive afsk. The only additional equipment required for a minimal system would be circuits for matching the impedance and output levels.

3) Narrow bandwidth. 200-Hz narrow shift keeps the bandwidth requirements small and facilitates using the narrow-bandwidth cw filters available on many rigs. Also, the 200-Hz shift could be made compatible with the 170-Hz shift used on conventional RTTY equipment.

4) Compatibility with computer communications. Many personal-computer users will already have all the equipment necessary. The same terminal and modem used for time sharing can also be used for Amateur Radio.

Personally, I prefer 300 baud because it is the maximum speed allowed and is more compatible with computer-to-computer data communications. I would also like to suggest using

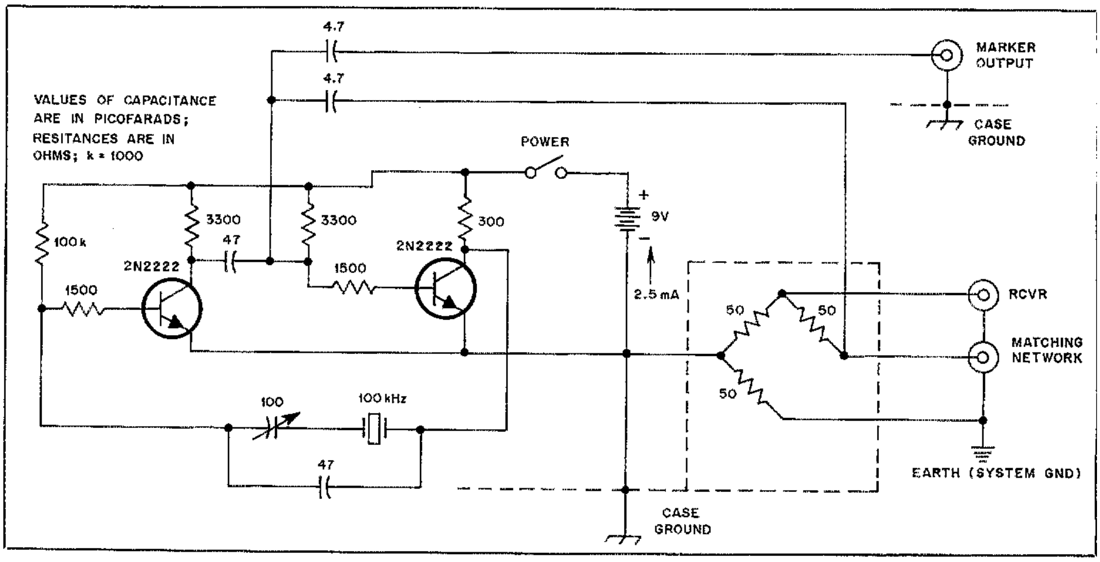


Fig. 2 — The "QRT" antenna-impedance matching instrument of N3BEK.

between 90 and 100 kHz above the bottom of each band as standard calling frequencies. There should be no difficulty distinguishing 300-baud ASCII for conventional RTTY, because it sounds quite different to the ear.

If you are interested in this standard, feel free to contact me. Any comments or suggestions will be welcome. I'll be looking for people to talk to using 300-baud ASCII on 7090 kHz in the near future. — *Peter Sichel, W8PS, 1517 Morton Ave., Ann Arbor, MI 48104*

"QRT" ANTENNA IMPEDANCE MATCHING

☐ Recently a number of approaches for off-the-air Transmatch or antenna tuning have been publicized. These procedures use some method of detecting the null on a 50-ohm rf bridge in which one leg is the input of the antenna-matching network.

Here is a simple bridge-nulling procedure that I have found effective. It makes a simple 100-kHz crystal calibrator do double duty as a signal generator to excite the bridge. The S meter of a receiver connected across the bridge is used as the null detector.

The schematic diagram of the combined marker generator/rf bridge is shown in Fig. 2. In my design, the entire unit is housed in a single pc-board enclosure; the bridge is shielded from the generator. Note that the generator ground and case are isolated from the bridge, and that the bridge ground is connected to the antenna-system ground. While not essential, a separate marker output has been included to provide a strong marker signal for other uses.

The generator is a free-running multivibrator which is frequency locked to a crystal reference. It is similar to one shown in the 1980 ARRL *Handbook*. It provides a strong signal at 100-kHz intervals through and beyond the 10-meter band. The three legs of the bridge are matched 50-ohm, 1/4-watt resistors.

The manner in which the receiver is used to detect a null is shown in Fig. 3. The marker generator excites the bridge with a signal every 100 kHz throughout the hf bands. When the receiver is tuned to one of the 100-kHz markers, the S meter is deflected. The capacitors and inductor of the matching network are then adjusted to provide a minimum S-meter reading — the bridge null. The null indicates that the bridge is balanced and the input impedance of the matching network is 50 ohms. It now can be connected to the transmitter. The SWR should be first checked on low power, and then fine tuned at operating power if necessary. After the fine-tuned settings are recorded, the transmitter can then be put on the air with the matching network preset.

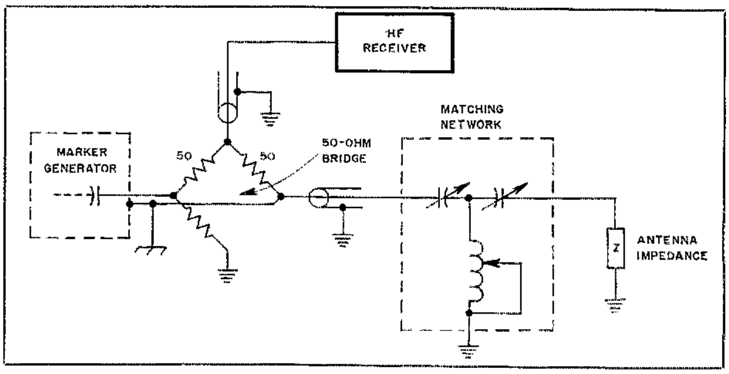


Fig. 3 — This simplified drawing illustrates how the marker generator, receiver and matching network are connected to the bridge. See text for details.

With this procedure, the receiver can be tuned through each band, with a matching-network adjustment being made and recorded at each 100-kHz marker. A chart of settings will allow the matching network to be preset before transmitting.

There is a disadvantage to the above technique: It is difficult to determine a deep null in the presence of rf noise, and may be impossible if a signal is on the marker frequency. Hence, some patience is required to obtain a complete matching-network chart. (The whole operation is made easier and more precise by observing the audio output of the receiver on an oscilloscope.) The effort will, however, certainly be worthwhile in saving the "strain" on the transmitter and in the satisfaction of not being an on-air "tuner upper." — *Jack Geist, N3BEK, 2205 Henderson Ave., Silver Spring, MD 20902*

Feedback

☐ In Fig. 1 of "IMUS Control," July 1980 *QST*, the identity of U1 was omitted. U1 is a 1458 dual op amp (Radio Shack part number 276-038).

☐ Vincent Luciani, K2VJ, who provided the TS-820 crystal-filter switching modification for the July *QST* "Hints and Kinks" advises that in performing step four, the two leads removed from S2 *must* be soldered together before taping and tucking them aside. If these two leads are not tied together after removal, the RIT will not work.

Product Review

Conducted By Paul K. Pagel,* N1FB

The AEA MorseMatic MM-1 and MK-1 Keyers

How many functions and features can be built into one keyer? Advanced Electronic Applications, Inc., of Lynnwood, Washington, seems to have put just about everything you can think of in their MorseMatic Model MM-1 computerized keyer. The MM-1 can operate as a Morse trainer, a memory keyer, a beacon-transmitter controller or simply as a keyer. To provide all of these functions, each of which we will look at in detail, the MM-1 uses two 3870 single-chip microcomputers. Each 3870 is a complete computer system, containing an 8-bit processor, RAM, 2 kilobytes of mask-programmed ROM and all the logic required for clock generation, control and I/O functions. In addition to the 3870s, the MM-1 contains only two other IC's and 11 transistors. One of the IC's is a 1024-by-4-bit 2114 RAM used to store the Morse messages.

Now let's look at each of the four operating modes of the MM-1. First, in the KEYER/MEMORY send mode the MM-1 provides the following features: speeds from 2 to 99 wpm in 1-wpm steps, selectable dit and dah memories, adjustable dit/space and dah/space ratios, semi-automatic (bug) operation and 10 memories. When used with a dual-lever paddle, keying is iambic. The only option not included is automatic character spacing. Compared to other keyers, the MM-1 produces code as well as the best of them. The operator timing requirements are not overly critical and the feel is very much like an Accu-keyer. The memory has space for a total of about 500 Morse characters, which can be divided in any desired manner between the 10 messages. The memory can be expanded to approximately 2000 characters with the optional ME-1 memory-expansion unit.

A feature of the MEMORY SEND mode that contest operators will like is the automatic serial number. A serial number can be placed at any point in any of the 10 messages and is automatically incremented after the message is sent. As the number is not changed until the message is over, it may be placed in the message more than once. The serial number can be changed to a new value at any time, or it can be decremented by one should you fail to complete a contact. By using one of the memories, the current number can be repeated should the station you are working request a repeat of the number only. This requires pressing three keys on the keypad. After a message is started, the operator can interrupt it by pressing a key on the keypad or simply by tapping the paddle. At that point, the message can either be restarted from the beginning or from the point of interruption.

To make use of the memories, you must load your messages into them beforehand. This is done in the MEMORY LOAD mode. Characters can be keyed into the memory from the paddles in one of two ways. The AUTOMATIC mode controls the spacing between words and characters for you, while the REAL TIME mode records the spacing just as it is sent. The AUTOMATIC mode does have provisions for creating pauses in a message by entering word and character spaces directly from the keypad. Should an error be made in loading a message it can be corrected by playing the message up to the point of the error, stopping the message and then continuing to load the correct characters. For the "long-winded," the MM-1 has an LED indicator to warn the operator when he nears the end of the memory space. The indicator lights when approximately 22 character spaces remain. This is important because, should the memory be overrun, all of the messages will be lost!

*Assistant Technical Editor

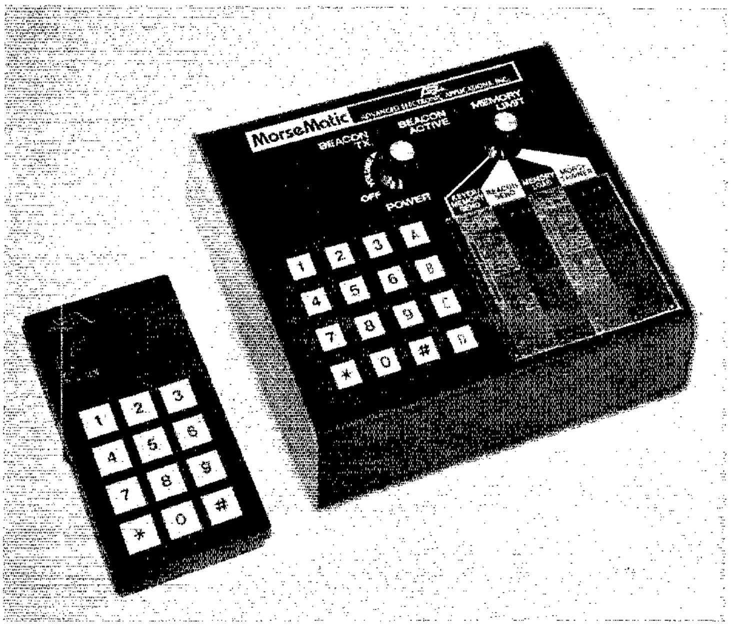


Fig. 1 — Microcomputer controlled, the MM-1 and MK-1 provide a multitude of features which should satisfy any cw operator.

Those of us that feel our cw copying ability is not quite ready for a contest should find the MORSE TRAINER mode of the MM-1 most useful. The Trainer will send perfectly formed characters at speeds of 2 to 99 wpm, and you can even program it to increase the speed as it is sending. Both the start and finish speeds are programmable, as is the time duration of the speed increase.

It is often found, particularly at low speeds, that the Farnsworth or slow-code method is helpful in increasing one's receiving speed. In this method, each character is sent at a relatively high speed, but the spaces between characters is increased so that the overall code speed is low. For example, 5-wpm code might be sent with each character at 18 wpm but with the spacing adjusted such that the word rate is 5 wpm. This is the method used for the W1AW code-practice transmissions up to 10 wpm. The MM-1 offers a choice between the Farnsworth method and standard code. One of two different character sets can be selected, the common set including the letters, numbers and most common punctuation marks, or the advanced set which adds a number of less commonly used punctuation marks and procedural signals such as parentheses and end of message ($\overline{AR}$). While not often used, at least by this reviewer, the hyphen has been included in the set of common characters. At first this caused some difficulty, but the character was soon learned and was no longer a problem. Also, the parentheses in the advanced set is coded incorrectly. Again, a relatively minor point, and, as pointed out in the instruction manual, it should not cause anyone difficulty. The character sequence sent by the MM-1 can be any one of 10 fixed strings or a random character string.

The remaining mode of operation of the MM-1 is the BEACON SEND mode. This mode allows a message loaded into one of the 10 memories to be transmitted, repeatedly, at a fixed time interval. Both the transmitter on and off times are programmable from the keypad. The speed at which the message is sent is automatically adjusted so that the message will till the transmitter on time. The message can include a serial number that is automatically incremented each time it is sent. That pretty well covers the four operating modes of the MM-1, but we can still find a few more features, such as remote control and positive or negative keying outputs!

Message memories 0 and 1 can be recalled by momentarily grounding one of two pads on the circuit board. Two auxiliary jacks are provided on the back panel of the case. These jacks can be connected to the two pads and then used to activate the remote memory recall. Also located on the back panel are the jacks for headphones, keyed output (a jack for each polarity), paddles and the 9- to 16-volt dc input. A mounting hole for the memory expansion selector switch is also provided on the rear panel. All other controls are located on the top of the unit. Most of the control functions are handled by the 16-key keypad. The power switch is combined with the sidetone volume control, and a four-position rotary switch is used to select the mode of operation. These can be seen in the photograph.

"With all the various functions, features and modes, how can anyone remember how to operate the MM-1?" That was a common comment when other operators saw the MorseMatic, and the same question crossed my mind when I first used the MM-1. The fact is that once the commands used to control the MM-1 are learned, its operation is simple. The commonly used functions are quickly learned, and those functions that are not used often can be found on the reference chart located next to the keypad.

During use at home, the most outstanding feature I found was being able to select the exact sending speed I wanted. After using the MM-1 for a short time, I could match the speed of a station I wished to work without having to "try out" the speed setting as I have had to with other keyers. After using the MorseMatic for about a week, the 2114 memory IC failed and refused to load. Replacement of the 2114 IC solved the problem and no further difficulties were encountered.

All errors in operation of the unit were caused by either pressing the wrong key or not pressing the right keys hard enough. The MM-1 sounds a tone from the sidetone speaker (slightly lower in tone than the normal sidetone) each time a key is pressed. This would eliminate the problem of not pressing the keys hard enough, except that I like to use headphones and listen to the sidetone in my rig. If the sidetone volume of the MM-1 is turned down, you no longer have the auditory feedback when a key is pressed. This caused me to become very careful when changing speeds; if you make a mistake you may not know it until you hit the paddle and nothing happens!

The instruction manual supplied with the MorseMatic was complete and easy to read. The examples shown for programming each mode made it very easy to understand how to operate the MM-1. The optional AC-2 wall-transformer type power supply was used to power the unit during testing. Two C cells were used to maintain the memory in case of a short-term power failure. The cells can maintain the memory for about three hours.

So have you been counting all the features? I gave up, for each time I tried, I found a new one! No matter what the count, any practitioner of the cw art should find that the MorseMatic MM-1 fills his or her needs for a home-station keyer. Oh yes! The MM-1 has a little brother. It's the Model MK-1, and has most of the features of the keyer section of the MM-1. It does not have the memory, beacon or trainer modes and, as shown in the photograph, is much smaller than the MM-1. This makes it a nice unit to carry along on those portable operations. Other differences are that it provides only one keying polarity, a positive voltage to ground. My transmitter requires a negative voltage to ground so I added a single transistor inside the case of the unit. No other parts or changes are required. The connector used for the paddles is a four-pin microphone jack, as there is not enough room in the small case for the standard 1/4-inch phone jack.

The price classes for the MM-1 and MK-1 are $200 and $70, respectively. The ME-1 memory expansion is $60 and the AC-2 power supply for the MM-1 without expanded memory is $10. The AC-1 supply for use with the MM-1 with memory expansion is in the $15 price class. Additional information on these and other products can be obtained from AEA, Inc., P. O. Box 2160, Lynnwood, WA 98036. — *George Collins, AD0W*

CLEGG AB-144 ALL-BANDER RECEIVING CONVERTER

It's said, "Good things come in small packages." Well, there is a whole world of entertainment waiting for you when you hook up the All-Bander. Its small size is no indication of its performance. If you own an all-mode, 2-meter transceiver or receiver, the All-Bander will convert it to a deluxe shortwave receiver. The performance is limited only by the features of your 2-meter receiver. Simply hook an hf antenna to the All-Bander antenna jack, plug in the 12-V dc power supply that comes with the unit, connect a jumper to your 2-meter antenna input jack, and the whole spectrum from 100 kHz to 30 MHz is at your fingertips.

Clegg AB-144 All-Bander Receiving Converter

Specifications

Size (HWD): 2-3/8 × 5-1/4 × 5-3/4 in (60 × 133 × 146 mm).
Weight: 1-1/4 lbs (0.57 kg).
Color: Walnut grain with white front panel.
Power requirements: 10 to 15 V dc @ 30 mA (min); 110 V ac to 12 V dc converter included.
Frequency range: 100 kHz to 30 MHz.
Price class: $130.
Manufacturer: Clegg Communications Corp., 1911 Old Homestead La., Greenfield Industrial Park East, Lancaster, PA 17601, Tel. 717-229-7221.

The All-Bander receiving converter is completely solid state, using separate crystals for each oscillator position. Switching is done with an eight-position bandswitch, each position covering four MHz. All tuning and mode selection is performed by the controls on your two-meter receiver. A Schottky-diode doubly balanced mixer is used for improved dynamic range. The hf signals are "up converted" to the 144- to 148-MHz intermediate frequency.

For most situations, a random-wire antenna will suffice, but a multiple dipole or separate dipoles cut for the frequency of operation will improve reception. If your transceiver has a separate antenna input jack, it is recommended that you use it. You can hook the All-Bander directly to the transceiver antenna jack if necessary, but disconnect the microphone and key to prevent accidental transmission into the All-Bander. Although input protection has been provided, this extra precaution may prevent damage to the All-Bander, the transceiver, or both.

One of the most useful aspects of this con-

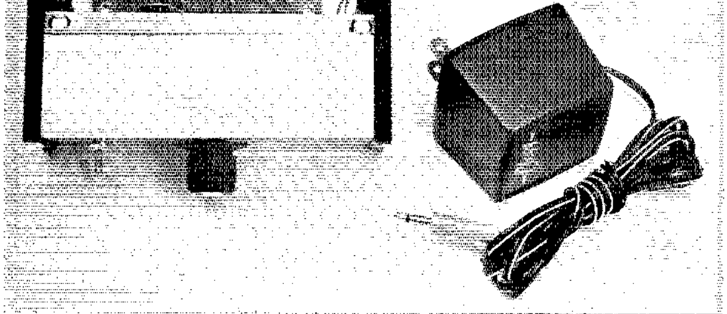


Fig. 2 — The Clegg AB-144 All-Bander and ac converter. The rectangular module close to the rear panel SO-239 connector is the doubly balanced mixer.

verter is using it as a ham-band receiver with your station receiver to check or monitor another portion of the band; it provides dual-frequency operation. The converter was useful for monitoring the frequencies of two nets that were operating at the same time. The shortwave-coverage feature is really a pleasure to use. Many pleasant hours were spent scanning the foreign broadcasts. With continuous coverage, the All-Bander is a valuable addition to your station. Making multiple use of your expensive 2-meter, all-mode receiver gives further justification to owning a Clegg All-Bander. — *Bernie Glassmeyer, W9KDR*

Z.R.C. COLD GALVANIZING COMPOUND

□ Do you have a steel mast, roof tripod or tower that is showing signs of rust through the once-protective coating of galvanized material? If so, you may be interested in Z.R.C. cold galvanizing compound. This substance should be of considerable value to those who use iron water piping as masting for beam antennas (if the pipe has not been galvanized to protect it from corrosion).

A badly rusted tower or mast can be restored to almost new condition by applying Z.R.C. with a brush after the rust has been removed. The success of the treatment is highly dependent upon cleaning the old metal thoroughly with sandpaper or a wire brush — preferably a brush that can be used with a drill motor. All oil and old paint must be removed before the Z.R.C. compound is applied. The manufacturer can provide a special cleaning fluid (metal conditioner) for the purpose, although any good degreaser should be suitable.

Once the work is ready to be treated you can apply the Z.R.C compound with a paint brush. It has the consistency of paint, and is a slate-gray color. Two coats are suggested to ensure good coverage of the metal. The finished product, after drying, has a bluish-gray nongloss coat. The protectant dries to the touch in 30 minutes and is sufficiently aged to permit application of a second coat in 24 hours. Proper application is realized when the compound has a dry thickness of 3 mils (0.08 mm). This is comparable to a hot-dip galvanize treatment.

A 24-pound (10.8-kg) container of Z.R.C. compound will cover 400 to 500 square feet (37 to 46 sq. meters) of surface at a 1.5-mil (0.04-mm) dry thickness. It can be applied with a brush or by means of a paint sprayer. Accelerated drying is possible by placing the coated work in an oven.

The compound consists of 95% pure zinc metal. It is flammable because it contains petroleum distillate. Since this material should not be ingested, and because the fumes should not be inhaled, it must be handled with care. It should be kept out of the reach of children.

Our sample was shipped in a 1-1/2-pound (680-g) can. Other quantities are available. We cannot attest to the longevity of the protective coating, since this review would have to be delayed 5 or 10 years as we watched for signs of deterioration. The steel pipe to which this material was applied certainly looks nice, and the coating appears to be tough and durable. The manufacturer is Z.R.C. Chemical Products Co., Quincy, MA 02171. A letter of inquiry will be answered with the name of the nearest distributor. Price class for the 1-1/2-pound (680-g) can is $5; the metal conditioner is $8.25 per gallon (3.8 liters). — *Doug DeMaw, W1FB*

BENCHER ZA-1 AND ZA-2 BALUNS

□ The *QST* ad reads, "The Ultimate 1:1 Balun," in a manner similar to Lew McCoy's July 1970 *QST* article title, "The Ultimate Transmatch." Just how *ultimate* any product or circuit design might be is a matter for the beholder to judge. Some may settle for the term "penultimate" (next to the last word), since there is probably no product on earth that can't be improved upon in some manner! Nonetheless, the Bencher baluns have the desired attributes to make them superior to some other baluns — under specific operating conditions.

Both balun models are devoid of magnetic core material. This means that the core is air rather than a ferrite rod or toroid. Each unit has a trifilar winding of heavy-gauge enameled copper wire. The transformer is wound on a 1-inch (25-mm) tubular coil form to represent the circuit shown in Fig. 3. This is the standard 1:1 balun configuration that appears in the transmitting chapter of recent ARRL *Handbooks*. So, there is nothing magical about the transformer concept. But, the absence of a magnetic core is an item of interest, since without a core the transformer will not saturate when subjected to high levels of rf power, or when a serious mismatch occurs. When a magnetic-core transformer saturates, square waves develop, and they can cause TVI through the presence of strong harmonic currents. In fact, if you've been experiencing a TVI problem that defies resolution after trying all of the usual cures, try removing the balun from your antenna. Chances are that the TVI will vanish after you remove the potential source of the problem.

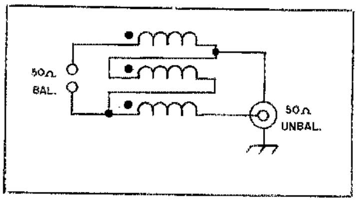


Fig. 3 — Schematic diagram of a 1:1 balun transformer. The black dots indicate the polarity of the windings.

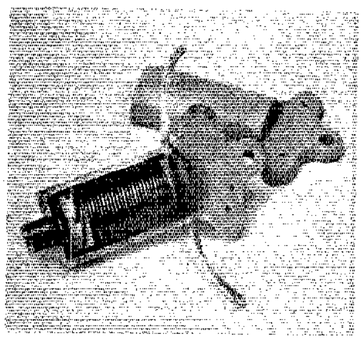


Fig. 4 — Photographic view of the Bencher ZA-1 balun, showing the interior of the assembly. Half of the molded-plastic case was removed for this picture, thereby breaking the weather seal.

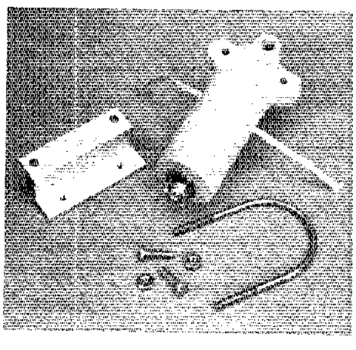


Fig. 5 — The Bencher ZA-2 balun is designed for use with mono- or triband beams and is supplied with mounting hardware.

The foregoing is by no means an indictment of the magnetic-core balun you bought or built. Rather, it may suggest that your antenna system is poorly matched to the feed line, that the ferrite core is too small in cross-sectional area, or that you're running more power than the balun is rated for (shame!).

The model ZA-1 is designed for use from 3.5 to 30 MHz. A typical application would be at the feed point of, say, a 40-meter dipole. This would provide a balanced-to-unbalanced transformation between the dipole and a 75-ohm coaxial transmission line. The plastic housing is built to accommodate dipoles and has a center-support hole at the top, which makes it ideal for use in supporting inverted-V antennas. Silver-plated shield braid emerges from each side of the assembly for making connection to the halves of the dipole. An interior view of the ZA-1 is shown in Fig. 4. The SO-239 style of coax connector at the bottom of the balun is equipped with an "O" ring to provide a seal against dust and moisture when the feeder is attached.

For those wishing to use a 1:1 balun on single-band or triband 50- or 75-ohm beam antennas, the model ZA-2 can be employed. It is similar to the ZA-1, but has fewer coil turns and comes with appropriate boom-mount (2-inch or 51-mm OD) hardware (see Fig. 5).

Among the claims made by Bencher is that the baluns will handle 5 kW of peak power. We were unable to verify this claim in the ARRL lab because we have no means by which to generate more than 1 kW of rf power. At the 1-kW continuous level, into a 50-ohm balanced load, no heating of the coil was observed at 14 MHz. The VSWR from 3.5 to 29 MHz under this condition (ZA-1) was less than 1.5:1, with the worst-case reading at 3.5 MHz. The ZA-2 showed a VSWR of less than 1.5:1 on 14, 21 and 29 MHz. Return-loss measurements with a Hewlett-Packard spectrum analyzer verified this set of conditions and showed the power loss to be substantially less than 1 dB.

Because of the type of winding the transformer has (see Fig. 3), the antenna is effectively grounded at dc. This is a useful feature in the event of rain-static buildup or voltages induced by lightning strokes in the area.

The ZA-1 sells for a price class of $16 and the ZA-2 for $18. The manufacturer is Bencher, Inc., 333 West Lake St., Chicago, IL 60606, Tel. 312-263-1808. — *Doug DeMaw, W1FB*

E-TEK FR-4TR FREQUENCY READOUT/COUNTER

☐ What can one say about a frequency display? Yes, it displays frequencies — to six places (to the nearest 100 Hz) and the 3-inch (76 mm) digits are bright red, perfect for overtaxed eyes. But be advised: This product is essentially a digital dial; don't expect to see the unit register 75- or 100-Hz shift when operating cw. The manufacturer states that the calibration has been adjusted to within ± 2 ppm. A front-panel 3-position toggle switch serves as the band selector — 80, 20 and normal (40, 15, 10 meters). The decor matches the Drake styling.[1]

Installation of the E-Tek unit requires connection to V1 of the TR-4CW transceiver (premixer/crystal oscillator) and to one circuit board. Accomplishing this was fairly simple, although, being a dedicated appliance operator, I looked upon probing into the entrails of the rig with as much enthusiasm as, say, spending the weekend in the Sahara Desert. A sigh of relief was heard upon completion of the minor surgery. Unfortunately, everything was not copacetic.

Bizarre (and incorrect) frequencies were being displayed on 10 and 15 meters. A call to E-Tek indicated that tweaking up the injection crystal oscillator would alleviate the problem (this procedure is outlined in section 5-10, page 5-2, of the TR-4CW instruction manual). With that completed, we thought we were "golden." The unit, however, was still unstable on 10 meters when the RV-4C external VFO was being used.

Another call to E-Tek and we received a modification kit which consisted of a 100-ohm resistor and an L-C network. Salvation at last! Well, not quite. The 33-pF capacitor that E-Tek sent disintegrated upon touch. The ARRL hq. lab supplied a replacement, and this modification concluded on a successful note. The FR-4tr then functioned properly on all five bands, regardless of which VFO was being employed.

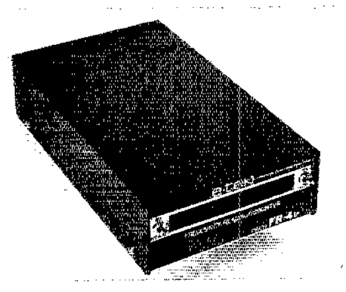
I enjoyed using this product and would recommend it to any active ham. It's great for split-frequency DX chasing as well as pinpointing a net or sked frequency. Nevertheless, an item with this price tag should already contain the appropriate refinements. E-Tek has indicated that all future runs will include the modification and that the FR-4tr instruction book will contain the injection crystal oscillator information.

There is one piece of bad news to report. The unit generates spurious signals. The spurs are practically inaudible when an antenna is connected. With one's skyhook removed, however, a continual "beep beep beep" is quite evident. This was first discovered on the 20-meter band, at approximately every 28 kHz. Further investigation revealed an equivalent on the 80-meter band. No spurious signals were discovered on the other three bands. Table 1 lists the spurious signals found on 20 and 80 meters. (Note: Because of the design of the transceiver, 20-meter tuning is right to left using the bottom scale of the linear dial, while all other bands tune from left to right per the top scale.) — *Robert Halprin, K1XA*

Table 1

FR-4tr Spurious Signals

20 meters		*80 meters*	
14.0004	14.2637	3.9996	3.7363
14.0284	14.2945	3.9716	3.7055
14.0566	14.3258	3.9434	3.6742
14.0852	14.3575	3.9148	3.6425
14.1142	14.3895	3.8858	3.6103
14.1433	14.4221	3.8567	3.5779
14.2729	14.4549	3.8272	3.5451
14.2028	14.4882	3.7972	3.5118
14.2331	14.5219	3.7670	3.4781



The FR4tr is designed to provide a digital frequency readout for the TR3/TR4 series of Drake transceivers.

E-Tek FR-4tr Frequency Readout/Counter

Dimensions (HWD): 3-3/8 × 5 × 8-3/4 inches (60 × 127 × 222 mm).
Weight: 4.5 pounds (2 kg).
Power requirements: 105 to 130 V ac, 60 Hz.
Price class: $170.
Distributor: E-Tek, 1028 Greene St., Marietta, OH 45750.

MSL DIGITAL QSK KIT

☐ The Micro Systems Labs Digital QSK board provides a cw QSK type of operation at moderate code speeds for ssb/cw transceivers (or with separate receivers and transmitters) that employ VOX-keyed cw transmission systems. The kit I received and assembled was tested with my Yaesu FT-101ZD transceiver and later with the Kenwood Twins, the R599D/T599D combination.

The MSL Digital QSK system uses a delay timer, shift register and sidetone oscillator. When the cw key is closed, the transceiver PTT line is closed, the delay timer started and the sidetone oscillator triggered. The keyed code is entered into the shift register, where it is sampled and delayed approximately 50 ms to allow the T-R relays to switch before rf is generated. (The normal 50-ms delay time may be extended to 100 ms if desired by the addition of another shift register.) When sending ceases for 60 ms or more, the shift register empties and the timed delay runs out, placing the station in the receive mode again. The switching delay between transmit and receive can be made adjustable by means of a potentiometer.

Instructions are provided to permit the MSL board to key both positive and negative PTT and keying lines. An instructional wiring error involving Q4 was discovered during assembly of the unit. The positive keying line modification (which involves installing different jumper wires) left the base of the keying transistor "floating." The correct jumper installation should have the base of Q4 connected to resistor R11.[2]

It was noted that the diode junction voltage drop of the keying-line polarity-protection diode (D3) was sufficient to prevent the internal audio oscillator of the '101ZD from being keyed. If the diode is placed between the collector of Q4 and ground, protection will still be afforded and the oscillator can be keyed.[1]

Basically, the MSL circuitry produces a keyed relay type of QSK system, which means that the effectiveness of the system depends upon the shift-register delay and the speed with which the T-R relays actuate. (Most vacuum relays used in other QSK systems operate at speeds of less than 10 ms.) If an average keying speed of 24 wpm is assumed, one dit will occupy a time period of 100 ms.[3] At a speed of 48 wpm, the dit will occupy the same time span as that offered by the shift register and the drop out time delay, 50 ms. The relationship between relay transfer time and keying speed becomes quite obvious.

No adverse keying characteristics were introduced when the system was in use. The MSL system does definitely eliminate the truncation of the initial dit or dah experienced with normal keyed-VOX circuits; the T-R relays are switched "cold." On-the-air testing proved that a breaking station could be heard without difficulty at most speeds normally encountered. At keying speeds of approximately 12 wpm or less, the MSL system will transfer between code elements; at higher speeds this transfer occurs between code groups.

In reality, most operators will not find the MSL onboard audio oscillator necessary. It will be virtually impossible for the operator to discern the 50 ms delay between key closure and the generation of the sidetone at most keying speeds.

When using the system I was bothered by the constant cycling of the transceiver or receiver/transmitter T-R relays and the accompanying noise. By using headphones, noise disturbances were reduced to a tolerable level, but the T-R relays are nevertheless still operating much more frequently than they would be under normal operating conditions. When the MSL unit was used with my '101ZD, I experienced popping in the receiver during the relay transfer, which also disturbed me. Another staffer tried the unit with a Yaesu FT-101E and found similar difficulties. Additionally, at speeds above 35 wpm, QSK was no longer possible and the '101E operated much like a VOX-keyed rig.

I can understand the possibility of transceiver owners using such a system for QSK operation, but I would personally prefer to use a faster, quieter system with separate receiver/transmitter combinations. A singular exception to this rule would be to utilize the board solely to eliminate the initial dit or dah truncation. The drop-out delay time may be lengthened, as mentioned earlier, thus avoiding the constant cycling of the T-R relays.

The MSL QSK system is available from Micro Systems Laboratory, 1429 Oak Grove Circle, Santa Ana, CA 92705. Pc board and instructions, $4; parts kit (includes board), $20 assembled and tested board, $40. — *Paul K. Pagel, N1FB* QST

[1] A model is also available for the Drake Twins. It requires no modification and no band-switching.

[2] The manufacturer was informed of these findings and has taken steps to correct them.

[3] *The 1980 Radio Amateur's Handbook*, 57th edition, p. 11-6.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

SIMPLE CORELESS BALUNS

☐ A *balun* (not "bay-lun") transformer is used to change a *bal*anced condition to an *un*balanced one, or vice versa. The most common amateur application is in antenna work, where a balanced 50-ohm feed is changed to an unbalanced 50-ohm status to permit the use of coaxial feed line. This would be a 1:1 type of balun application. Baluns are also used to convert a 300-ohm balanced condition to a 75-ohm unbalanced one (4:1 type of balun), or to change 200 ohms balanced to 50 ohms unbalanced. In this manner, a 300-ohm folded dipole could be used with a 75-ohm coaxial feeder without disturbing the radiation pattern (balance) of the antenna.

Most commercial baluns contain ferrite cores, which, if the core material is of sufficient cross-sectional area to prevent saturation, do an excellent job. TVI problems have been traced to balun-core saturation at the higher power levels, however, when too small a core was used. The TVI is caused by harmonic generation that results from core saturation.

Bencher, Inc. (of keyer-paddle fame) recently solved the problem by introducing two 1:1 baluns that use air cores. The winding format is identical to that used on toroid or rod cores, and this is shown in Fig. 1. The dots indicate the polarity of the windings. An effective 1:1 air-core balun for 3.5 to 30 MHz can be fashioned inexpensively by placing 12 trifilar (three wires of identical length in parallel) turns of no. 12 or 14 enameled wire, closewound, on a 1-inch (25-mm) OD coil form. The leads that connect the ends of the windings are routed along the inner wall of the coil form. Phenolic or fiberglass tubing is suggested for the coil-form material, but PVC tubing can be used if the SWR in the system is maintained below 2:1 at the higher power levels. PVC tubing will heat and burn when subjected to high values of rf voltage in the hf spectrum.

Fig. 2 shows a photograph of a large balun that was built for use from 160 through 40 meters at W1FB. Above 40 meters it is unsuitable because of excessive inductance and distributed capacitance. It is wound on a 5-inch (125-mm) length of 2-inch (51-mm) OD PVC pipe. There are 13 trifilar turns of no. 18 insulated hookup wire on the form. Each wire is a different color to help identify the ends of the windings during final assembly. A U-shaped aluminum bracket is attached to each end of the coil form, using two no. 6 sheet-metal screws for each bracket. An SO-239 coaxial jack is affixed to the "unbalanced end" of the form, and a pair of binding posts is used on the opposite bracket to permit connection of the balanced load or source. Assuming an SWR of 1:1, and matching 50 ohms to 50 ohms, the developed rms ac voltage will not exceed 224 at 1000 watts of transmitter output power. Since most amplifiers are approximately 60-percent efficient, the operating power in the balun (at 1-kW dc input) will be roughly 600 watts, yielding 173 rms volts. The PVC tubing can handle this easily, even at 29 MHz.

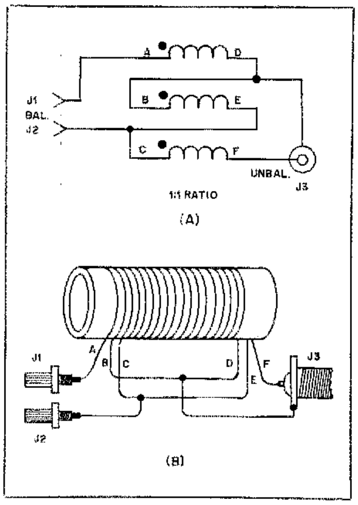


Fig. 1 — Schematic diagram of a 1:1 balun. At A, the winding polarity is indicated by the black dots. A pictorial view is shown at B.

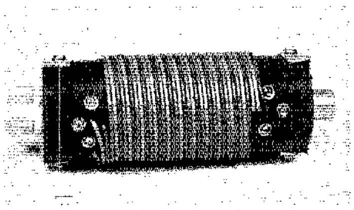


Fig. 2 — Photograph of a homemade coreless balun for 1.8-7.3 MHz. It will handle 600 watts of rf power safely if the system SWR is less than 2:1.

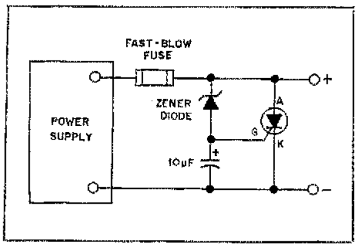


Fig. 3 — Schematic diagram of Pelham's crowbar overvoltage protection circuit.

The ends of the windings are held in place by means of six no. 6 machine screws, solder lugs and nuts. All wiring is inside the coil form. If the balun is to be used out of doors, it should be protected from the weather. A plastic refrigerator box can be used for that purpose. — *Doug DeMaw, W1FB*

*Assistant Technical Editor, *QST*

POWER-SUPPLY CROWBAR OVERVOLTAGE PROTECTION

☐ I use a high-current 12-volt supply to power my 200-watt hf solid-state transceiver and 150-watt vhf amplifier. One day while I was on the air, a series regulator transistor shorted, applying the full unregulated supply-rail potential of 26 volts to my equipment. Luckily, only one device (the first mixer FET in the hf transceiver) failed, but the spectre of what could happen, should the supply fail again, has moved me to incorporate a simple overvoltage protection circuit in the supply. This general technique is applicable to most any power supply.

The circuit shown in Fig. 3, uses only four components — a capacitor, a Zener diode, an SCR and a fast-blow fuse. Most supplies already have a fuse, reducing the number of needed components to three! The voltage rating of the Zener diode is chosen so that when the supply output voltage exceeds its normal value, the SCR is triggered, conducts heavily and blows the fuse. The current and voltage rating of the SCR and the fuse size depend on the characteristics of the supply. The voltage rating of the SCR must be higher than the output voltage of the power supply. The current rating of the SCR must be higher than the maximum output-current capability of the supply. The fuse must be capable of passing the load current, but must have current rating low enough to open when the SCR conducts. I have a 20-ampere supply; I used a 20-A fuse and an SCR rated at 35 A. The terminal potential of the supply is 13.8 volts, so I chose a 15-volt Zener diode.

If this modification is added to a high-current supply, it is essential that low-resistance connections be made from the supply to the anode and cathode of the SCR. If this isn't done, the wiring may act as the fuse, instead of the fuse itself! — *John C. Pelham, W1JA*

[Editor's Note: A crowbar circuit such as this is valuable for avoiding *prolonged* overvoltage application to the equipment being powered. Because there is some finite delay time in blowing even a "fast-blow" fuse and because the overvoltage *must* occur in order for the SCR to operate, this circuit may not prevent destruction of the devices being powered.]

ADDITIONAL SAFETY FOR THE FIELD DAY OVERVOLTAGE PROTECTION CIRCUIT

☐ The circuit for the Field Day overvoltage protection circuit shown in March "Hints and Kinks" will not allow K2 to be properly energized. The connections for the coil of K2 and lamp DS1 (open circuit) should be on the input (left) side of the K2 contacts. The only way K2 could energize would be either to backfeed 117 V into the outlet (inadvisable) or to reach into the enclosure and pull in K2 manually (likewise inadvisable!).

I'd feel a little safer if power were applied to the normally open contacts so that the arms are only "hot" when K2 is energized. One advantage of this is that if a dpdt relay is used, the two normally closed contacts could be tied together and grounded externally (not just to the enclosure.) This would minimize the chances of electrical damage to equipment or harm to the operator, whether overvoltage was caused by generator runaway or nearby lightning strikes. Common sense would tell us to avoid operating during a thunderstorm but we could be caught by stretching a QSO as a storm approaches or by neglecting to watch the sky. That first bolt has to land somewhere!

If I were building the AA5C circuit (and I may), I would probably add three instantaneously operating metal-oxide varistors (MOVs). These little gems are voltage-transient protectors for use across the 117-V ac lines. They are available from most radio supply houses. The accompanying circuit not only offers the advantage of the MOVs, but also provides for fuses and an improved ground circuit. Additionally, these modifications will prevent any surges above 180 V, either between lines or line-to-ground. As shown in the diagram, the equipment side of the ac line is grounded when the power is off. This arrangement would be a good idea for the home station, but can be a real safety factor for Field Day.

Don't forget to provide a solid ground, preferably with the use of ground rods at the generator and equipment. Also, the ground circuit should be bonded to all towers. A nonmetallic box would be preferable for this project. Also the use of a neon lamp for DS1 is desirable so that the amount of current drawn will not be enough to pull in K2! (They are in series!) — *"Ivy" Iverson, WDØBZK, Waterloo, Iowa*

☐ I wish to suggest that *QST* readers make the following correction in the overvoltage protection circuit I described in the March 1980 "Hints and Kinks": Wire R10 to pin 3 of U1. This change will permit K2 to operate as intended and Q1 can be turned on. — *Greg McIntire, AA5C, Lewisville, Texas*

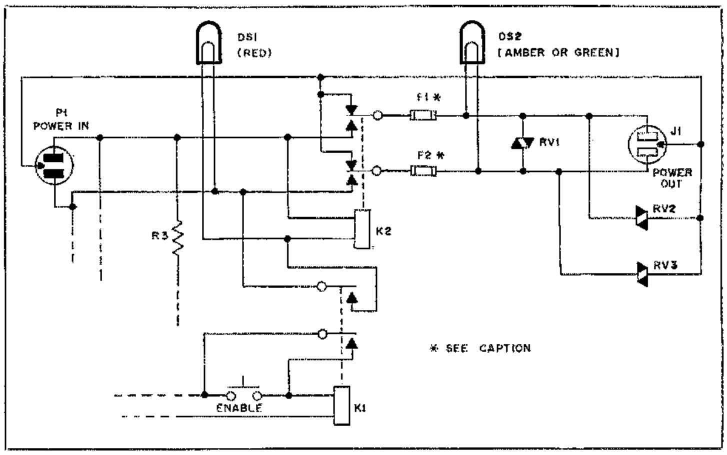


Fig. 4 — Additional protection for the overvoltage protective circuit described in March 1980 "Hints and Kinks" is provided by the modification suggested by "Ivy" Iverson, WDØBZK. Fuse-current rating should equal that of the contacts of K2 or the generator output rating (intermittent). Select the lower rating. The MOVs, RV1-RV3, incl., are made by General Electric.

SMOOTH AND NO-SLIP DRIVE FOR HEATH VFOS

☐ Slippage, which pesters Heath no. 100-450 VFO drive assemblies, can be cured in a very easy manner that also leaves the drive smooth and light to turn. Locate a piece of spring that fits into the elliptical hole of the dial escutcheon and above the drive-shaft bushing. See the drawing. Find a nut that fits on the shaft bushing to accompany the existing nut. Tighten the two nuts on the bushing, leaving enough leeway to allow the bushing (with the shaft in it) to move slightly against the spring.

I performed this modification about five years ago. It still is working fine; no readjustments have been necessary since. — *Hannu Hälli, OH6KP, Jyväskylä, Finland*

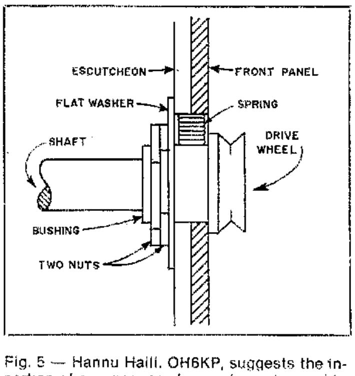


Fig. 5 — Hannu Hälli, OH6KP, suggests the insertion of a spring, as shown above, to provide a no-slip drive for Heath VFOs. See text.

OILERS FOR MECHANICAL PARTS

☐ An alternative to the device for oiling mechanical parts suggested by W8WX in January *QST*, page 53, is a comparable lubricating aid, the Chem-O-Jector, sold by G-C Electronics. It is available at many electronic supply stores. Olson Electronics of Akron, Ohio, likewise offers a similar syringe for injecting oil into mechanical parts that are difficult to reach. Additionally, G-C sells a useful leakproof pocket-style oiler resembling a fountain pen.

Acquisition of one of these tools, rather than the medical syringe mentioned in the January "Hints and Kinks" might, in some areas, avoid possible legal embarrassment. Regulatory efforts are being made to restrict the use of the medical instrument to authorized medical purposes. Thanks to the many *QST* readers who volunteered the above information. — *Stu Leland, W1JEC*

VACUUM CAPACITOR FOR ANTENNA TRAP

☐ Some of us "not so young" amateurs are familiar with the 50-pF fixed-value vacuum capacitors which still appear as surplus after WW II. These capacitors were contained in the antenna relay boxes that were used with Command transmitters. In addition to the vacuum capacitor and 28-volt relay, there was an rf ammeter. The capacitor is rated at 5 kV. A 5-ampere rf current flow is specified as maximum. These are conservative ratings, owing to military specifications. For amateur work the capacitors can handle full legal power, with plenty of safety factor.

The capacitors are constructed ideally for use in antenna traps. The trap coil can be wound over the glass portion of the capacitor body, with the ends of the windings soldered to the metal end posts. The photograph (Fig. 6) shows how 0.5-inch (13-mm) stainless-steel hose clamps can be used to provide electrical and physical contact to the antenna wire. These vacuum capacitors are relatively immune to changes in value with variations in temperature. Furthermore, they exhibit high Q.

The L/C ratio of an antenna trap is not especially critical. It should be tuned by means of a dip meter before it is installed in the antenna. Resonance should be in the center of the planned operating range of the antenna. Fig. 7 shows the circuit for a 40-meter tap which could be built around the surplus vacuum capacitor. Watch the flea markets for these capacitors. They are often available for as little as 50 cents! — *Doug DeMaw, W1FB* QST

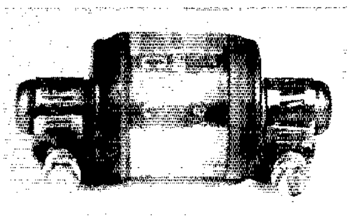


Fig. 6 — Photograph of a surplus 50-pF vacuum capacitor from the antenna relay box of a Command transmitter. Hose clamps are used to attach the trap to the antenna wire. The trap coil can be wound over the glass part of the capacitor.

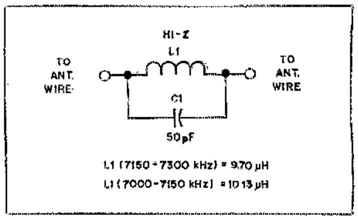
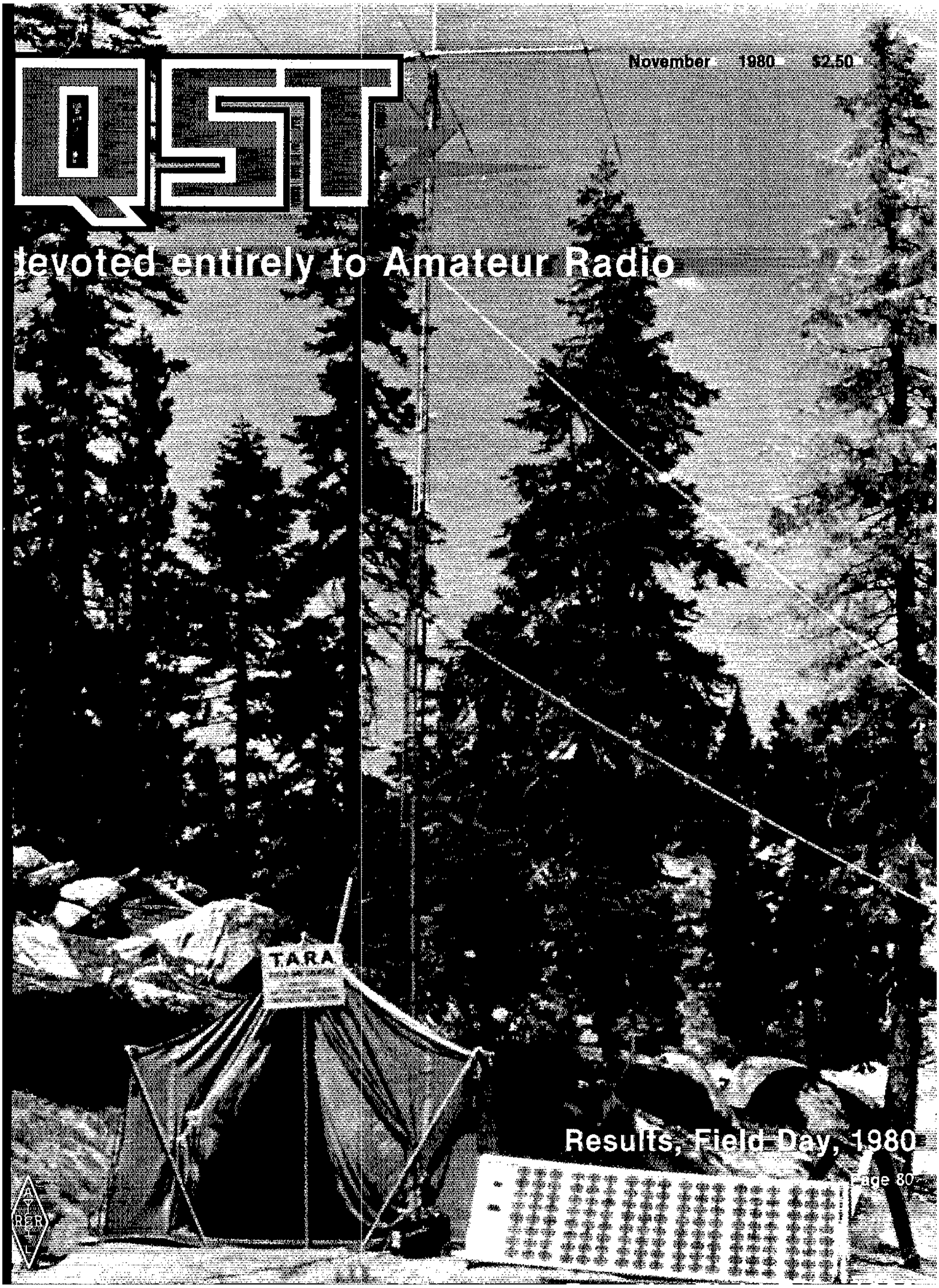


Fig. 7 — Circuit for a 40-meter antenna trap with inductance details for the phone and cw portions of the band. C1 is the surplus vacuum capacitor appearing in the photograph.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T.A.R.A.
Results, Field Day, 1980
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THE COVER

Old Sol donated his energy to the WB6NQJ/7 Field Day effort. The Tahoe ARA was one of the scores of groups using natural power during Field Day 1980.

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SSTV in Colour

First 2-way color SSTV transmissions across the Atlantic! Technical details on the equipment used at the European end of the path are included here.

By Jeremy Royle,* G3NOX

After many years of experimenting with fast-scan amateur television in the 436-MHz band, I visited the slow-scan station of Richard Thurlow, G3WW, to see his Robot 400 in operation on the hf bands. I was immediately impressed with the picture quality, in particular the bright fast-scan display of received and transmitted pictures. At the time, the technique of standards conversion was completely new to me.

I decided to buy a Robot 400 and to link it with my full-size image orthicon fast-scan television camera. The results in terms of picture quality were so good I immediately realized that by using the frame-storage system it would be possible to produce color pictures by sequentially loading two or more memory stores with color-separation signals.

The first stage in converting to color was to see whether my Pye 2014 image orthicon camera would produce the red, green and blue color-separation signals necessary for a full-color system using Wratten no. 47B, 58 and 25 filters. The results were good in terms of sensitivity and colorimetry, so I decided to remove the neutral-density filters from the supplementary filter turret (used in this camera for outside broadcast applications) and to install the Wratten filters on a permanent basis. A motor was also fitted so that the filters could be selected from the operating position.

To obtain the best signal-to-noise ratio with each of the red, green and blue (RGB) filters I use a Thorn Artificial Daylight fluorescent tube to illuminate the objects being televised. This type of tube, in conjunction with the filters used and the spectral response of the image orthicon tube, results in a near-perfect amplitude balance between the RGB color separation signals. Having produced the RGB signals from the camera, it is of course possible to load them one by one into a single Robot 400 and to transmit

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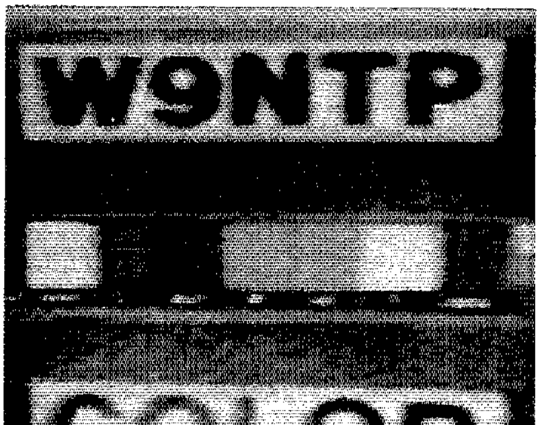


On March 15, 1980, at 1430 UTC, Jeremy Royle, G3NOX, made the first transatlantic two-way SSTV contact with Don Miller, W9NTP, a pioneer of color SSTV. Signals consisted of electronically generated red-green-blue color separations from G3NOX, transmitted on 29.150 MHz using field-sequential emissions. W9NTP transmissions consisted of only two color separations, red and green. Shown here are the transmitted color picture as photographed directly from the monitor screen at G3NOX and the W9NTP picture as received.

The author uses a Thorn Artificial Daylight fluorescent tube to illuminate the objects being televised, not visible in this photo. The original rainbow test card is visible in front of the modified image orthicon camera, as is a BBC test card for use as a flesh-tone reference.

them in turn. However, in order to obtain a color-monitor display of incoming and outgoing pictures, it is necessary to be able to store all three colors simultaneously and to feed the outputs to a color monitor via an encoder. An alternative method is to feed separate RGB signals to a monitor having individual video inputs for each color.

At this stage I discussed the problem of synchronization with Martin Emmerson, G3OGD, who has built his own standards converter. He came up with a most elegant method of synchronizing the fast-scan clocks of the three Robot 400s. The method used is shown in Fig. 1.

Before carrying out the modifications to the Robot 400s, I gave considerable thought as to how the digital links could be made in such a way that things could be quickly returned to normal if necessary. The solution to this is to mount on the rear panel of the master 400 two DIN sockets, with a further one on each of the slave units. The result is neat and in my view does not detract in any way from the value of the 400! The internal connections can be made to the main Robot 400 circuit board via "header" plugs plugged in to the U48 and U10 sockets of each 400. These can be removed and the ICs plugged in again if it is desired to revert to normal. Any modifications can result in the warranty being affected and it is up to each Robot owner to make his own decision on this before carrying out the modifications!

It will be seen from Fig. 1 that one Robot 400 becomes in effect the master and through U48 controls the fast-scan synchronization of the remaining two units. For this reason it is not necessary for the crystal oscillators in the two slaves to function. In fact, to avoid possible beat patterns, I have removed the crystals in the two slave units.

In order to ensure black-level stability and constant color balance it is also necessary to install black-level clamps to the fast-scan video inputs of each Robot 400. This can be done by means of the circuit shown in Fig. 2. Existing pulses that are available on the Robot 400 board are used. Signals can be conveniently routed through spare pins on the main edge connector. The diodes and components can be mounted on the spare terminals of the board associated with the power supply. The black-level clamps make it possible to preset the "snatch" contrast and brightness controls, resulting in more consistent pictures in black and white, as well as being essential for color.

Monitoring

Having modified the Robot 400s as shown in the circuit diagrams, we come to the question of how to monitor the color picture produced by the synchronized Robot 400s. There are two approaches: (1) Use a standard color television set as a monitor, in which case it will be necessary to encode the RGB color signals and apply them to the color set via an rf modulator, or (2) use a professional RGB color monitor by feeding the output of each 400 as a separate signal to each input of the monitor.

Although the second method is expen-

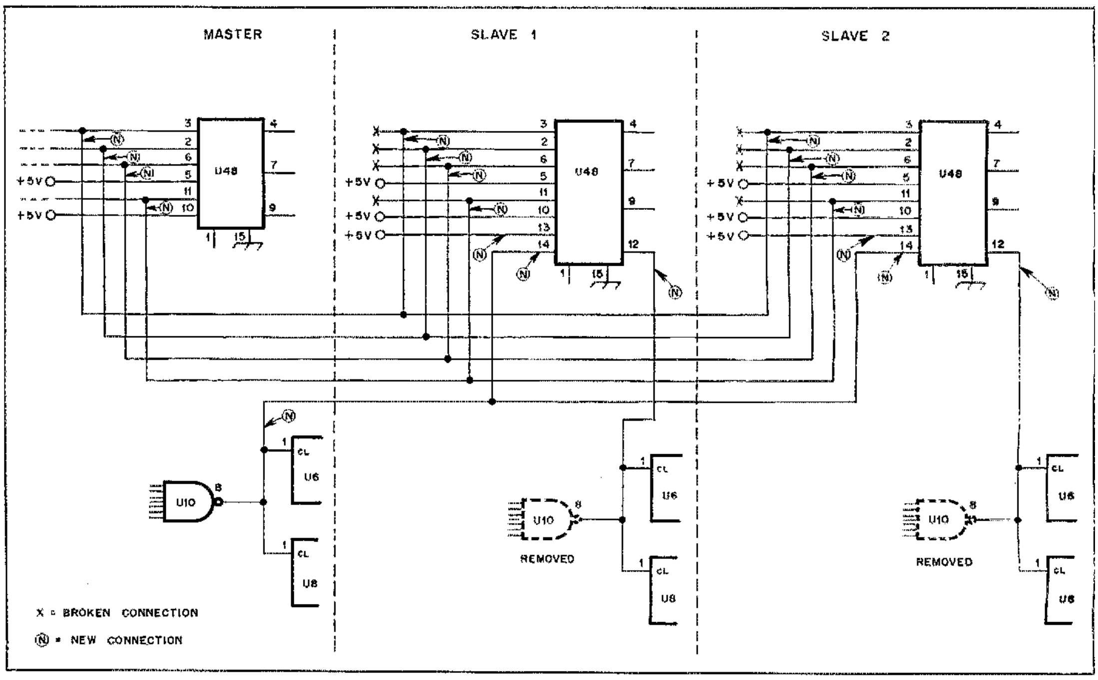


Fig. 1 — Circuit for synchronizing the fast-scan clocks of three Robot 400 scan converters. Two of the 400s thus became "slaves" to the "master." IC numbers are those of the manufacturer. See text regarding interconnections.

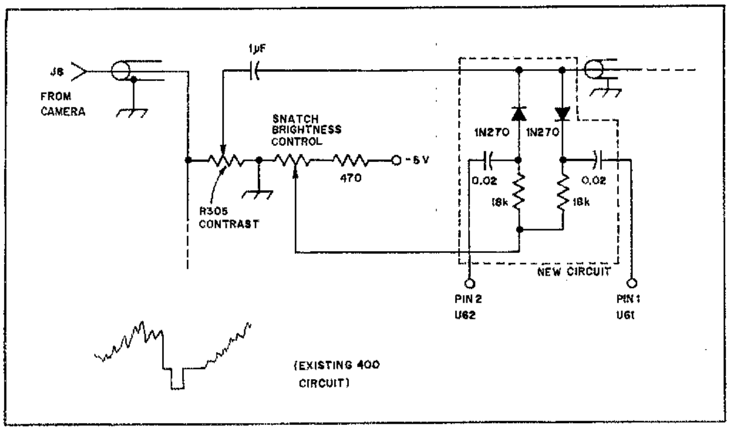


Fig. 2 — This circuit clamps the black level at the end of each scan line. Once they are adjusted, it is not necessary to readjust the controls. Only the camera iris need be set according to lighting conditions — a good procedure for black-and-white pictures, and essential for color!

G3NOX transmitted the first full-color SSTV signals on March 8, 1980, at 1145 UTC on 28.6 MHz. The color signal was received and tape recorded at K2RZ near New York, played back and received in color by G3NOX. The picture arrived at G3NOX with some interference, as shown here, after traveling a path distance of approximately 7000 miles.

The G3NOX color picture received at W9NTP on March 15, 1980. *(Photo courtesy of Don Miller, W9NTP)*

sive, the writer feels that this is really the best way, for it eliminates the problems of encoding and rf modulation, and gives the most accurate color.

Connecting the Complete System

To produce a color picture, the whole system is connected as shown in Fig. 3. The composite video and sync from the camera is fed to the video inputs of all three Robot 400s using BNC T connectors with a 75-ohm termination resistor on the last unit. Video outputs from the 400s are taken to the RGB monitor and to a 3-way switching unit which enables the black-and-white monitor to be switched to look at each of the three stored images — useful for normal black-and-white operation as well as for examining the RGB color separations.

The outputs from the transceiver, tape recorder, etc., are fed into the appropriate sockets on all three Robot 400s. In order to provide complete control of SSTV and microphone functions the three units are connected together as shown in Fig. 4. This also means that no extra switch boxes are needed to sequentially transmit the three color SSTV signals.

I have considered the possibility of making up a sequential switcher but experience with color SSTV on the hf bands has shown that at least two frames of each color are desirable to overcome QRM. This is most easily done with manual switching at both stations where human intervention can result in the best frames being held.

Setup and Color-Balancing Procedure — Transmission

Place the red filter on the camera. Adjust the iris, lighting and contrast control on the camera to give a good picture on a black-and-white monitor. If a scope is available, this should be connected to monitor the fast-scan video. This will assist in getting the correct video levels.

Next, cap the camera lens to give a black level. Switch all three Robots to the CAMERA DISPLAY position and turn all three snatch brightness controls fully counterclockwise. Set all the snatch contrast controls at the 3 o'clock position.

Now select the Robot gray-scale position on the memory-input switch and press all three snatch buttons. The color monitor should now display a neutral gray scale with no color tinting. If a color bias is apparent, the color monitor bias and gain controls should be carefully adjusted to give a completely neutral gray scale.

Select the CAMERA position on the memory switch and CAMERA on the display switch, leaving the lens capped. Adjust the snatch brightness on the red channel so that a red tint is *just not visible*. Repeat for the green and blue. The color monitor should now show a *black* level. If not, the color monitor brightness should be adjusted for the correct black level.

Uncap the lens on the camera and adjust the snatch contrast controls on each Robot to give a neutral gray picture consistent with correct contrast. Do not limit whites by setting the contrast too high. After this stage has been reached it is worth capping the lens again and repeating the preceding paragraph to ensure accurate black-level tracking.

Snatching a Color Picture

Switch to the memory display on all three Robots. Select the red filter on the camera and press the red snatch button. Repeat for green and blue and you should have a color picture. Because of lighting, camera spectral response and other factors it will probably be necessary to carry out fine adjustments of the snatch contrast controls *only* to get a true gray balance when using a gray scale in front of the camera.

I know this sounds complicated, but it is a once-and-for-all process, as the Robots are very stable. All you will have to do normally is to snatch a color picture and carry out fine adjustments. Make sure your lighting and camera exposure are correct by monitoring the camera video level on your scope against a graticule.

Setup and Color-Balancing Procedure — Reception

In order to receive accurate color pictures it is necessary to align the receive

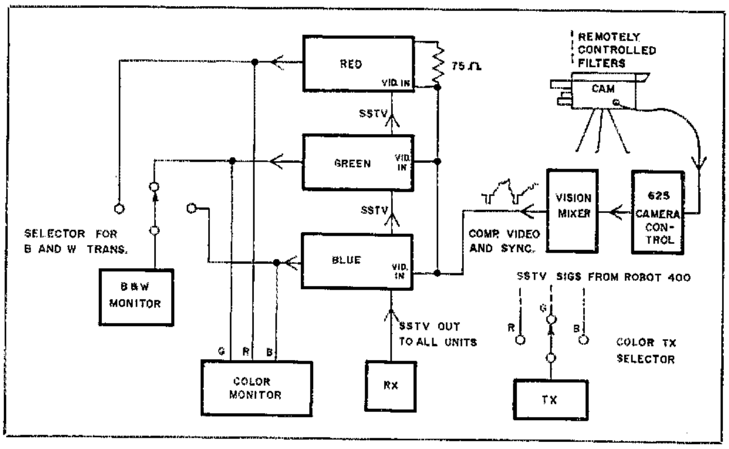


Fig. 3 — System interconnections for a complete color SSTV system using three Robot 400s.

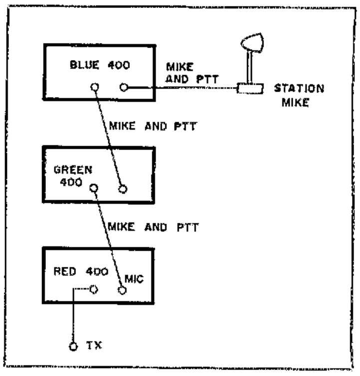


Fig. 4 — This system allows the switching of each Robot 400 to transmit in turn without making extra switching arrangements. Just use the normal Robot VOICE-VIDEO TRANSMIT switches on each unit.

brightness and receive contrast controls on each of the Robot 400s using the following procedure. Record about 5 minutes of gray scale from one of the Robot 400s after having previously checked the SSTV sync and black-and-white levels for the correct frequency, as laid down in the instruction manual.

Follow the procedure recommended for setting the receive brightness and contrast controls by comparing the taped gray scale with the local snatched gray scale. Repeat for each of the 400s. When this is done correctly, the *occasional* sampling error should be visible in the black and white ends of the scale. This indicates that no tones are being lost at either end by compression. Take your time with this setting as this is a once-and-for-all operation. *Do not* touch the receive contrast and brightness controls once this condition has been obtained.

Feed the tape-recorded gray scale into the red 400 and set the width control to just fill the screen. Adjust the width control on the green and blue 400s to obtain perfect registration of the gray scale on the color monitor.

To receive a color picture from another station switch all three Robot 400s to CONTINUE. Wait for the red frame to complete, switch to hold, wait for the green frame and switch to hold, and wait for blue frame and hold. If the transmitted signal was correct you should now have a color picture!

Operating Procedure

The standard color sequence of red, green and blue should be used for all transmissions and at least two frames of each color transmitted. This allows for a second chance at the receiving end if there is QRM or QSB. Caution: Color SSTV takes at least three times as long to transmit as black and white. Make sure you do not overheat your linear!

Avoid adjusting *any* of the controls on the 400 when using color. It is only necessary to adjust the video gain and lens aperture on the camera for correct levels.

The standard Robot Gray Scale will appear at the foot of all color pictures. This provides an excellent check on the overall alignment of the SSTV frequencies produced by the Robot 400s at the transmitting station. It also checks the correct adjustment of the receive contrast and brightness at the receiving station.

Providing that the incoming SSTV frequencies are correct, it should be possible to adjust your transceiver for "natural" speech and to receive the color SSTV picture without further adjustments. In any case the receiver tuning should not be altered during the reception of color frames or balance will be lost. If one of the color frames is lost because of QRM, it is possible to "repair" the picture by asking the sending station to send this color again.

The transmission of color SSTV is more complex than black and white. It is therefore necessary to reduce the number of operational controls to a minimum, and this has been achieved by treating all the Robot 400 controls as presets, using the procedures already detailed. On a well set-up system, all that is necessary is to set the camera iris, select the correct filter, and operate the snatch buttons.

Results

Some idea of the results that can be achieved with color SSTV are shown in the accompanying photos. However, it must be remembered that in these printed illustrations two *further* color-reproduction systems have been used — off-the-screen photography and the color printing process. The actual results on the monitor must be seen live to really appreciate the quality!

At the time of writing only about three stations in the world are known to be equipped for color SSTV. For this reason the writer has been sending color SSTV to stations equipped with audio tape recording and playback facilities connected to their transceivers and having them play back the color. The results have been very good, particularly when QRM and the Woodpecker[1] are absent!

Summary

The development of this field-sequential color SSTV system has involved some interesting problems of colorimetry, digital electronics and interfacing different types of equipment that were never intended for producing color pictures. Although this is a good example of the ham approach of using what is available to form a complete system, I appreciate that it is fairly costly — but then color in any medium usually is!

The thrill of seeing a full-color SSTV picture form on the monitor screen after its traveling many thousands of miles over a normal speech type circuit is a thrilling experience — certainly the most exciting thing the writer has done in Amateur Radio.

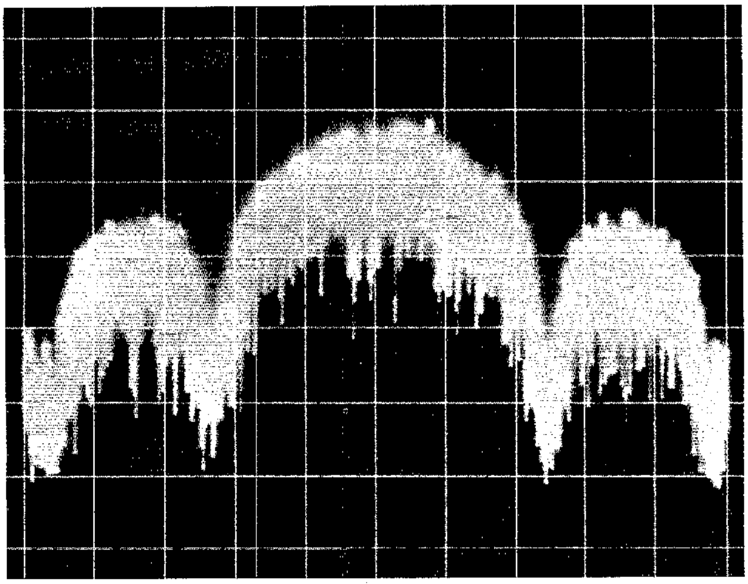
I would like to acknowledge the great assistance I have received on this project from Martin Emmerson, G3OQD, who developed the digital synchronization system and has given valuable advice to me. QST

[1]See "More Woodpecker Thoughts," *QST* Technical Correspondence, Jan. 1980.

Spread Spectrum and the Radio Amateur

Spread-spectrum signals are unlike any emissions presently used by radio amateurs. But we stand at the threshold of what may be a new mode for amateur communications.

By Paul L. Rinaldo,* W4RI



A modulation technique that has been in development since the late 1940s, spread spectrum (SS) has, until recently, been virtually unthinkable for use by radio amateurs for a number of reasons. First, SS occupies bandwidths far in excess of the necessary bandwidth; that would be illegal! By using a pseudo-random digital sequence to scatter energy over a wide band, there is only a small amount of energy in any one hertz; that would make it an unauthorized code. SS systems have been complex and expensive; that would be beyond the resources of radio amateurs. Much of the development has been conducted under government contract; most hams knew little or nothing about the subject. There were more than enough reasons to deter hams from even dreaming about an SS rig in their shacks.

The situation has changed greatly in recent years! SS technology has progressed to the point where affordable systems can be built for amateur and other non-governmental uses. The replacement of the Federal Communications Commission's Office of the Chief Engineer with the Office of Science and Technology (OST) carried with it the mandate to encourage the use of new technology. The FCC's OST sees the Amateur Radio Service as a test bed for new techniques. Some at the FCC feel that the long-term retention of amateur frequencies, in competition with other radio services, depends largely on continued technological advancements by amateurs. We may be entering an "experiment or expire" era.

Why the sudden interest in SS? The reasons are many. First, there is the simple technical imperative, meaning that the technology is there as a result of many years of government-sponsored development, so why not use it for civilian applications? Another reason is that a number of SS users, say in the Land Mobile Service, could be overlaid on top of an existing band already "full" of mobile users employing conventional frequency modulation. Similar overlays could be tried by amateur experimenters in the ham bands. If this is done with care, the preexisting users wouldn't even detect the presence of the SS overlay. Yet another possibility is the creation of new bands, maybe a 900-MHz band, which would use SS exclusively to accommodate

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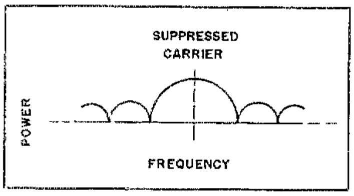

Fig. 1 — Power vs. frequency for a direct-sequence-modulated spread-spectrum signal. The envelope assumes the shape of a $\left(\frac{\sin x}{x}\right)^2$ curve. With proper modulating techniques, the carrier is suppressed.

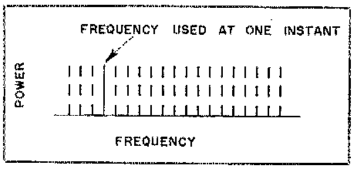

Fig. 2 — Power vs. frequency for frequency-hopping spread-spectrum signals. Emissions jump around in pseudo-random fashion to discrete frequencies.

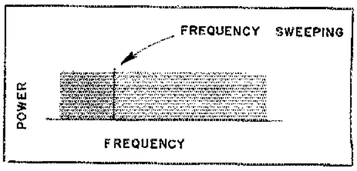

Fig. 3 — Power vs. frequency for chirp spread-spectrum signals. The carrier is repeatedly swept, continuously, from one end to the other in a given band.

thousands of users. Moreover, SS could afford these users both privacy and immunity from interference through proper code settings. In general, SS offers possibilities for more extensive sharing of frequencies while minimizing interference.

Spread-Spectrum Fundamentals

SS systems employ radio-frequency bandwidths that greatly exceed the bandwidth necessary to convey the intelligence. Bandwidths for SS systems generally run from 10 to 100 times the information rate. By spreading the power over a wide band, the amount of energy in any particular hertz or kilohertz is very much smaller than for conventional narrow-band modulation techniques. Depending upon the transmitter power level and the distance from the transmitter to the receiver, the SS signal may be below the noise level.

SS systems also use coding sequences to modulate and demodulate the transmission. Receivers with the wrong code will not demodulate the encoded SS signal and will be highly immune to interference from it. On the other hand, receivers with the right code are able to add all the spread energy in a constructive way to reproduce the intended modulation. In fact, the use of coherent correlation can yield some process gain. Changing the code to another sequence effectively creates a new "channel" on which a private conversation can take place. Many good code combinations could be made available on a single chip and selected by means of thumbwheel switches on the SS transceiver.

Types of Spread Spectrum

There are four basic types of spread spectrum: direct sequence, frequency hopping, pulse-fm and time hopping. In addition, there are hybrids consisting of combinations of two or more of the above basic types.

Direct Sequence (DS): Direct sequence SS is produced by modulation of a carrier with a digitized code stream. This type of modulation is also known by the terms pseudo-noise (PN), phase hopping (PH), direct spread, or direct code. Phase-shift keying (psk) is usually used to produce the marks and spaces, but frequency-shift keying (fsk) could also be used. The wide rf bandwidth arises from the use of a high-speed code. Of course, if the transmitter were allowed to rest on the mark frequency, there would be a steady carrier in one place whenever there is no modulation. This would produce interference to a narrow-band user on that frequency. It would also pose problems for other SS users of the same band, particularly if they did the same thing. So it is conventional for SS systems to include techniques to continue a pseudo-random code sequence even during intervals when intelligence is not being transmitted.

The power spectrum for a DS signal (as might be seen on a spectrum analyzer) is not uniform across the band, but has a main lobe and sets of sidelobes as illustrated in the title photo and in Fig. 1. The bandwidth of the main lobe as measured from null to null is two times the clock rate of the code sequence. The bandwidth of the side lobes is equal to the clock rate. To receive a DS signal, the receiver must collapse or "despread" it to the original bandwidth of the information. This is done by using a replica of the code sequence used by the transmitter.

Frequency Hopping (FH): As the name implies, frequency hopping is simply jumping to a number of different frequencies in an agreed sequence. The code sequence is usually at a slower rate than for direct sequence and is normally slower than the information rate. The hopping rate may also be determined by practical considerations, such as how long it takes for a particular frequency synthesizer to settle down on a new frequency.

Actual modulation of the frequencies uses normal narrow-band techniques such as frequency modulation. At any instant, an FH transmitter is emitting all of its power on a specific frequency slot and potentially could interfere with someone else using a narrow-band system on that frequency. However, the FH dwell time on that particular frequency is so short that most narrow-band users would not be bothered. Mutual interference between two or more FH users sharing the same band could be extremely low, depending upon the design of the code sequences. Fig. 2 illustrates the power spectrum for an FH signal.

Pulse-FM (Chirp): A chirp spread-spectrum system sweeps its carrier frequency over a wide band at a known rate. Again, conventional narrow-band modulation of the sweeping carrier is used to convey the intelligence. The receiver uses a matched, dispersive filter to compress the signal to a narrow band. Chirp systems typically do not use a code sequence to control the sweep generator. Sweep time can be largely independent of the information rate. Normally, a linear-sweep pulse is used, similar to that produced by a sweep generator. The power spectrum for a chirp system is illustrated in Fig. 3.

Time Hopping (TH): Time hopping is a form of pulse modulation using a code sequence to control the pulse. As in other pulse techniques, the transmitter is not on full time and can have a duty cycle of 50% or less. Several systems can share the same channel and function as a time-division multiple-access (TDMA) system. TH is more vulnerable to interference on its center frequency than other SS systems. Seldom seen in its pure form, TH is typically used in hybrid systems using frequency hopping as well.

Hybrids: In addition to the TH/FH hybrid system just mentioned, there are also DS/FH and DS/TH combinations. Hybrid systems are typically designed to accommodate a large number of users and to provide a higher immunity to interference. They also produce better results at practical code sequence rates governed, for example, by how fast a frequency synthesizer can be switched. Also, hybrids can produce greater spreads than those which are practical for pure SS systems.

Some Considerations

Synchronization: In the design of a spread-spectrum system, usually the toughest problem is synchronization of the code sequence at the receiver with that of the incoming signal. If sync is not attained, even just one bit off, nothing but noise can be heard. The problem becomes worse when more than two stations are trying to communicate in a net. This is because of the different propagation delays between stations; i.e., it takes a different time for a signal to travel over paths A-B, A-C, or B-C if the stations are not equidistant. These differences may be only slight but just enough to degrade the signal-to-noise ratio of the received signal.

Glossary of Spread Spectrum Terms

Chirp — Same as pulse-fm.
Code sequence — A series of 1 or 0 bits arranged in a known pattern.
Direct code — Same as direct sequence.
Direct sequence — A type of spread-spectrum modulation using a code sequence to modulate a carrier, normally using phase-shift keying.
Direct spread — Same as direct sequence.
Frequency hopping — A type of spread spectrum which employs rapid switching between a large number of discrete frequencies.
Hybrid — A spread spectrum system that combines two or more basic types of spread spectrum.
Phase hopping — Same as direct sequence.
Pseudo-noise — Same as direct sequence.
Pulse-fm — A type of spread spectrum that uses a swept carrier.
Spread spectrum — A class of modulation types that produce bandwidths far in excess of the bandwidth necessary to convey the intelligence.
Time hopping — A type of spread spectrum using a form of pulse modulation in which the pulses are controlled by a code sequence.

In addition to the time uncertainty related to propagation, there is also a frequency uncertainty in trying to keep oscillators at two or more stations from drifting.

Because the stations cannot be expected to synchronize on their own with no reference, it is normal for at least one station to transmit an initial reference for sync purposes. Upon reception, the receiving stations can generate the code sequence at a rate different from the code sequence used at the transmitter. Eventually, the two code streams will slide into phase with one another and may then be locked up. After initial synchronization, maintaining sync presents another problem which can be solved in different ways. One is to use a code sequence preamble at the beginning of each transmission. Another is to use ultra-stable clocks at all stations to ensure that the code-sequence clock frequency does not change. Numerous other schemes have been devised and implemented with varying degrees of difficulty. The exception is that chirp systems do not have this problem because the matched filter used in demodulation inherently achieves sync on each pulse transmitted.

Transmitter and Receiver Design: One difference between SS and conventional rf equipment is that SS requires transmitters and receivers that have 10 to 100 times the bandwidth of narrow-band systems. That may pose some problems at lower frequencies, but in the 420-MHz band the amateur television (ATV) experimenters already have equipment that can handle wideband signals. The transmitter design, which should be well within amateur capability, amounts to taking care in broadbanding the rf stages after modulation to maintain amplitude linearity, and in keeping the antenna system VSWR very low. Receivers must not only have wideband front ends but must have good dynamic range and linearity to handle both the desired signal and any interference. Where an i-f is used, the frequency chosen must be higher than for conventional transceivers. In practice, 70 MHz is a common SS i-f. Components (such as filters) are available for this frequency to build SS i-f modems (modulator/demodulators).

Amateur SS Experimentation

The Amateur Radio Research and Development Corporation (AMRAD) has formed a group to experiment with several different types of SS systems. Before on-the-air tests are conducted, it will be necessary to obtain a Special Temporary Authorization (STA) from the FCC. Readers wishing to participate should contact AMRAD via the author.

The continued existence of the Amateur Radio Service depends, in part, on amateurs' contributions to the state of the art through experimentation. Spread spectrum is fertile ground for amateur investigation. While SS has been developed extensively for military and other governmental applications, civil uses are virtually unexplored. Hams have the capacity to build SS systems which are practical and inexpensive. There is no guarantee that SS will prove itself worthy of regular use in civilian radio services, but the technology is ripe for Amateur Radio experimentation.

[The title photo, a spectrum analyzer display of a direct-sequence spread-spectrum signal, is reprinted through the courtesy of Robert Dixon and John Wiley & Sons, Inc. The photo appears on the cover of *Spread Spectrum Systems.* — Ed.]

Selected Bibliography

Reading material on spread spectrum may be difficult to obtain for the average amateur. Below are references that can be mail ordered. Spread spectrum papers have also been published in IEEE Transactions on Communications, on Aerospace and Electronic Systems and on Vehicular Technology.

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Current published searches on spread spectrum are available from the U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161 for $30 each:

Spread Spectrum Communications (99), May 79 NTIS/PS-79/0494/9.

Spread Spectrum Communications (188), May 79 (EI) NTIS/PS-79/0495/6.

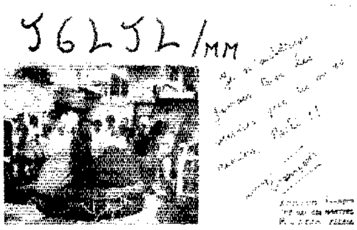
Strays

HAMS RESCUE HAM IN BERMUDA TRIANGLE

☐ Three seagoing Amateur Radio operators recently had an unusual rendezvous. Captain Emerson Hiller, KA1CYA, master of the research vessel *Knorr*, and Bill Edwards, K5CN, radio officer on the *Knorr*, brought Francois Erpicum, J6LJL/MM aboard the ship where he was a guest for almost a month.

Francois was certainly maritime mobile when he was found in the Bermuda Triangle area where he had been adrift in a life raft for four days and nights. His sailing vessel, the *Nanesse*, had been struck, holed and sunk within seconds after being hit on May 20. He was rescued just after midnight on May 24, when the watch on the *Knorr* sighted his red flare. He never learned what it was that struck his vessel. Word of his rescue was sent to the U.S. Coast Guard and over amateur frequencies.

Francois departed the *Knorr* upon its arrival in Ponta Delgada, Azores, where he was met by Belgian officials who assisted him in matters of immigration, missing passport and the like. During a continuation of his cruise, aboard another sailing vessel, he plans to write a magazine article and a book about his experiences. Keep your ears open for Francois, J6LJL/MM, from the far reaches of the Pacific. It will help if you speak French, but when last seen, Francois was picking up English quite rapidly. — *Bill Edwards, K5CN, McAllen, Texas*



The covered life raft, featured on this unique QSL card, is one reason why Francois Erpicum, J6LJL/MM was in excellent condition after four days and nights adrift in the Bermuda Triangle.

I would like to get in touch with . . .

☐ someone interested in a game of chess via OSCAR 7, mode B. Albert Weiss, K6VU, 2461 Crestview Dr. S., Salem, OR 97302.

A 15-Meter Beam for $10

Got more time and trees than money? Enjoy the challenge of making a top performer out of a "primitive" set-up? See what can be done with a little ingenuity.

By Bruce Burnham,* C6ADN

Here is a very simple, extremely lightweight 3-element stationary beam antenna for 15 meters that is easy to build and adjust, and so cheap that it's practically disposable. It also works like a charm, and is ideal for antenna tinkerers — just lower it to waist height and stroll around it, making your changes. I will admit that it looks odd, and appears too flimsy to last, but mine has been up for nearly two years now, even surviving a hurricane with only minor damage. When I designed it, my goal was to maintain communications between the Bahamas and the home QTH in Aroostook County, Maine. This little cat's cradle delivers a consistently good signal from my old Hallicrafters HT-44.

Put This on Your Pipe and Smoke It

The bill of materials is just two 16-foot (4.9 m) lengths of 1/2-in. (13 mm) PVC pipe, a ball of nylon twine, some wire and a couple of empty laundry soap bottles. You will also need two lengths of 1/4 in. (6 mm) or larger rope long enough to toss over nearby trees so you can haul this thing up into the sky. My wire elements are made of heavy aluminum stuff, sold as grounding cable for the local CB fraternity. Copper should be an improvement, but at the time I didn't have any.

It's best to stake the parts out on the ground approximately where the antenna will be raised, because once you begin putting it together, it starts to develop a "mind of its own." I considered using bamboo poles, but none were available. Besides, 32 feet of bamboo is heavy enough to offset the light, flexible design I had in mind. If you can find 'em, try 'em. When you buy the PVC pipe, get the cheapest, lightest stuff you can find; the grade I got was marked "irrigation." It will be so limber and floppy that you'll have trouble getting it home on the roof of the car, but don't worry; we'll fix that with string and ingenuity.

A 3-element beam antenna is just a dipole with a reflector element behind it and a director element in front at the proper distances to nudge your radiated signal in the direction you'd like it to go. The only problem is holding these parasitic elements out away from the driven element with lightweight, weather-resistant components. Take the two 16-foot (4.9-m) lengths of PVC and lay them down on the ground between two trees or other high points that are approximately at right angles to the direction you want to cover. Hold them down with something about 23 feet (7 m) apart at the reflector end and 21 feet (6.4 m) apart at the director end of the intended beam.

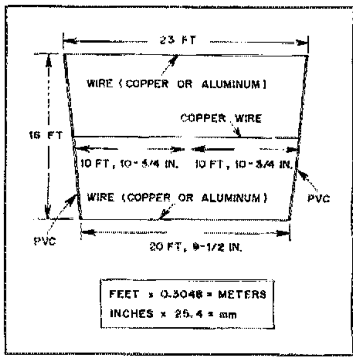


Fig. 1 — Diagram for laying out the elements of the beam.

Now calculate your dipole length based on the proposed frequency of operation, using the standard formula: length in feet equals 468 divided by the frequency in MHz. The reflector will be 5% longer than this length, the director 5% shorter. Since my sked is on 21.4 MHz, an electrical half-wavelength comes out to 21.869 feet (6.7 m).

Now drive a spike into the living-room floor [(?) — Ed.] or other convenient spot; bending a hunk of wire around the

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nail, measure off exactly 1/4 wavelength, and mark the parallel wires with tape. Cut the wires 4 or 5 inches (100 or 125 mm) beyond the tapes to give yourself attachment and tuning length. Cut the wire at the bend and fasten each side to a center insulator. Cut your reflector 1 foot longer than the dipole assembled length, tape to tape, plus the same few inches for attachment. The director element is made the same way, only it is 1 foot shorter than the dipole (5% of 21.9 equals 1.09 foot [332 mm]). Overall dimensions are given in Fig. 1.

Next, cut six 1-inch strips from around the plastic laundry soap jugs — Era containers have a nice red color that turns passionate pink in the sun. Make them long enough to go around the tubing and leave a double tail 4 or 5 inches (100 or 125 mm) long to which the wires will be fastened (Fig. 1). Crimp these straps onto the PVC with small bolts or "pop" rivets and washers, up close so they will stay put. Place one strap an inch in from each end, and one at the midlength of each piece of pipe. Drill two holes about 3/16-in. (5-mm) dia in the last inch of each end of the spreaders, one hole vertical and one hole crosswise.

Now fasten the dipole between the centers of the two spreaders, the reflector across the end that will be the "back" of the beam, and the director across the end that will be pointing in your preferred direction when the antenna is hoisted in place.

The eight-foot spacing thus obtained between elements falls within the recommended 0.16 to 0.23 wavelength called for in the *Handbook* section on Yagi antennas. If you want to experiment with tuning the array for maximum efficiency, start with the full length of wire and trim for a peak at your frequency. You can also change the relative spacing of elements by moving the center driven element back and forth. I just slapped this together at the calculated dimensions, and it has worked so well that I haven't felt the need for any improvement.

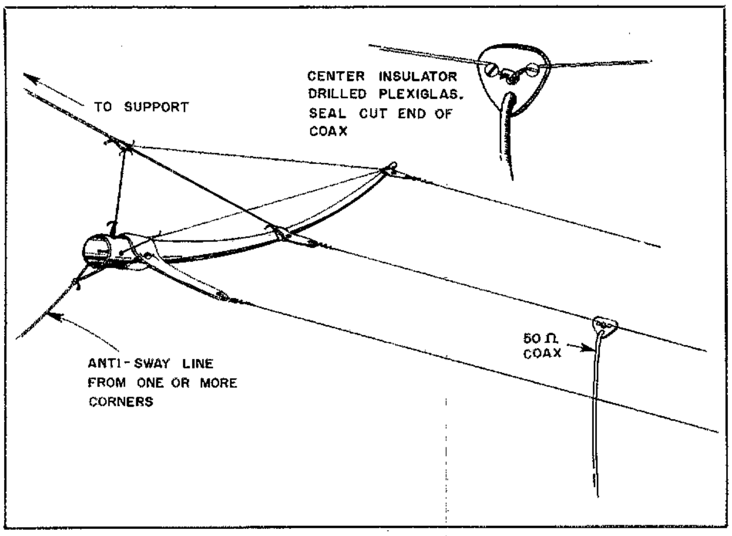

Fig. 2 — Detailed view of one side of the 15-meter beam. Notice how the bow and bridle work against each other to hold the beam rigid. An exploded view of the feed-line hook-up is shown in the inset.

Bow Plus Bridle Equals Backbone

Now is the time to put some backbone into those utterly limp lengths of PVC that had you worried until now. Assembly details are given in Fig. 2. Thread one end of some nylon twine through the transverse holes in one end of the spreaders, tie in a bowline knot and stretch the twine down to the other end of the spreader and through the same set of holes in that end. Haul up tight so the pipe forms a shallow bow about 18 in. (460 mm) deep, and tie it off so it holds that shape. Using the other set of holes, form a bridle of more twine from one end of the spreader, out to a point about 10 feet from the midpoint of the PVC, and make it fast at the other end. At the apex of the triangle formed, tie in a ring for your hoisting line. I made the rings from short sections of heavier plastic pipe. The twine used was nylon mason's chalkline. Run another cord from the ring to the pipe at the center insulator, winding the string over and around the dipole strap to hold it in place. These three cords must be equally tensioned so that when a strain is taken on the hoisting lines, the bows will stand vertically with the "bowstrings" uppermost, each held in place by the pull of the wires on one side and the bridle on the other. It's much easier to do than it sounds.

When you have treated the other spreader the same way, and made fast your coax feed line to the center insulator, toss a weighted string over your two support trees. Haul up the hoisting lines, tie into the two rings and haul away. The antenna is so light that the topmost branches will easily take the weight without damage. Raise the assembly off the ground and see how it all hangs together. By tightening or slacking on the various cords, you can make this conglomeration into a surprisingly stable array, as long as you keep a strain on the two ends.

Before final hoisting into place, tie a length of cord to one or more corners of the beam so you can lead them off at an angle for stability. The array is very light and will sway in the wind, so these lines will control it and keep it from capsizing in a strong breeze. My antenna had been up for a year when Hurricane David struck while I was off the island. The array survived 90 mi/h winds with only a broken reflector and a capsize. Twenty minutes' work repaired the damage.

Don't try to shortcut construction by eliminating the strap insulators. If you fit the wires directly to the tubing, the ends will flex in the wind and break off as the array moves about; that's what happened to my reflector. The straps act as shock absorbers as well as insulators, and they have lasted over a year here at 26° north latitude in the sun and salt air.

Since I run a rather primitive station, I can't give very precise measurements; with my old 130-watt HT-44, however, I appear to get a doubling of signal strength out, and the same on receive. Any time the band is open I get 5/9 reports from New England and Canada, and have worked Hawaii, Alaska, Europe and Africa off the sides. Not bad for an antenna at 25 feet (8 m), surrounded by tall pines, with a power line only one wavelength in front of and above it.

There must be a respectable front-to-back ratio, because signals from South America are generally lousy. The fact that the driven element hangs about 2 feet (600 mm) below the parasitics doesn't seem to hurt. The thing shows me an SWR of 1.3 to 1 at 21.3 MHz, and no more than 1.4 to 1 at the band edges, as compared to 1.1 to 1 for my dummy load (50 ohms worth of 1000-ohm, 2-watt resistors in a peanut-butter jar full of oil. . . . I *told* you this was a primitive operation.) My advice to you is to try this antenna. What have you got to lose?

Ladder Crystal Filter Design†

Build a high-performance hf filter at a fraction of the cost of a commercial unit — yet with virtually no constructional problems. Refer to December 1978 QST for earlier information.

By J. A. Hardcastle,* G3JIR

In previous articles on ladder crystal filters[1] experimental results were presented without any accompanying theoretical analysis, since the practical difficulties of measuring crystal parameters accurately would have made this information valueless to most radio amateurs. However, a simple measuring procedure has now been devised which, in conjunction with a set of capacitor coefficients, allows the construction of filters of predetermined bandwidth. Sets of design coefficients for filters using up to eight crystals are given and accompanied by a description of their derivation.

Frequency Response

Fig. 1 shows two frequency response curves. The first is known as the maximally flat or Butterworth response, and the second as the equi-ripple or Chebyshev response. Ideally the number of positive peaks in this latter response should equal the number of crystals, and be of equal amplitude over the whole passband. However, in practice, fewer peaks than expected are usually found, some having merged with each other. And the ripple amplitude usually increases towards the band edges because the crystals and capacitors have a finite and unequal Q; these effects are particularly marked in higher-order filters.

In applications where some passband ripple is acceptable, the Chebyshev response is preferred because it has a steeper rate of cut-off and requires a lower impedance circuit than an equivalent Butterworth filter. This latter factor can be a decided advantage in circumstances which would otherwise require impracticably small capacitors.

Filter Design Coefficients

It has been shown previously[2,3] for Butterworth filters that much of the labor can be taken out of filter design if each capacitor is assigned a coefficient, determining its relationship with its neighbors, and hence the filter frequency response. Fig. 2 gives design coefficients, for 3rd-, 4th-, 6th- and 8th-order Chebyshev filters which have been calculated from formulas published by Amstutz.[4] Actual capacitor values are derived from these coefficients by applying the formula

$$C = \frac{k \times 10^6}{2\pi f R} \qquad \text{(Eq. 1)}$$

where

k = capacitor coefficient
f = filter center frequency (MHz)
R = circuit impedance (ohms)
C = capacitance (pF)

In hf ladder networks it is advantageous to use shunt capacitors rather than series capacitors because this allows stray capacitance to be absorbed and allowed for in the physical components. Fig. 2 also shows these Type 2 filters where the input and output series capacitors have been transformed into their shunt equivalents. Unfortunately this requires an increase in circuit impedance which may not always be convenient, in which case the Type 1 filter must be used.

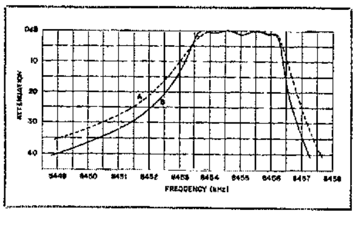

Fig. 1 — Frequency responses of two typical 4-crystal filters, (A) Butterworth, (B) Chebyshev. The Butterworth filter bandwith is actually 2369 Hz and the whole response has been scaled up to allow direct comparison with the 2762-Hz bandwidth Chebyshev filter.

Filter Bandwidth

One of the most important parts of a filter specification is its bandwidth. Dishal's procedure[5] allows this to be determined from a knowledge of the equivalent series inductance of the crystal, which, as was said previously, is a difficult parameter to measure, and the subsequent calculations are lengthy.

Previously, a disadvantage of the simplified capacitor coefficients method has been the need to make several trial filters before the required bandwidth could be attained; however, it has now been found that these initial trials can be simplified by making systematic measurements on a 2nd-order filter. These results are then applied to whichever higher-order design is required.

Initial Tests

The test filter is connected as shown in Fig. 3, and its frequency response and bandwidth measured using the filter test set described previously.[1] Choice of an initial value for capacitor C is arbitrary, but a value of 33 pF would be suitable for many crystals. The test impedance may then be calculated by transposing Eq. 1:

$$R = \frac{k \times 10^6}{2\pi f C} = \frac{0.613 \times 10^6}{2\pi \times 8.454 \times 33} = 349.7\,\Omega \qquad \text{(Eq. 2)}$$

The test-set input and output impedances are now set to this value. To set

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†Adapted from an article of the same title in *Radio Communication* (RSGB) for February 1979.
[1]References appear on page 23.

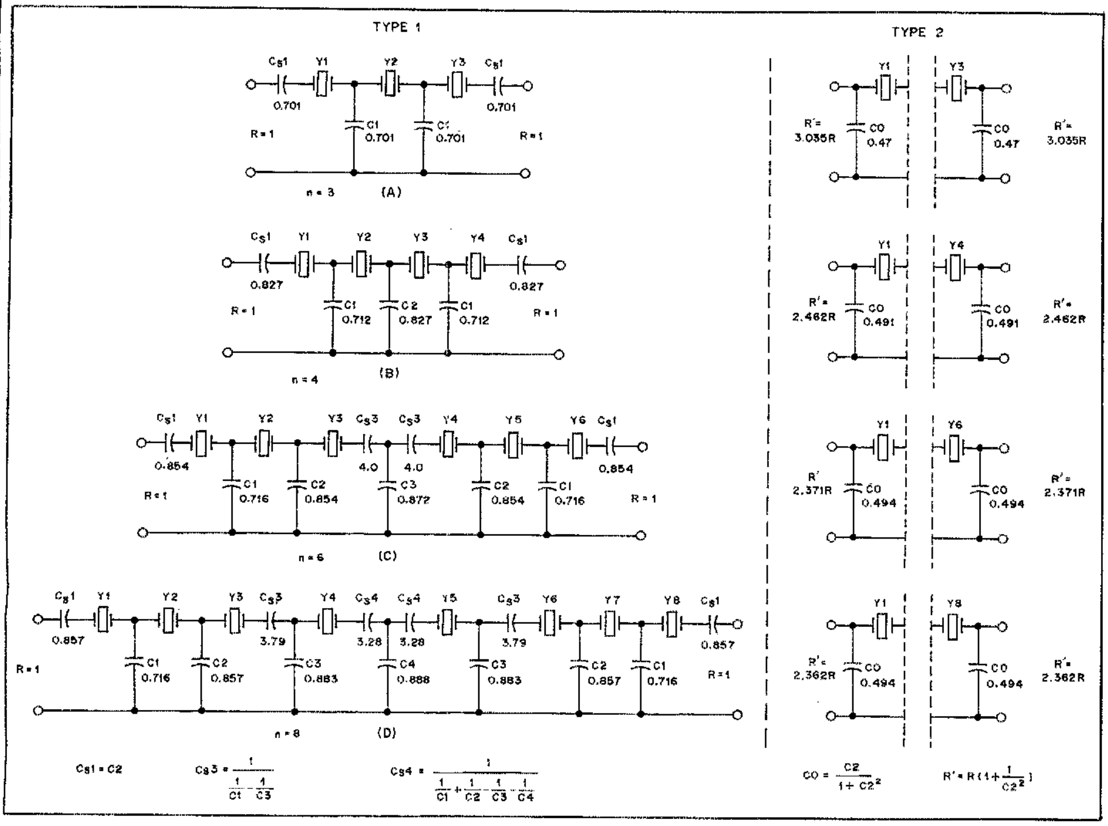

Fig. 2 — Design coefficients for Chebyshev filters.

the input impedance, measure across A-B with an ohmmeter while adjusting R3; to set the output impedance, measure across points X and Y and adjust R4. The different input and output circuits are necessitated by the particular circuit arrangements of the test set.

A typical frequency response curve obtained by this method, Fig. 4 shows a dip of very nearly the theoretical 1 dB in the center. Ideally the peaks on either side should be equal, but rarely are, because of minor differences between the two crystals. However, the most important parameter, the bandwidth, is well defined and easily measured because the response is falling rapidly at the 3 dB-down points.

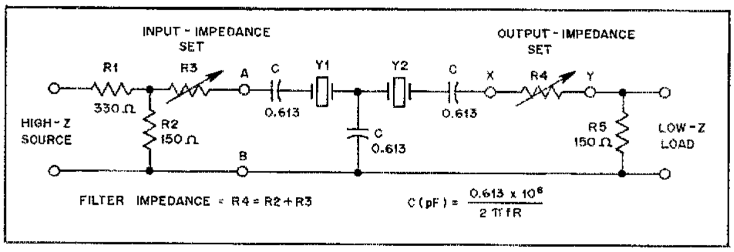

Fig. 3 — Preliminary tests to determine filter bandwidth use this circuit in conjunction with the filter test set (see text).

Filter bandwidth has been found to be inversely proportional to the square root of the coupling capacitance, and once an initial measurement has been made a very close approximation to the correct capacitance may be calculated from:

$$C2 = C1 \times \left(\frac{BW1}{BW2}\right)^2 \qquad \text{(Eq. 3)}$$

where C1 and BW1 are the capacitance and bandwidth found in the first measurement, and BW2 is the design objective.

Eq. 2 is used again to determine the new value of impedance to be used with C2. If these components prove to give the desired bandwidth, this impedance is used to calculate the required higher order filter from the coefficients given in Fig. 2.

Design Example

A 6th-order Chebyshev filter will now be designed to illustrate the application of the procedures described so far. From Table 1 the components giving the bandwidth nearest to 2400 Hz are selected and C2 calculated.

$$C2 = C1 \times \left(\frac{BW1}{BW2}\right)^2$$

$$= 18 \times \left(\frac{2287}{2400}\right)^2 = 16.34 \text{ pF}$$

The new circuit impedance is then calculated

$$R = \frac{k \times 10^6}{2\pi f C}$$

$$= \frac{0.613 \times 10^6}{2\pi \times 8.454 \times 16.34} = 706\ \Omega$$

Using this value for R, the filter-capacitor values can be calculated from the coefficients given in Fig. 2:

$$C1 = \frac{k1 \times 10^6}{2\pi fR}$$

$$= \frac{0.7159 \times 10^6}{2\pi \times 8.454 \times 706} = 19.1 \text{ pF}.$$

Similarly C2 = 22.7 pF, C3 = 23.2 pF and C_s3 = 106.7 pF. This filter was constructed using miniature wire-ended crystals and preferred-value capacitors. The circuit is shown in Fig. 5, and the frequency response is shown in Fig. 6. Note that the 3-dB bandwidth is 2580 Hz, which is considered to be sufficiently close to the design objective for amateur purposes.

Components

Choice of crystals is largely limited to whatever is available cheaply, but it has been found that the miniature wire-ended crystals require a circuit impedance which is higher than for HC-6/U types. Although very satisfactory filters have been made using these miniature types, the high-impedance circuit is vulnerable to stray capacitance. Some individual capacitance trimming may be necessary to obtain the best performance. Therefore, when available, HC-6/U crystals are preferred.

Capacitors may be polystyrene or silver-mica types. Where very small capacitances are called for, a trimmer may be adjusted to the required value or a short piece of miniature coaxial cable may be cut to the required length.[6]

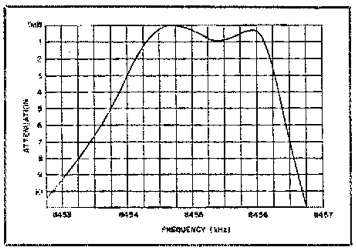

Fig. 4 — A typical test-filter response. The dip in the center of the passband is 0.9 dB and the bandwidth 2287 Hz. Ideally, the peaks would be symmetrical and the center dip 1 dB.

The Evolution of a Ladder Crystal Filter

Fig. 7 shows successive stages in the evolution of a ladder crystal filter. The initial low-pass prototype, Fig. 7A, is converted into a bandpass filter, Fig. 7B, by adding an inductor to parallel-resonate each shunt capacitor to the center frequency. Similarly each series inductor is series resonated by adding a series capacitor. The next stage of the process uses an impedance inverter, Fig. 7C and D, which converts a shunt, parallel-resonant circuit into a series, series-resonant circuit.

Although the impedance inverter uses a negative capacitor in its series arms, this is later absorbed by other, more positive capacitors, so there are no physically unrealizable capacitors in the final design. This procedure was described by Cohn[3] for use in the design of coupled resonator filters and was applied to crystal filters by Amstutz[4] by assuming that, for narrow-band filters, the series-resonant circuit within the dotted line in Fig. 7E is approximated with sufficient accuracy by a piezoelectric crystal, as shown in the filter of Fig. 7F.

Chebyshev Filter Coefficient Calculation

The Amstutz calculations may be illustrated by the following calculation of the coefficients for a 3rd-order filter.

Let the ripple amplitude be a = dB and e = 2.718 and n = number of crystals

Calculate $m = \frac{a}{8.686}$

$s = e^m$

$t = \frac{1}{n} \text{arctanh} \frac{1}{s}$

If a = 1 dB and n = 3, then t = 0.476.

The circuit impedance coefficient is now calculated from

$$R = \frac{\sinh t}{\sin\left(\frac{180}{2n}\right)} = 0.988 \qquad \text{(Eq. 4)}$$

and the coupling capacitor coefficients are calculated from

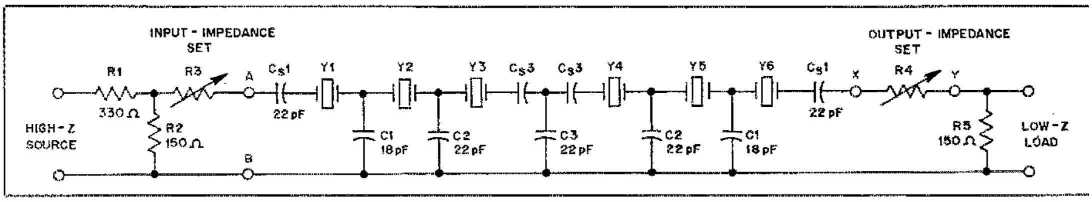

Fig. 5 — Six-pole Chebyshev filter.

Table 1

Test Measurements Made on a Pair of Crystals Using Various Capacitors (C) and Circuit Impedances (R).

R(Ω)	*C (pF)*	*f_1 (kHz)*	*f_2 (kHz)*	*Bandwidth (Hz)*	*Ripple (dB)*
769	15	8,454.198	8,456.742	2544	1.3
641	18	8,454.001	8,456.288	2287	0.9
525	22	8,453.837	8,455.912	2075	0.8
427	27	8,453.742	8,455.611	1869	0.9
350	33	8,453.660	8,455.333	1673	0.9

Note: R was calculated from Eq. 2 in each case.

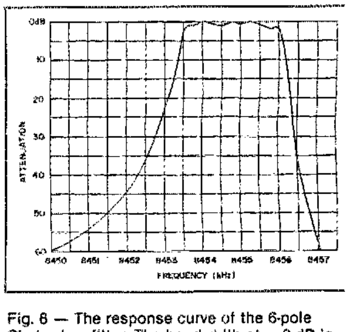

Fig. 6 — The response curve of the 6-pole Chebyshev filter. The bandwidth at −3 dB is 2581 Hz and at −60 dB is 7002 Hz. Note that there are only five peaks in the passband instead of the theoretical six.

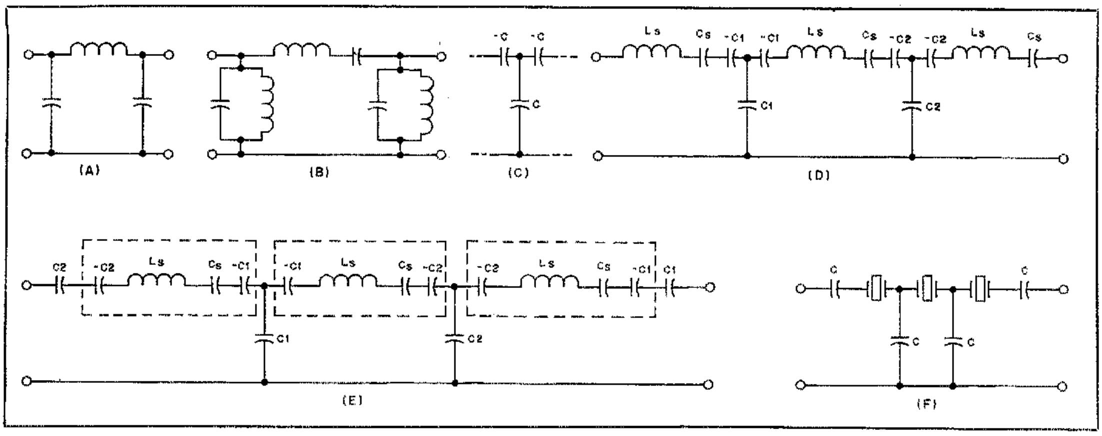

Fig. 7 — Stages in the evolution of the theoretical design of a 3-crystal filter.

$$C_b = \sqrt{\frac{\cos\left(\frac{180}{n}\right) - \cos\left(\frac{360\,b}{n}\right)}{\cosh 2t - \cos\left(\frac{360\,b}{n}\right)}} \qquad \text{(Eq. 5)}$$

For b = 1, 2, . . . (n − 1)
Hence C1 = 0.7092 and C2 = 0.7092.

The filter now appears as in Fig. 8A. This is normalized for a circuit impedance of 1 Ω by dividing the impedance by 0.988 and multiplying all the capacitors by the same amount, with the result shown in Fig. 8B.

As mentioned earlier, the series input capacitors may be replaced by shunt capacitors, C0 in Fig. 8C, and these are derived by the simple calculation shown in the diagram. In this example the impedance is increased by 3.035 by the circuit rearrangement. Colin[8] and Pochet[3] took this calculation one stage further by again normalizing for an impedance of 1 Ω, but this has not been done here in order to preserve the simple relationship between the Type 1 filter and the test filter.

Butterworth Filters

It is not necessary to give full details of the derivation of Butterworth filter coefficients because they follow a similar procedure to the previous paragraph. However, for completeness, the Amstutz formulas are given below so that anyone who wishes may confirm for themselves the coefficients published previously.

$$C_b = \sqrt{\frac{\cos\left(\frac{180}{n}\right) - \cos\left(\frac{360\,b}{n}\right)}{2}} \qquad \text{(Eq. 6)}$$

For b = 1, 2 . . . (n − 1)

$$R = \frac{1}{\sin\left(\frac{90}{n}\right)} \qquad \text{(Eq. 7)}$$

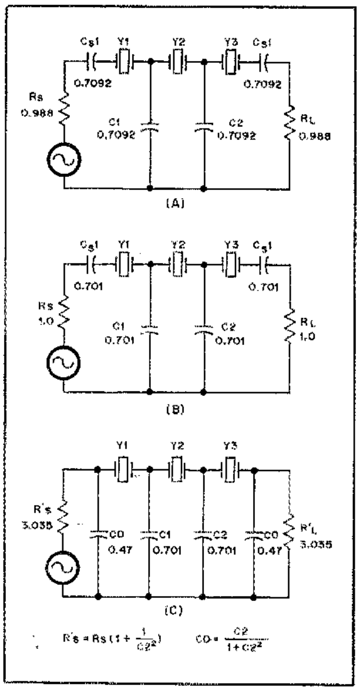

Fig. 8 — Three stages in the calculation of a set of design coefficients. At A, coefficients obtained from Eqs. 4 and 5; at B, coefficients for the Type 1 filter normalized for 1-Ω impedance. At C, coefficients for the Type 2 filter.

Design coefficients have been presented for a range of filters which should satisfy most amateur requirements. They have been tested by constructing filters using 2, 3, 4, 6 and 8 crystals, and the results of these measurements confirm that they behave in a virtually identical manner to filters made from Dishal's design. However, it must be noted that this simplified design method is limited to filters having relatively symmetrical frequency characteristics, and single-sideband filters must be designed using Dishal's more comprehensive design. Now that most of the experimental element has been removed from this simple procedure, it is hoped that more amateurs, particularly beginners, will be encouraged to construct their own filters, especially when inflation has placed commercial products almost beyond reach.

Acknowledgements

It is wished to acknowledge the many sources of information listed in the references; all have made their own contribution to an understanding of ladder crystal filters, without which the simplified method of predicting filter bandwidth could not have been developed. It is also wished to acknowledge the expert assistance of Miss A. E. Howarth for carrying out literature searches and making translations. QST

References

[1] Hardcastle, "Some Experiments with High-Frequency Ladder Crystal Filters," *QST*, December 1978 and *Radio Communication* (RSGB), January, February and September 1977.
[2] Colin, "Formulas for the Calculation of Narrow Bandpass Filters with Identical Piezoelectric Crystals and Maximally Flat Attenuation Behavior" (in French), *Cables and Transmission*, Vol. 22, April 1968.
[3] Pochet, "Crystal Ladder Filters," Technical Topics, *Radio Communication*, September 1976 and *Wireless World*, July 1977.
[4] Amstutz, "Narrow Band Filters" (in French), *Cables and Transmission*, Vol. 21, April 1967.
[5] Dishal, "Modern Network Theory Design of Single Sideband Crystal Ladder Filters," *Proc. IEEE*, Vol. 53, September 1965.
[6] Hawker, "Technical Topics," *Radio Communication*, September 1977.
[7] Cohn, "Direct Coupled Resonator Filters," *Proc. IRE*, February 1957.
[8] Colin, "Narrow Bandpass Filters Using Identical Crystals Designed by the Image Parameter Method" (in French), *Cables and Transmission*, Vol. 21, April 1967.

Improved RTTY Reception with the Yaesu FT-101

A few simple wiring changes will help your '101 "hear" better when copying RTTY and will "scrub" your transmitted afsk signal.

By Dr. Jesse E. Sherwood,* K4DLQ

Just about any ssb transceiver can be used for hf RTTY transmission when afsk is employed,[1] but unless the receiver section has an RTTY filter, the ssb i-f filter passband normally used is too wide to provide optimum reception. Audio filters can be an aid in such a situation, but the wide i-f passband allows nearby QRM to affect the receiver agc and introduce error in the decoded information.

A Filter-Switching Technique

The Yaesu FT-101 transceiver cw-filter center frequency (3179.3 kHz) differs from the usb local-oscillator frequency (3178.5 kHz) by 800 Hz. For most hf narrow-shift RTTY operation, with the mark and space frequencies at 2125 and 2295 Hz respectively, the corresponding intermediate frequencies cannot pass through the cw filter; they fall well outside the cw filter passband. See Fig. 1. If the lsb oscillator (3181.5 kHz) is used in place of the usb oscillator, however, it will cause the corresponding RTTY intermediate frequencies to be correctly positioned for use with the cw filter: 3181.5 kHz − 3179.3 kHz = 2.2 kHz. The use of the lsb crystal frequency also provides the right mark/space relationship required for RTTY operation.[2] The modification employed here consists of rewiring the switching circuitry so the lsb local oscillator and the cw filter are switched into operation when the MODE switch is in the AM position.

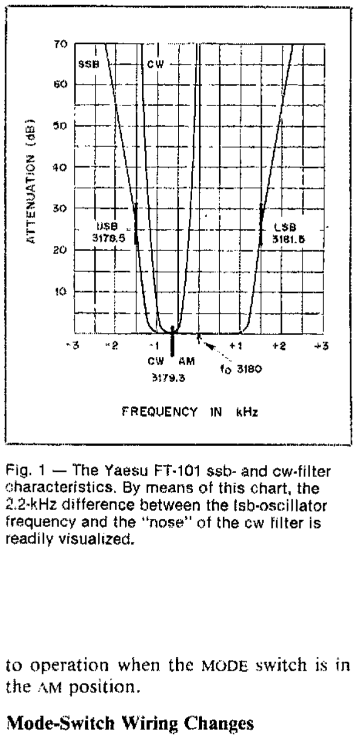

Fig. 1 — The Yaesu FT-101 ssb- and cw-filter characteristics. By means of this chart, the 2.2-kHz difference between the lsb-oscillator frequency and the "nose" of the cw filter is readily visualized.

Mode-Switch Wiring Changes

Fig. 2A shows the wiring of the FT-101 MODE switch (S2) as it appears in its original configuration. The changes required alter the switch wiring to that shown in Fig. 2B. Note also that the wiring to S5B (HEATER) is removed and a wire connected between MJ(4) pin 9 and MJ(5) pin 4. After carrying out these changes, the following operational features apply: The AM position of the MODE switch is now used for RTTY; no a-m operation is possible other than exalted carrier reception when using the USB and LSB positions. The sidetone is generated in the TUNE position, and in the CW position the sidetone is generated even with the HEATER switch in the OFF position. The latter makes it possible to use the sidetone oscillator for code practice without fear of transmitting a signal.

Summary

The improvement in RTTY reception is quite impressive; strong signals a few hundred hertz from the desired signal are easily rejected by the cw filter. During transmission, the transmitted afsk signal will pass through the cw filter. This will aid in the suppression of both the unwanted (upper) sideband and audio harmonics. No doubt similar modifications can be applied to other transceivers that use equivalent techniques. QST

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Notes

[1] [Editor's Note: This assumes the equipment is properly designed, constructed and operated. Unwanted sidebands, audio distortion and carrier must not be present to a degree which will cause interference in receiving equipment of good engineering design.]

[2] [Editor's Note: For amateur RTTY operation, mark is transmitted high and space is low.]

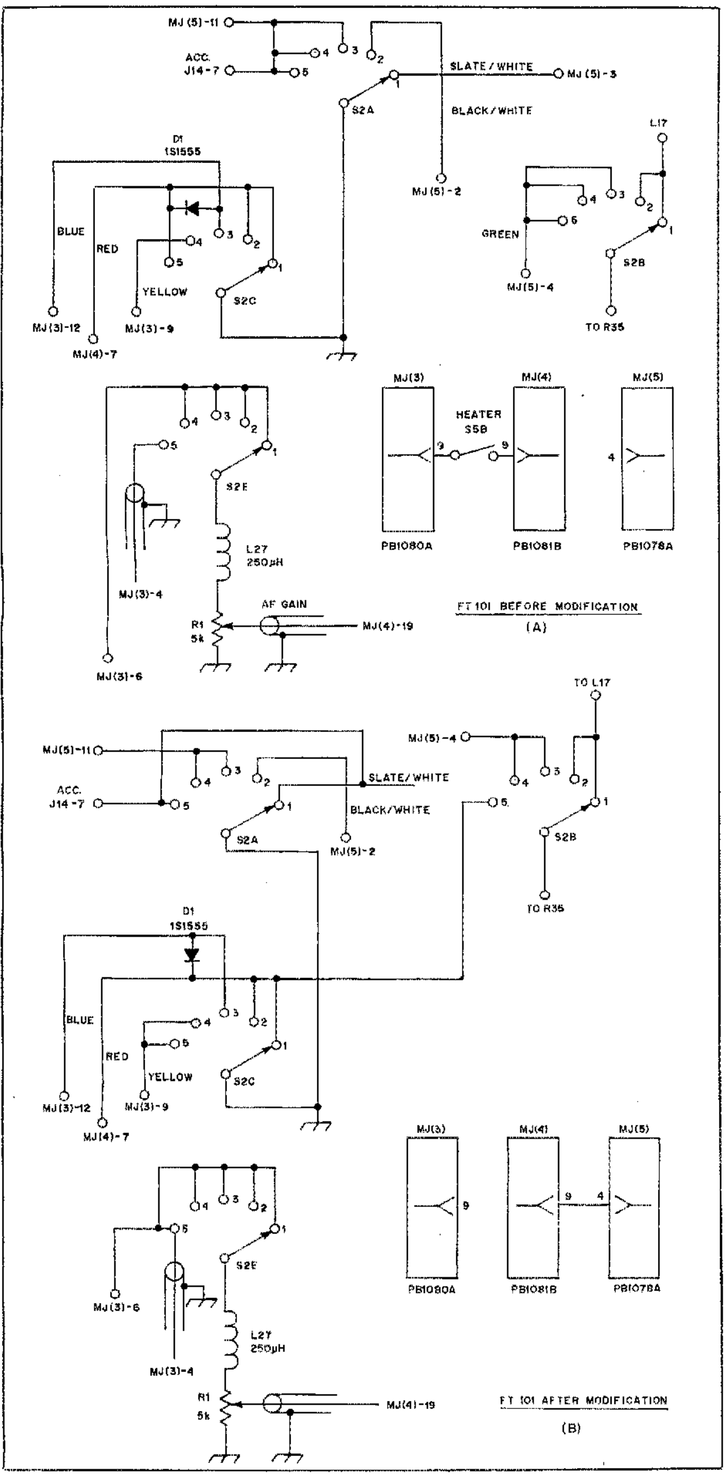

Fig. 2 — At A, the partial diagram of the FT-101 before modification. The wiring color codes may be different and L27 may not be present in some models. MODE and HEATER switch wiring modifications are shown at B. Resistances shown are in ohms; k = 1000.

Strays

EUROPEAN 10-METER FM REPEATER

□ A European 10-meter fm repeater, DB0QK, has started operation in Mainz, Germany, 10 miles southwest of Frankfurt. The call sign is transmitted automatically every 45 seconds in the output frequency, 29.670 MHz. Operating hours are from 6 A.M. until 8 P.M. daily. The repeater is activated by a 1750-Hz tone burst on an input frequency of 29.570 kHz. Interested amateurs are invited to try the fm repeater during 10-meter band openings. — *Amateur Radio DB0QK, Postbox 4040, D-6500 Mainz, Federal German Republic*

TA PROFILES

□ With our appreciation for his services, we introduce ARRL Technical Advisor (TA) Jefferson H. Walker Jr., W4AAD/W3JW. His field of expertise is equipment performance measurements and EMC/RFI.

First licensed in 1953, Jeff now holds an Extra Class license. His primary interests in Amateur Radio include measurement and instrumentation applications, with particular emphasis on rf (vhf — microwaves), MARS, RTTY and computer applications. He is a life member of ARRL, a member of Army MARS, AMSAT and Baltimore Apple Corporation, and past president of the Peninsula Amateur Radio Club.

Jeff received his BSEE degree from North Carolina State University. He now resides in Pasadena, Maryland and is the Project Manager/Research Engineer for the Illinois Institute of Technology Research. Besides Amateur Radio, Jeff's other hobbies are skiing, boating, scuba diving and personal computers. — *Marian Anderson, WB1FSB*

TA Jeff Walker takes a break from his busy work schedule to smile for a photograph.

Results, Great Ionospheric-Hole Experiment

What happens when a large rocket punches a hole in the ionosphere? Scores of U.S. and Canadian amateurs pooled their listening talents to find out.

KP4 Beacon Transmitter Network

By Dick Simpson,* W6JTH (ex-K1KRP); Ray Vélez,** KP4EKA and Paul Bernhardt***

Both NASA and the Department of Energy are studying the feasibility and the environmental impact of proposed Satellite Power Stations (SPS), giant arrays of solar panels placed in geostationary earth orbit. Among the host of environmental questions to be considered in such a vast project are the potential effects of the exhaust of the new generation of large rockets which would be required to transport the materials into space to construct the SPS.

Any propagation changes because of large rocket exhausts would be of interest to all users of the radio spectrum, including shortwave broadcasters, the military, other government users and, of course, radio amateurs. To determine effects on propagation, a group of amateurs set up a plan to observe and report on this type of ionospheric depletion following a rocket launch on September 20, 1979.[1] Since the rocket creating this hole was to be launched from the Kennedy Space Flight Center in Florida, propagation paths between the eastern half of the United States and the Caribbean were expected to suffer the most severe interruption. To facilitate the amateur observations, we organized a network of beacon transmitters in Puerto Rico on the 80- through 6-meter bands.

We began soliciting KP4 volunteers in mid-summer 1979. Promises of glory were tempered with warnings that operation would probably be from midnight to 6 A.M. on two or more weekday mornings in late August or September. Nevertheless, after six weeks of recruiting, we had secured the tentative assistance of a dozen island hams.

Peter Mason, N6BBP, at the Jet Propulsion Laboratory (JPL) in Pasadena and the JPL Explorer Post 509 were to construct tape-cassette-actuated keyers and tapes so that each beacon could be operated in as simple and uniform a manner as possible. The ability to start a tape containing 5-wpm Morse text describing the experiment and letting it run for 30 minutes, with blank spots at five-minute intervals for identification, would free the operator for chores such as logging, monitoring transmitted power and other tasks.

Details of the beacon network operation had been left unspecified pending W6JTH's arrival in Puerto Rico a few days before the launch; the assumption was that he could devote full time to organization during these final few days. This was not to be, however, as the transportation he had been promised in advance did not materialize. With travel restricted and with the knowledge that many residents of Puerto Rico do not subscribe to telephone service, it became obvious that the stations we could use would be restricted to those owned by hams in the north-central part of the island — the only portion of Puerto Ric we could physically visit in borrowe automobiles in reasonable amounts o time. There simply was no way to com municate with the other KP4 volunteer on short and unpredictable notice.

We obtained the bare minimum numbe of stations required for all-band coverag and stumbled through a prelaunch test The experiment itself was almost anti climactic. All stations were on the air an operated as scheduled.

Organizational Tips

We have a few comments which ma help others set up similar ventures in th future. First, reliable communication among the beacon stations is highl desirable. Only a few of our stations wer equipped for 2 meters, and they were to widely separated for effective groundwav communications. A network for *receivin* stations was coordinated by W1JR o 75-meter phone. For us to have interacte via that net would have been difficul since medium-power stations in th Caribbean would find the U.S. East Coas a fairly long haul. Further, most of ou stations were not equipped to operate o more than one hf band at a time.

Our second suggestion is that an ag gressive planning effort be made. One o our early concerns was to avoid makin wrong decisions early or to change direc tion too often. Instead, when faced wit transportation and communication limita tions late in the operation, we found i very difficult to pass any instructions o decisions on to our network.

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[1] Bernhardt, Klobuchar, Villard, Simpson, Troster, Mendillo and Reisert, "The Great Ionospheric-Hole Experiment," *QST*, September 1979.

A Power-Stepping Beacon

By Dick Simpson,* W6JTH (ex-K1KRP); Cameron Pierce,** K6RU and Paul Bernhardt***

The original goal in the Great Ionospheric Hole (GIH) Experiment, as far as Amateur Radio participation was concerned, was to detect fluctuations in received power and relate those to expansion of the exhaust cloud produced during the Atlas-Centaur launch of the High Energy Astrophysical Observatory (HEAO-C).[1] One of the problems to be faced, however, was that no two amateur installations would have the same receiving characteristics; in fact, without a thorough and elaborate calibration procedure, it would be difficult even to estimate the significance of the fluctuations reported at a single station.

One solution was to transmit carefully prepared calibration signals from a beacon unit. Implicit in reception reports then would be the receiver's own characteristics, which presumably could be factored out during processing of the reports. With the cooperation and support of the Northern California DX Foundation (NCDXF), we put together a beacon unit that was used in Puerto Rico during the GIH experiment. Its design may be of interest to hams having need of relatively simple power-stepping capability for short-term tests.

Fig. 1 shows the important modules in the beacon. We used a Kenwood TS-180, but any transceiver capable of generating 100 watts of power and having good frequency stability would have sufficed. A cassette recorder fed a bridge rectifier that, in turn, drove a relay which keyed the transmitter. The wattmeter was initially used to check output power into the antenna tuner and later to monitor power delivered to the antenna. A transmitter drive control was used to lower the output power from 100 watts to 10 watts. After that, 10 dB steps of attenuation were inserted manually to reduce the power successively to 1 watt, 0.1 watt and, finally, 0.01 watt. Our prerecorded tape allowed for 10 seconds of key-down at each power level; this was actually an operator choice and could have been changed simply by recording a new tape using the transmitter's sidetone oscillator. We kept several tapes on hand to cover various situations.

The beacon was semi-automatic. An operator was needed to start each transmit sequence and then intercede manually each time the power level was changed. Full automation could have been achieved by substituting relays, adding remotely controlled two-level drive and including control circuitry that would operate from a master clock. In our case this was not necessary and saved us the trouble of making modifications to a commercially valuable piece of equipment.

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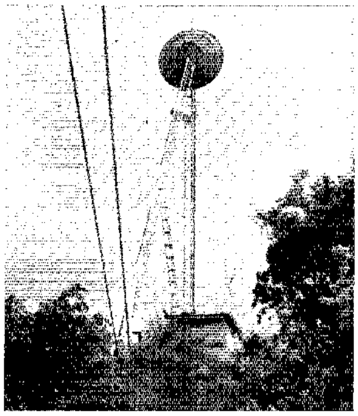
[1]References appear on page 28.

Choosing a Site

Finding a good location for a beacon is often the most difficult problem. One need not go to the Caribbean, but, if the best information is to be obtained from the transmissions, some thought should go toward the propagation path expected.

The beacon was prepared in California but was to be operated in Puerto Rico. The modules shown in Fig. 1 were assembled, along with spare parts and miscellaneous accessories, and packed into two heavy-duty suitcases.

Initially we had considered sharing the home of one of the other beacon operators in Puerto Rico. After inspection, however, it was clear that the limited space would make simultaneous operation of two independent stations difficult. Eventually we located a hilltop site overlooking the city of Arecibo and maintained by the Arecibo Observatory at one end of a microwave data link. The hilltop site offered a small shelter, commercial power, a spectacular view to the north and east, and very little else (see photo).



A small shelter at the north end of a microwave link provided space for W6YX/KP4. The 20-meter dipole was draped over the bushes and small trees (which behave rather like poison ivy or oak, as we later discovered) to the right in this photograph.

Reaching this site required a 15-minute uphill climb through hurricane-fed jungle vegetation and over limestone cliffs. We were able to winch the equipment to the top by using a fixed steel cable and trolley.

We erected a half-wave, 20-meter dipole outside the shack and aimed roughly toward the northwest to maximize the signal at most receivers. The match between the transmitter and antenna tuner was very good; between the tuner and the antenna it was slightly less satisfactory and varied some from day to day for no apparent reason. As we were

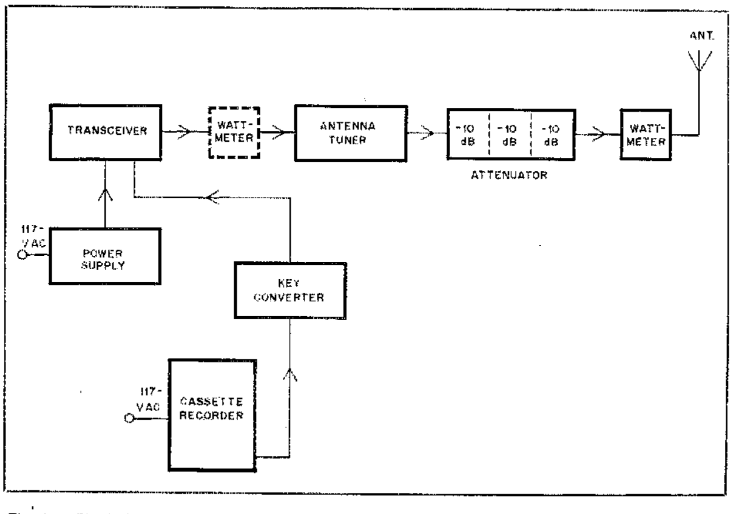


Fig. 1 — Block diagram of the W6YX/KP4 power-stepping beacon. A prerecorded message was stored on tape. When activated, the cassette recorder fed a bridge rectifier and relay (the "key converter") which keyed the transmitter. The first 10 dB of attenuation was obtained by reducing transmitter drive; thereafter 10 dB steps of attenuation were switched in via resistor networks. The wattmeter was used, first to optimize the output circuit tuning, and later to monitor forward/reflected power to the dipole antenna.

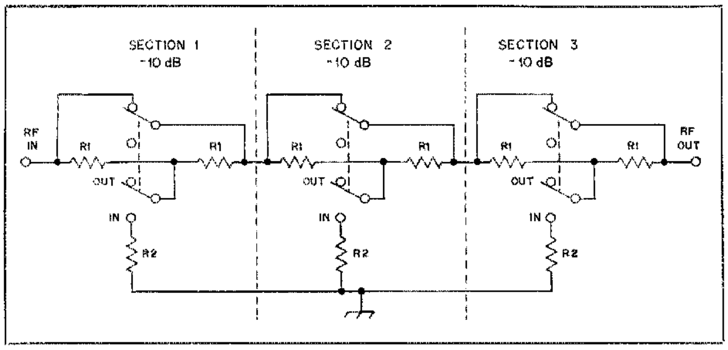


Fig. 2 — Detail of the attenuator network. R1 is 27 ohms (ten 270-ohm 5% resistors in parallel); R2 is 39 ohms (ten 390-ohm 5% resistors in parallel). One-watt resistors are used for the input arm and 2-watt resistors for the ground leg of stage 1; elsewhere 1/2-watt resistors suffice. The switches are dpdt ceramic rotaries.

more concerned with relative power during the stepping process, we put less effort into optimizing the antenna system than we might have otherwise.

A Few Small Problems

The actual experiment proceeded essentially without incident. Shortly after the rocket launch, at 0528 UTC on September 20, 1979, we suffered our only transmitter failure — a 10-minute break for which we have yet to find a cause. (Our two best candidates are that the transmitter overheat-protection circuitry was activated, or that a transient in the line voltage somehow upset the unit.) After checks for smoke, downed antennas and loose connections, we cycled the power and continued operation until local dawn without further interruption.

Because of unexpected problems in organizing the beacon transmitter network, we had failed to provide receiving operators with a good set of baseline transmissions prior to the rocket launch. To compensate partially for this, we decided to operate the power-stepping beacon the night after the experiment. Most stations reported hearing the 0.1 watt level both nights. Later we learned that several hams in the Stanford area had copied at 0.01 watt (a kilometer/watt figure of about 600,000) using beams. K6RU copied at 0.1 watt with a vertical antenna.

During the next few days we made general QSOs on 20 and, later, 15 meters. Results were interesting. We contacted what seemed to be an unusual number of QRP stations even though we were neither advertising QRP nor generally transmitting anything but 100 watts. The W6YX/KP4 call sign was very attractive — this may be truly appreciated only by a W6 operator who had not previously used an "exotic" call sign.

The NCDXF beacon now has a semipermanent beacon completed and operating on 14.1 MHz.[2] It is a more elaborate project than most hams would consider tackling. For those interested in a short-term beacon for some specific application, a design such as the one presented here could prove more feasible. The fact that an operator is required ensures flexibility should the needs of the beacon change during the test. Operator presence also guarantees that the transmissions are fully and directly controlled, as required by FCC regulations for most amateur stations.

References

[1]Bernhardt, Klobuchar, Villard, Simpson, Troster, Mendillo and Reisert, "The Great Ionospheric Hole Experiment," *QST*, September 1979.
[2]Troster, Villard, Ouimet and Pierce, "The WB6ZNL Beacon," *QST*, January 1980.

High Frequency Propagation Results

By J. A. Klobuchar,* W1BZT; Paul Bernhardt** and J. H. Reisert,*** W1JR

The amateur community has proven that the search for large-scale hf propagation changes caused by rocket exhausts in the ionosphere can be undertaken successfully by volunteer amateur observers. While satellite launches have long been routine, the particular launch we chose to observe and report on using amateur observers was special because it was one of a few where the rocket continued to burn at ionospheric heights in order to attain the desired satellite orbit. Amateurs responded enthusiastically, making this experiment a success.

Theoretical studies of hf propagation in the vicinity of an ionospheric hole show that focusing, defocusing, multipath fading and escape of radio waves could occur through the hole.[1] We wanted an experimental setup to look for all of these effects. We solicited amateur participation through announcements in *QST*, *Ham Radio* and *Ham Radio Report*, and by an article in *QST*[2] giving many of the preliminary details of the experimental plan. We asked that interested volunteer participants send for additional information. More than 220 people requested and were sent detailed information, including specialized log sheets. Each station was assigned a specific beacon frequency to monitor during the experiment. Our intent was to obtain an even geographic distribution of monitoring stations with the majority of them listening to the 14.1-MHz beacon, which was closest to the anticipated maximum useable frequency (muf) for the Puerto Rico-to-U.S. path. We expected that frequencies nearest the muf would be most affected by the ionospheric changes produced by the Atlas-Centaur launch.

The log sheets we distributed asked that observers note the average received signal level and fading rate over time intervals of one to two minutes for approximately one half hour after the launch, and over two- to five-minute intervals before and well after the launch period. We also asked for a list of receiving station equipment, including antennas used, so that we could judge, at least in a relative way, the reports received from stations located near each other.

Results-Data Received

We received quantitative reports of signal strength from 156 volunteer observers. The average quality of the reception reports was very high, with many stations recording averaged S-meter readings every few minutes. Some gave maximum and minimum readings over a one- or two-minute time interval; others commented on any changes in fading rate observed.

Reports were received from 35 states including Hawaii, and 3 Canadian provinces, including British Columbia. Fig.

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[1]References appear on page 31.

gives the location of the stations in the continental U.S. and Canada who sent in reception reports on KP4 signals. Many stations used more than one receiver so that 220 separate beacon reception reports were received, with 110 received for the 14.1-MHz beacon, the one we had hoped would show the greatest effect.

In any kind of volunteer experiment care must be taken to see that data quality is good. Besides the somewhat fortuitous power failure of W6YX/KP4, which enabled us to determine data quality of the 14.1-MHz observers, we judged the logs by the care used in recording signal strength, whether average or peak signal was indicated, the time interval and spacing over which the S-meter readings were taken, comments on fading rate, any QRM or QRN noticed and relative signal strength versus station equipment used. We used a data quality index ranging from 1 to 5, with 5 rated as outstanding and 1 rated as not useful. The 156 observers' data (rating followed by number of reports) were judged as follows: outstanding — 17; excellent — 77; useful — 22; doubtful — 19; and not useful — 21.

Some of the logs judged to be doubtful or not useful were the result of observers trying to monitor several frequencies with one receiver, resulting in not enough data being recorded on any one frequency to give a good quantitative picture of the signal-strength changes on any one beacon frequency.

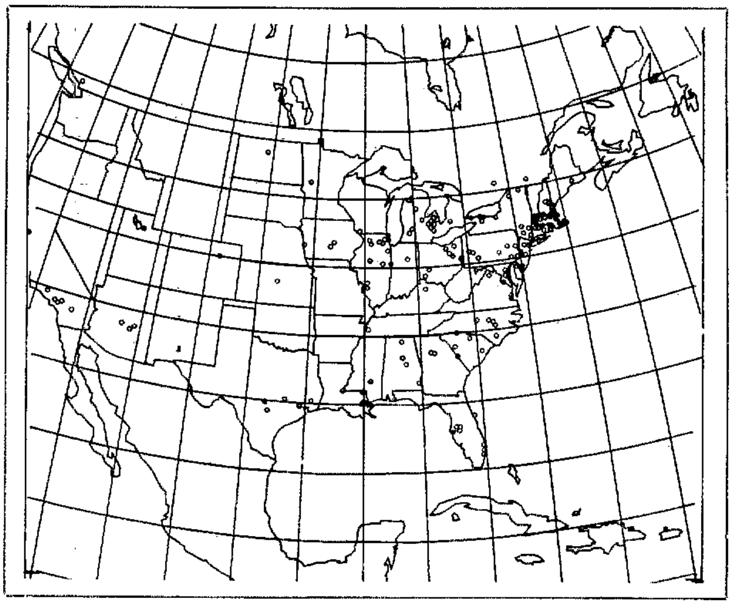


Fig. 1 — Map of observers in the continental U.S. and Canada who sent in reports of hf beacon reception.

QRP Results — 14.1-MHz Power-Stepped Beacon

The 14.1-MHz beacon generated the most interest because five different power levels were transmitted, from an output of 100 watts down to the lowest of only 10 milliwatts, in 10 dB steps. Of the 110 operators who sent in logs monitoring the 14.1-MHz beacon, 102 heard at least the highest three power levels; 74 stations heard signals down to the 100 mW level and 25 copied signals down to the 10 mW output level at least 50% of the time, even with many reports of QRM on the frequency. Who said QRP wasn't fun?

Many stations noticed that the 10 dB power steps, while noticeable on the receiver S-meters, were accompanied by normal ionospheric fading of even greater amounts at times, so that it was important to read average signal-strength values. W6YX/KP4 sent long dahs of 10 seconds' duration at each power level for observers to try to obtain average readings at each power-output level. The fading observed is the typical QSB encountered on hf propagation paths because of the received combination of energy from several rays at one time, adding randomly in amplitude, phase and polarization. The power-stepped beacon on 14.1 MHz afforded an opportunity for many stations to observe first-hand the relative fading depth and influence of different transmitted power levels on a one-hop, F2-region, hf-propagation path.

Propagation Results By Band

3.6 MHz — Strong signals were heard by at least 31 stations from KP4AAQ. No station reported any fading or signal dropouts which could reasonably be attributed to the hole in the ionosphere produced by the rocket exhaust.

7.1 MHz — With 35 stations reporting with data on this frequency there were a few reports of short fading intervals at or near the rocket launch time. We have taken the log sent by KA3DVR, Carlisle, Pennsylvania, located less than 150 miles north of the optimum ground locus for one-hop signals transmitted from Puerto Rico, and plotted the relative received signal strength versus time to give an illustration of propagation on 7.1 MHz from Puerto Rico to Pennsylvania. Fig. 2 shows the maximum and minimum signal strength readings of KP4X beacon transmissions taken by KA3DVR from approximately 0510 to 0628 UTC on September 20, 1979. Note the normal fading of 15 to 30 dB observed during much of the receiving period, buildup of signal from 0510 to 0525, followed by fairly steady average readings until 0542 and with somewhat lower received average signal strength after 0544. We know from independent measurements of the F region that the hole in ionization was produced fairly soon, at least within a few minutes of the time that the rocket reached the F region maximum at 0535 UTC, so the small drop in signal seen by

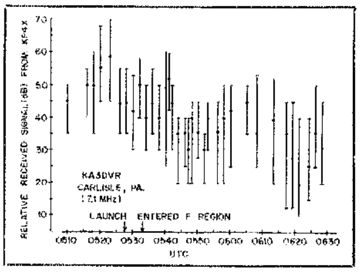


Fig. 2 — Relative signal received from KP4X by KA3DVR on 7.1 MHz in Carlisle, Pennsylvania.

KA3DVR at 0544 was probably not because of any rocket-launch exhaust effects. We concluded from this excellent data taken by KA3DVR, and from similar logs received from others for 7.1 MHz, that there were no significant effects seen on 7.1 MHz.

14.1 MHz — We have already discussed the QRP aspects of propagation on 14.1 MHz. The power-stepped beacon, while very interesting for a QRP demonstration, did not provide the expected advantage to signal-strength reception, primarily because of the approximate 50% duty cycle of the transmissions. The loss of power from 0537:21 to 0541:51 also led to some confusion. A chart recording made by WA8TRG, Sugar Creek, Ohio (Fig. 3) is a good synopsis of reception on this band. Note that the different power levels, the off-the-air times and the interference levels can be seen clearly on

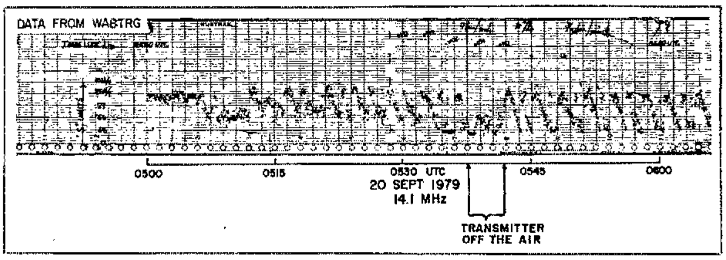


Fig. 3 — Chart recordings of signals from W6YX/KP4 on 14.1 MHz received by WA8TRG, Sugar Creek, Ohio.

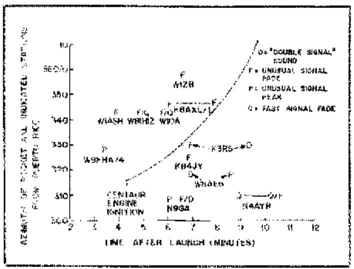


Fig. 4 — Plot of the azimuth of the rocket trajectory and various stations, as viewed from Puerto Rico, versus time after launch.

the chart recordings. Again no major band dropout was seen by anyone on 14.1 MHz, and on the recordings of WA8TRG, typical of other log information received, the received signal levels were relatively constant well past the launch time.

21.1 MHz — Reception of signals from KP4AS was a bonus. Our calculations, made well in advance of the rocket launch, had shown that the expected muf would be below 21 MHz, so we concentrated on assigning listeners to the 14.1-MHz power-stepped beacon. When we discovered, two hours before launch, that many stations were able to hear the 21.1-MHz beacon, we asked several operators, via our net held on 3.82 MHz, to listen on 21.1 MHz, anticipating that any propagation disturbance would be most severe hear the muf.

In general, as the frequency of an hf ray approaches the muf, it is refracted higher in the F region. Since we knew that most of the rocket burn would be high in the F region, we were pleased that the muf on the launch night was above 21.1 MHz. We received 28 reports of signals heard from the 21.1-MHz beacon. None showed a complete dropout of signal which could be attributed to the rocket launch. Several of the reports, however, mentioned fast fading, hollow-sounding signals or other short-term effects. We also had reports of rapid fading from some stations observing on 14.1 MHz. In an attempt to determine which of the received reports of signal fading corresponded to the rocket launch we plotted the azimuth of the rocket-launch trajectory as seen from the beacon location versus time. On the same graph we also plotted the fixed azimuth of the stations reporting the fading on 21.1 MHz versus the time of the reported fades. We restricted this short fade analysis to the 21.1-MHz beacon reports because of the intermittent nature of the 14.1-MHz transmissions and the fact that 21.1 MHz was much nearer the muf. By making a plot in this manner, we could tell whether the fade resulted from a disturbance in the ionosphere caused by the passage of the rocket, since it would occur after the rocket had passed the azimuth of the station seeing the fade. Fig. 4 shows the results, from stations reporting fades near rocket-launch time, on signal reception of the 21.1-MHz beacon. Note that, for the observed fades to have been associated with the rocket passage, we expected that their occurrence should have been near the time the rocket trajectory passed the station azimuth. While there are indeed some reports which seem to have been caused by the rocket passage at the same azimuth from the transmitting station, several of the reported fades cannot be explained in this manner.

K1KSY monitored the transmissions from Radio Nederland, located on the island of Bonaire, and heard several fades on that signal, one of which occurred soon after the rocket passed the same azimuth from Bonaire along the great-circle path to this station. He also observed a similar fade approximately four minutes before the rocket passed the same aximuth, indicating that the rocket launch was not responsible for the first fade. We conclude that the signal-strength fades seen by K1KSY, and by the stations illustrated in Fig. 4, some of which probably were the result of the rocket's passage along the same azimuth from the transmitter to the receiving station, are indistinguishable from those which occur frequently because of natural changes in the ionosphere.

One Canadian station noted a large drop in signal which lasted for many minutes, but it occurred before the rocket entered the ionosphere. The station was located near the outer edge of a one-hop F2 path and the reported dropout was likely because of a naturally occurring gradient modifying the outer edge of the propagation zone.

28.10 and 50.1 MHz — We had hoped that some stations might observe scattered signals on 28.1 (KP4EOT) or 50.1 (KP4Q) MHz from any irregularities which might have been produced near the edges of the hole. We asked observers in the southeastern U.S., and some others who specifically indicated that they wanted to listen on one of these bands, to monitor for any scattered signals. No positive reception reports were received on the 28.1-MHz beacon, but seven negative reports were received. On 50.1 MHz nine negative reception reports were received.

Some of the negative reception reports did not include reception near the launch time, however, so we may have missed an important point: to ask stations to listen carefully for a few minutes immediately after the rocket entered the ionosphere.

144 MHz — K4GFG and KP4EOR reported attempts to make contact on 144 MHz between Florida and Puerto Rico, with no success. If there were irregularities produced in the ionosphere by the rocket exhaust, they were not in evidence on the paths being monitored.

Independent Ionospheric Measurements and Conclusions

We know from observations of total electron content made along several paths from Florida, Georgia and Bermuda by personnel from Stanford University, Boston University, the Naval Research Laboratory, SRI International and the U.S. Army Electronics R and D Command that the total change in F-region electron content, of which the greatest percentage is above the F-region maximum, was large and long lived. The lower values of total electron content persisted until sunrise. The loss in total electron content was approximately 75% of the background ionization present at the time along the rocket trajectory.

From airborne optical-all-sky camera measurements made by an Air Force Geophysics Laboratory aircraft flying under the launch trajectory, and from low-orbit satellite differential Doppler measurements taken by personnel from the Applied Research Laboratory of the University of Texas at Austin, we know that the affected region extended approximately 600 kilometers north and south of the rocket trajectory. None of the other measurements observed any irregular ionization changes which might have allowed scattered signals to propagate. The question is, then, if a region of the ionosphere approximately 1200 kilometers in horizontal extent was affected, and if the change in the middle of that region was 75% of the total number of electrons in a vertical column, why weren't any significant effects seen in hf propagation for paths which went through that region?

We have several likely reasons that no major dropouts were seen. First, the process of hf propagation does not depend upon a point reflection from a small area in the ionosphere, but is the combination of rays bent over a fairly large region, including off-great-circle paths. If the gradients in electron density do not exist in the optimum midpoint location for ray bending, but they do exist in another location not too far removed, then hf propagation between the two points can still exist.

Second, the major changes in the ionosphere probably occurred mainly above the peak of the F region, where approximately two-thirds of the electrons normally exist. Fig. 5 shows the rocket trajectory versus downrange distance from the launch location. On the left-hand portion of the figure is plotted an assumed profile of electron density versus height. From the bottom of the ionosphere to the height of the peak the rocket covered less than 350 kilometers in horizontal distance, while from the peak to engine shutoff it covered over 1400 kilometers in downrange distance. Thus, most of the burn was above the region where hf propagation would have been affected. The majority of the hf-ray energy is reflected below one-scale height, or approximately 50 kilometers below the peak of the F region, under normal conditions. Therefore, most of the hf rays from Puerto Rico to the U.S. probably did not exceed 300 kilometers in vertical height, and the effects of rocket exhaust were well above this height for most of the rocket burn.

Can we use these results to tell NASA and DOE about any potential hf effects of proposed large rockets for lifting the components for solar-power satellites into orbit? The answer is a qualified "yes." The experiment demonstrated that the exhaust from the Atlas-Centaur burn did not have

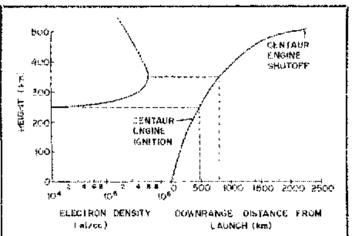


Fig. 5 — Rocket height versus downrange distance from the Kennedy Space Center. Also, on the left-hand side, is a plot of an assumed ionospheric height profile. The rocket went quickly through the height region of potential hf effects.

significant effects on hf propagation, probably because most of the burn was at heights above the peak of the F region. From this experiment we cannot say that proposed solar-power-satellite rockets will have an unfavorable effect on hf propagation. We can say, however, that if rocket burns in the ionosphere were limited to the size of the Atlas-Centaur burn, and were confined mainly to heights above the F-region maximum, the effects on hf communications would be negligible.

Suggestions for Further HF Propagation Tests

Similar experiments should be attempted during the launch of larger rockets that burn in the lower F-region. The effects on hf propagation during the day, as well as at night, would be of interest. The daytime effects would be different because of the absorbing D region at 90 km altitude and because the sun would reionize the affected region.

As suggested by K4CAV, the transmitter signals should use fsk rather than keyed-carrier transmissions. The standard cw keying speed of 13 wpm should be used by the beacon so that all observers could copy.

With fsk the carrier would be on the air 100% of the time and signal-strength readings, especially in the presence of fading, could be made easier. It would also be much easier to make chart recordings with 100% duty-cycle signals.

Better timing accuracy is required. We found that many of those who reported the signal dropout on 14.1 MHz logged times that were over two minutes in error. With the ready availability of WWV standard-time transmissions and inexpensive digital watches there is really no excuse for timing errors this large. An alternative way of ensuring that timing accuracy is standardized would be to have the beacons transmit time as part of their fsk-cw messages; then receiving stations would all presumably report the same time.

If audio-cassette tapes are to be recorded at the receiver, the agc should be turned off so that the audio output level can vary in response to input signals, rather than be held at the relatively constant levels agc is supposed to maintain.

Finally, in any future experiments using volunteers, all participants must be urged to stay on one single frequency and carefully log signals, or lack of them, rather than band-hopping to see how other beacon frequencies are doing.

Acknowledgements

Special thanks go to KP4s EKA, Q, EOT, AS, X and AAQ, who volunteered to run the beacon transmitters in Puerto Rico, and W6JTH, who operated W6YX/KP4. The keyers for the transmitters were built by members of Jet Propulsion Laboratory (JPL) Explorer Post 509 using NASA funds made available by Dr. W. Huntress of JPL. G. Stark oversaw the Post member activity. Stark and KB6JN built the units, and WD6GKE and KA6DWN recorded the tapes.

KB4LK, K8KSA, K9EID and K4CAV took chart recordings using the units we furnished them. K1CH, WA1LZA, W2ANA, KB2FS, WB2JXS, AI3C, N3RW, W4OQG, AB7Q, WA8TRG, W9IJ and VE2XL sent in unsolicited chart recordings. Audio cassette tapes were sent by K1MC, K3RS, N4CK, KA8EZM and K9EID.

We are indebted to D. B. Odom, C. Rush and R. Simpson for their assistance and suggestions in the preparation of this report. All participants who sent in quantitative information were sent a certificate of participation in "The Great Ionospheric-Hole Experiment." Many thanks for your assistance!

References

[1]Helms and Thompson, "Ray-Tracing Simulation of Ionospheric Trough Effects Upon Radio Waves," *Radio Science*, Vol. 8, pp. 1125-1132, December 1973.

[2]Bernhardt, Klobuchar, Villard, Simpson, Troster, Mendillo and Reisert, "The Great Ionospheric-Hole Experiment," *QST*, September 1979.

New Books

☐ *The Illustrated Dictionary of Electronics*, by Rufus P. Turner, Published by Tab Books, Blue Ridge Summit, Pennsylvania, First Printing, 1980. Softcover, 8 × 5 inches, 868 pages. Price: $14.95.

This hefty volume takes you from "A" for gain to "Z" for (believe it or not) zymurgy, and should have a place on many a ham's bookshelf; it would be especially ideal for beginners as a handy source of information. In the electronics field you'll invariably come across a term, word or abbreviation with which you're not familiar. Not every time is there a "brain to pick" for an explanation, but with this dictionary, you're probably going to find just the information you need.

A section at the rear contains tables and data that will also come in handy. In these pages you'll find the resistor color code, electronics symbols, a table of wire gauges, Ohm's Law, temperature conversions, a table of electronic abbreviations and math symbols, to name some.

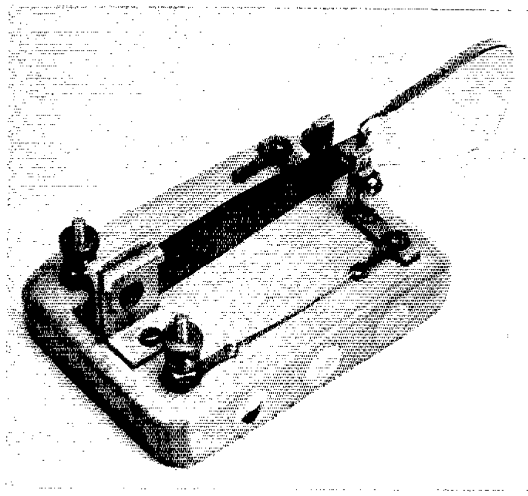
Within the over 24,000 terms contained in the book is information relating to computer and other scientific areas. A number of illustrations are scattered throughout the text as an aid to understanding some of the definitions. By the way, "CMOS" will be found under "COS" and "MOS". — *Paul K. Pagel, N1FB*

• *Basic Amateur Radio*

Zero-Cost Key

Looking for a simple project to get that budding Novice started? This paddle-key can be used as a straight key now and as a paddle for an electronic keyer later.

By Antonio G. O. Gelineau,* W1HHF



It all started when a group of four high school students indicated an interest in Amateur Radio. Accepting my invitation to visit my station, they were intrigued and very enthusiastic, particularly when we were working DX on 10- and 15-meter ssb. They were fascinated watching the cw readout on the Kantronics Field Day unit. Immediately, of course, the question of cost to enter the field of Amateur Radio arose.

On their second visit, I demonstrated a crystal-controlled three-transistor 10- and 15-meter transmitter mounted on a small plastic box. I put it on the air and, to their amazement, proceeded to work stateside and DX stations on cw.

If You Ain't Got It — Make It

I emphasized the pleasure of building your own gear as much as possible and the skills developed while doing so. The first project I started the group on was making their own keys to use with code-practice oscillators. Of several different designs, the most popular was the key shown in the photograph. It could be used as a straight key at first with view of future usage in keying an electronic keyer.

To duplicate this design, all that is needed is right-angle aluminum stock, a mini-hacksaw blade (cut as shown and with the teeth removed by grinding), a piece of 3/8 in. clear plastic (cut from the side of a refrigerator food container box, for the paddle grip), six 2 oz. lead fishing sinkers (for weighting the key base) and a wood block for the base. Miscellaneous materials include hardware and auto-body mending tape. Double-backed adhesive tape may be used for holding the key to the table.

First, cut the hacksaw blade and grind away the teeth (Fig. 1). After shaping the paddle from the plastic block, a 1/2-in. slot is cut in the center of the small end to accept the end of the hacksaw blade (Fig. 2). The blade is then cemented in place with epoxy. After the epoxy has set, cover the paddle grip with the aluminum auto-body mending tape, if desired. Drill three 7/16-in. holes through the wood block and then coarse-sand it to the correct shape (Figs. 3 and 4). Complete by sanding for a smooth finish. After cutting the lead sinkers (Fig. 5), place them into the 7/16-in. holes in the wood base. Prepare a mixture of white glue and plaster of paris. Add plaster of paris to the glue until the mixture has the consistency of putty. Fill the holes with this putty and let dry (about four hours). Meanwhile, cut the right-angle stock to the size as shown in Fig. 6. Final sandings, coarse and fine, prepare the blocking for varnishing (or painting).

The hacksaw blade with plastic paddle grip is then rivited to the two 1- × 3/4- × 1/2-in. right-angle aluminum pieces. The two 1- × 1-in. right-angle pieces are drilled and tapped as shown in Fig. 7. All pieces are then assembled as shown in the photograph.

The key shown is being used for single-circuit keying only. Two-circuit keying

*142 Home Ave., Burlington, VT 05401

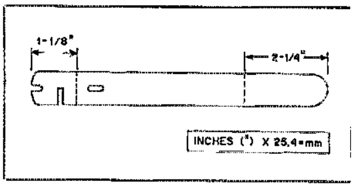


Fig. 1 — Dimensions for cutting the hacksaw blade. Grind teeth from blade.

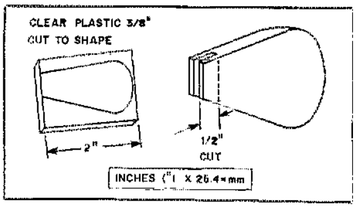


Fig. 2 — Cut paddle grip from 3/8-in. plastic as shown. Dimensions shown are representational; the precise size and shape should suit the taste of the builder.

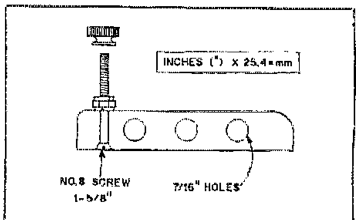


Fig. 3 — Drill three holes in the side of the block of wood as shown above.

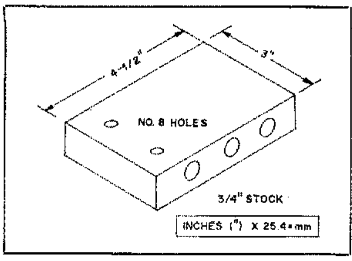


Fig. 4 — Overview of block with holes drilled.

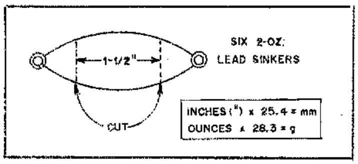


Fig. 5 — Cut the six lead sinkers as depicted above.

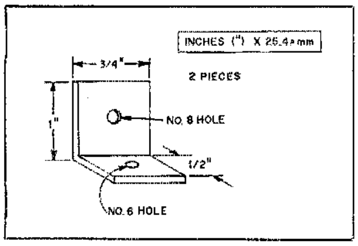


Fig. 6 — Cut and drill two pieces of right-angle stock.

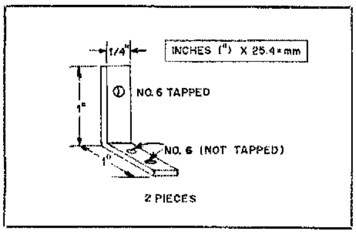


Fig. 7 — Cut and drill two additional pieces of right-angle stock as shown above.

may be obtained with the addition of a third binding post attached to the right-hand contact.

Two strips of double-backed adhesive tape are pressed to the base of the key, then trimmed to shape. After the operating position has been selected, the protective paper backing is removed. The key is placed in position and pressed for holding. The "feel" of the key is very good; it seems to please all those who have tried it. The cost is right, too — zero! QST

Strays

MOUNT ST. HELENS UPDATE

☐ Scientific research on Mount St. Helens continues, with area amateurs assisting scientists studying the mountain. Forest Service safety requirements for work in areas near the mountain require two-way radio communication in the field and a continuously manned base station near a telephone.

David Lievsay, K7UUH, and Roger McCoy, W7DAV, members of the Tektronix Employees Amateur Radio Club (TERAC), act as middlemen in helping researchers find amateurs to accompany scientific parties to the mountain and to man nearby base stations. If the Forest Service wants to evacuate the area, it telephones the base station. The base station operator tells the amateur with the field party to get the party moving out of the area.

The amateurs have been helping for a long time and are now trying to convince the Geological Survey and Forest Service to provide radio equipment to the researchers who have permission to enter the restricted areas near the mountain. As long as there is a need, however, Amateur Radio operators will be there to lend a hand.

Members of TERAC began providing communications assistance in the Mount St. Helens area before the May 18 eruption. (See July 1980 *QST*, page 28.) Amateurs continued their volunteer efforts during the mountain's major eruptions in May and June. (See August 1980 *QST*, page 47.) — *Information courtesy ARRL Northwest Division PIA John H. Brown, W7CKZ, Olympia, Washington*

KH6 QRP DXPEDITION

☐ The Big Island ARC will make its first QRP DXpedition to South Point, on the island of Hawaii, from 1800 UTC, November 29 until 2400 UTC, November 30. South Point is the southern-most area of the 50 states. A special QSL card will be sent to all stations worked during the expedition. Frequencies will be 7115, 21,115 and 28,115 kHz cw and 7225, 21,375 and 28,750 kHz ssb. — *Russell Roberts, KH6JRM, Honokaa, Hawaii*

I would like to get in touch with . . .

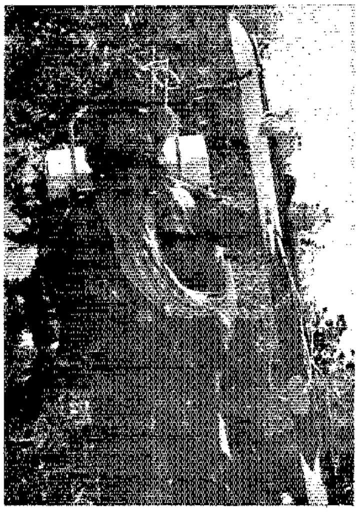
☐ anyone who can help me set up a traffic net for 15 U.S. military personnel stationed with me in Israel. Major Richard Osimo, K1CRR/4X, USMOG — UNTSO (OGL), APO NY 09672.

TA PROFILES

☐ Introducing ARRL Technical Advisor (TA) Richard A. "Dick" Simpson, W6JTH, with our thanks for his services. His professional area of expertise is EME/radio propagation.

Dick received his Novice class license in 1959 and now holds an Advanced class license. QRP and Field Day are his principal interests in Amateur Radio. He also enjoys backpacking, cross-country skiing and writing. Residing in Palo Alto, California, he is a member of the Palo Alto Amateur Radio Association and the Stanford Amateur Radio Club.

Dick received his BS degree from the Massachusetts Institute of Technology, and his MS and PhD from Stanford University. He is the Senior Research Associate in the Radioscience Laboratory of Stanford University. — *Marian Anderson, WB1FSB*



TA W6JTH equipped for QRP mountaineering to summit of Mount Langley for Field Day 1975. (July 1976 *QST*, p. 54).

FIRST ATV COMMUNICATION?

☐ We claim to have carried on the first live two-way amateur television communication on June 5, 1954, with TV cameras and transmitters of our own design and construction. Are there any challengers? — *John C. Davis, W4ATO and Asa F. Tift, W4PGK, Albany Georgia*

SDI — Dangerous Crippler of Radio Amateurs

SDI? Smoke Detector Interference, the latest ham "crippler" from those wonderful people who brought you TVI, etc.

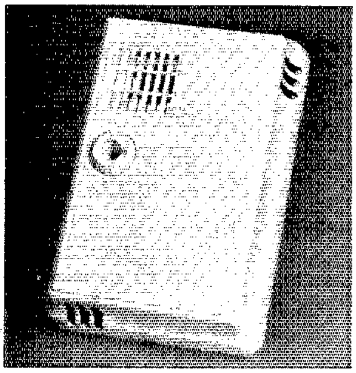
By Pete O'Dell,* AE8Q

For a ham, moving from one's own house to an apartment building is never fun. In our case, insult was added to injury when we found that rf was getting into the ac-powered smoke detector in our apartment. As soon as it was convenient, I added a few feet to the length of the long-wire antenna (the lease clearly prohibits outside antennas); no more interference to *our* smoke detector. Before we had a chance to open a bottle of bubbly, there was a knock at the door. Our neighbor wanted to know if we were having trouble with our smoke detector; hers was going off intermittently and she was thinking of calling the maintenance personnel.

Every once in a while in this type of situation you run across a rare individual like our neighbor — someone who is even-tempered, patient and understanding! I told her that I would stay off the air until I could figure out how to fix the detector. I also mentioned that I would be happy if she did *not* contact the maintenance staff. No problem, she said.

I removed the detector from our apartment and found that it had three wires extending from a sealed case. Two of the wires were connected to the ac mains; the other one (yellow) was left dangling. There was a tag on the unit that indicated it had been manufactured in a distant town in Connecticut.

The next morning I placed a call to the plant. It wasn't that they were uncooperative; they just didn't seem to know what could be done for smoke detectors that "falsed" in the presence of rf; I had the feeling that mine was not the first complaint they had received about this sort of thing. After I had been bounced around from one to another of their employees, someone suggested that I call their engineer who had designed the



External view of the smoke detector. The red LED is mounted inside the rotatable cylinder marked TEST-RESET. Rotating the cylinder to the TEST position moves a slit so that light from the LED shines directly into the photocell. The screened openings in the sides permit air (smoke) to flow through the internal chamber of the smoke detector.

unit. I was given a telephone number — a local call from Newington! My luck must be changing. It was; from bad to worse.

The engineer was quite sympathetic, but not terribly helpful. It seems that there had been some problems with these alarms falsing before. Certain problems had been taken care of, but he had no idea of what to do about rf. I asked if bypassing the ac lines might help. He thought that it might. He told me that the yellow wire was for paralleling two or more units.

He also told me that it was against company policy to provide any technical information about the functioning of the circuit. He suggested that I *return* it to the company where it would be replaced if it were defective. Did the company know what to do about rf getting into their circuits? No. What good would it do to replace one poorly designed unit with another? The last question was never asked out loud; I just thanked him for his time and hung up.

I tried bypassing the ac lines going into the sealed unit. At home that night I made arrangements to switch the altered alarm for the one installed in my neighbor's apartment. After making the switch, we made a short test — if anything, it was worse. I then tried blocking the rf by wrapping the leads from the detector through toroids to make an rf choke. That didn't help either. I thanked my neighbor and told her that I would get back in touch with the engineer who had designed the thing to see if he had some more ideas.

The next day I called the engineer again and got essentially the same run-around. He suggested that I return the unit to the factory to be replaced. I asked if he would supply me with a schematic. Absolutely not! It would void the warranty if anyone other than a factory employee opened the unit. Did anyone at the factory know how to prevent it from falsing in the presence of rf? No. Again, I politely refrained from asking the obvious question.

Cracking the Egg

After I hung up with the engineer, it took me about an hour to circuit-trace the detector and draw the schematic (Fig. 1). There are probably some minor mistakes in it, but there is enough information here for solving the problem at hand. (After all, I was looking to "fix" a design flaw, not design an alarm from scratch.) The two photocells are offset by 90 degrees. The white LED shines directly into one of the photocells. The other is recessed into a tube so that only light coming from straight ahead will reach it. Everything is painted flat black inside. Presumably, when smoke enters the chamber, light is reflected off the smoke, turning on the second photocell, which in turn causes the

*Basic Radio Editor

CMOS op amp to change states and turn on the triac.

As I looked over the diagram, it was impossible to pinpoint the culprit. Obviously it was going to be a trial-and-error procedure. Although our neighbor had been delightful about this whole thing, it might strain the relationship a bit to run in and out of her apartment each time I tried something different. A little reflection suggested that I could duplicate the situation (more or less) in the lab. The setup diagramed in Fig. 2 was the final result. A touch of the finger indicated that rf was present in abundance.

Since I had the most trouble while operating on the 40-meter band, we chose it as the test frequency. Before making any modifications to the smoke detector, we placed it on top of the Transmatch. I keyed the transmitter and slowly brought the power up. With the wattmeter indicating about 15 watts going into the Transmatch, the smoke detector falsed. I then began the modifications. I added 0.01-μF disc-ceramic capacitors to the circuit anywhere that I thought there might be trouble. After each addition, I checked the detector to see if rf still plagued it. For the first four additions, nothing changed. Then I added a 0.01-μF disc (C1) between the inverting input (pin 2) of U1 and ground. The first thing I noticed was that the smoke detector falsed for a couple of seconds when it was first plugged back into the ac line. I turned on the transceiver and brought the power up. The unit no longer falsed! Removing the other capacitors did not cause the problem to return.

I installed the alarm in my neighbor's apartment. I explained that if the power failed for a few minutes that the alarm would false when the power came back on. A couple of months later I woke up in the middle of the night during a severe electrical storm. I was wondering if she would appreciate it if the power failed for a few minutes then came back on. Surely her four-year-old son and six-week-old daughter would not sleep through that. I decided that it was time to do some more work on the alarm. Back to the test set-up again, but with my smoke detector.

Perhaps a smaller capacitor across the inverting input would handle the rf and yet not false during the initial power-up. After discussing the idea with other Hq. staff members, I decided to try a 0.001 μF disc capacitor in place of the 0.01 μF disc. Tests confirmed that this was a workable solution to the problem. The unit functioned normally as a smoke detector, rf did not bother it, and it did not false on the initial application of ac. Results were the same when the value change was made to my neighbor's detector.

At this point I decided to call the engineer back again. I told him I had the cure to the problem, and he was *most* interested in finding out what it was. We chatted for a few minutes. I offered to help him out with any

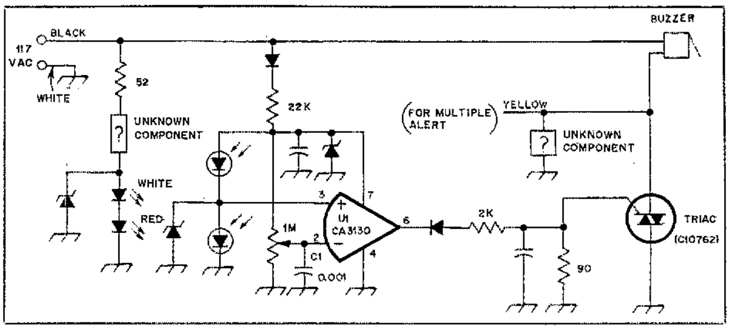


Fig. 1 — Schematic diagram of smoke detector as circuit-traced by the author. Although it is probably not precise, there is enough accuracy and detail here to provide an amateur with sufficient information to RFI-proof the unit. C1 is the ceramic disc capacitor that was empirically determined to be the solution to the falsing problem.

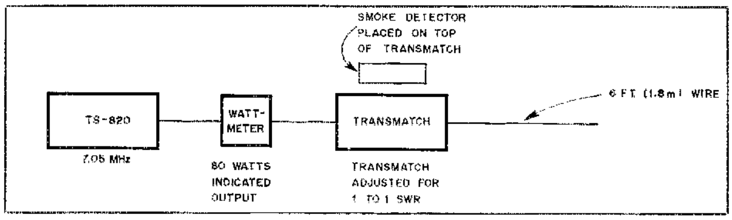
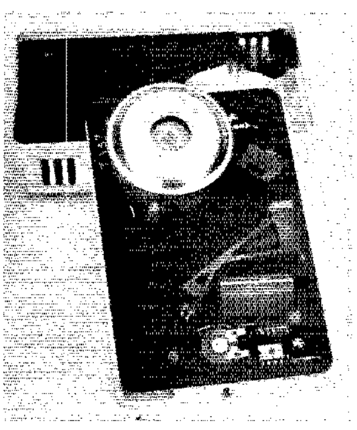


Fig. 2 — This is the experimental setup that the author used for testing various "cures" for the smoke detector interference. In general, similar pieces of equipment and procedures could be used to troubleshoot any device suffering from RFI.

rf problems that his company might have with the design of any additional consumer-type items. He then informed me that his company had people who were quite good with rf-type problems and that they needed no assistance whatsoever. Again, I refrained from asking any of the obvious questions.



Smoke detector with case removed. The red LED is located just below and slightly to the left of the buzzer (upper left corner).Unobstructed, the LED shines directly into the offset photocell. Within the chamber, all surfaces are painted flat black. The added capacitors were mounted on the other side of the circuit board.

Lessons to Be Learned

1) Most hams already have all the equipment necessary for testing and RFI-proofing electronic devices.

2) A detailed and highly accurate schematic diagram is not an absolute necessity. You can probably draw one of your own that will suffice for this kind of work.

3) Some companies seem to be incapable of assisting with RFI problems. Any of several factors may be at fault here ranging from lack of engineering competence to a callous decision of the front office to "stonewall it." If you get nowhere with them, then go ahead on your own — but it wouldn't hurt to let the FCC, Consumer Product Safety Commission and other government agencies know about your difficulty in dealing with the companies.

We live in a world of increasing dependency on electronic devices. We also live in a world that is increasingly making use of the rf spectrum. Until it becomes cheaper for companies to build equipment right to start with, you can expect that sooner or later you are going to have some problems with interference. You may decide to forego civil relations with your neighbors or you may let this ugly disease cripple your operating enjoyment. But there is a better approach, and that is to take the bull by the horns and solve the problem. *Non illegitimi carborundum!* QST

The Tower Alternative

Puzzled about installing a tower for your new tribander antenna? A rooftop tripod could solve the problem and save you a few dollars plus yard space.

By Laurence Wolfert,* WA2FDB

Pick up any Amateur Radio magazine and you will find ads galore for freestanding towers. Also, with alarming regularity, there are articles describing a new crank-up, stack-up or tilt-over model, or else articles with someone's experience and advice on installing one. But what does the amateur do who wants to put up a Yagi but his XYL says, "I don't want that oversized erector set in the middle of my backyard!" Obviously, he puts a tripod tower on the roof of the house.

Articles about tripod towers are rarely written, possibly because amateurs who use them are in a minority or because some of these same people think that tripods are so simple to erect that writing an article about their installation is hardly warranted. You might ask what justification, therefore, I might have for this article. Clearly, my reasoning is that there are amateurs who need information to help them decide on the other tower alternatives. I'm dedicating this to them. Those who choose to install a tripod atop a roof very likely will have the same concern I did for the roof and supporting structure. I just moved into my first house and have no desire to cause the roof to come apart or create leaks (time alone will be kind enough to do that for me!).

The Hardware

Once the decision was made to install the tripod tower, I began a search for the make and model I wanted. One consideration was to keep my TH-3JR at an effective height, but not to where it would be an eyesore. With the peak of my roof up around 26 feet (8 meters), I felt a 10-foot (3-m) tower would be adequate. With a Ham-II rotator 18 inches (460 mm) above the tower and the antenna 15 inches (380 mm) above the rotator, the antenna would be approximately 36 feet (11 m) above ground. The reason for keeping a minimum height above the tower was to maintain maximum support and minimize both torque and wind sway.

*59 Bosko Dr., East Brunswick, NJ 08816

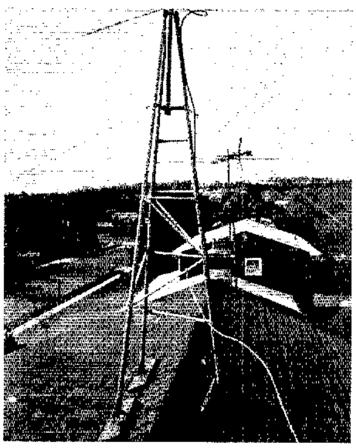


Fig. 1 — This tripod tower supports a rotary beam antenna. Besides saving yard space, a roof-mounted tower can be more economical than a ground-mounted tower. A ground lead fastened to the lower part of the frame is for lightning protection. The rotator control cable and the coaxial line are dressed along two of the legs. *(photo courtesy Jane Wolfert)*

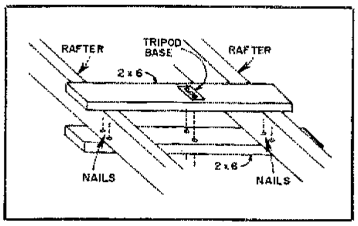


Fig. 2 — This cutaway view illustrates how the tripod tower is secured to the roof rafters. The leg to be secured to the cross piece is placed on the outside of the roof. Another cross-member is fastened to the underside of the rafters. Bolts, inserted through the roof and the two cross pieces, hold the inner crossmember in place because of pressure applied. The author nailed the inner cross piece to the rafter for added strength.

I chose a brand of tripod that had a built-in ladder between two of the tripod legs. This eliminated the need for a separate ladder and the need for an additional person to hold it down on the sloped roof when installing the mast and attached paraphernalia. The model also came 90% assembled which, to the lazier people like me, is always a persuasive selling point!

The Instructions

Assembly is simple. The instructions are clear. Parts are color coded. However, the instructions for mounting on the roof are a totally different matter. They are brief at best. I found they left me far from comfortable concerning this part of the installation.

The instructions suggest two possible means of anchoring the tower: (1) Anchor the legs to the cross beams in the roof with the lag bolts provided, or (2) anchor the legs to a section of 2 × 6 secured between the rafters.

The first recommendation offers a reasonably secure foundation for the tower if you find the exact center of each beam and that these centers correspond to the distance between the legs of the tripod. My first concern was that the width of each beam was only 1-5/8 inch (41 mm). That doesn't give much leeway to make mistakes. Unless the lag bolt is fairly well centered, the bolt will not be securely anchored. Compound this with the concern that the beams may not be exactly 16 inches (406 mm) apart. Mine weren't. Oh, the distances were close, like 15-5/8 inches (397 mm) between one pair and 16-1/2 inches (419 mm) between the adjoining pair. To complicate the matter further, the two legs of the tripod that would share the same side of the roof were not exactly 32 inches (813 mm) apart as they were supposed to be. All this added up to a risky proposition that would

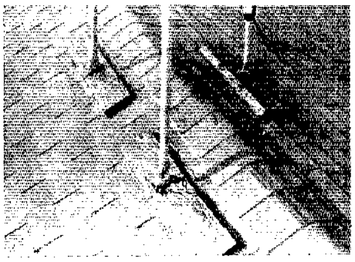


Fig. 3 — Three lengths of 2 × 6 wood mounted on the outside of the roof and reinforced under the roof by three identical lengths provide a durable means for anchoring the tripod. Liberal coatings of tar guard against weathering and leaks.

aerate my roof but not secure my tower effectively.

The second method was far simpler to implement, yet I doubted the reliability. The idea of this alternative is to nail lengths of 2 × 6 between the attic beams and against the roof. Then anchor the legs between the rafters by securing them to the cross members. I concluded that the only advantage this approach offered was the support of the few nails that would hold the cross pieces to the beams. While this method of installation might be adequate for a while, just how secure the anchorage would remain with repeated weathering and swaying from wind seemed questionable.

Solution

After much thought about how to provide a sturdy, immovable anchor for the tower, I elected to nail the 2 × 6s to the underside of the rafters. Bolts could be extended from the leg mounts through the roof and the 2 × 6s. To avoid exerting too much pressure on that area of the roof between the rafters, I decided to place another set of 2 × 6s on top of the roof (a mirror image of the ones within the attic). Installation details and the final results are shown in Figs. 1 through 4.

Once the course of action was mapped out, I anxiously proceeded to collect the required hardware that included nails, roof tar, wood and long bolts. The bolts, which had to be 10 inches (254 mm) long, became a disconcerting obstacle. Supply stores in my area carried bolts only up to 6 inches (152 mm) long. My frustration level surpassed that encountered while trying to get through the pileup for a 3V8 station!

Searching all available bins, however, turned my dismay into a feeling of cheer. I came across a solid threaded metal rod 6 feet (1.8 m) long. No one seemed to know exactly what the purpose of the rod was. All I knew was that a 1/4-inch nut fit it perfectly. "Must be made for putting up a tripod tower," I mused. "Look out all you DX stations, I'm coming." Thereupon, I grabbed the rod, along with an ample supply of nuts and washers, paid the cashier, and was on my way.

Installation

I measured the turning radius of the antenna to ensure freedom from obstructions such as trees, the TV antenna and chimney. Fortunately there was plenty of clearance between these and the proposed location of the tripod.

Once the approximate location on the roof is selected, choosing the pair of rafters for anchoring the tower is next in order. A vent pipe protruding through the roof serves as a good reference point for measurements. I determined the distance from the vent pipe in my attic to the nearest rafters, then transferred these measurements to the roof. I then chalked the location on the shingles. The approximate location of the other rafters is easily determined by marking lines in 16-inch (406-mm) increments from these initial lines. Because there is a space of over 14 inches (356 mm) on the 2- × 6-inch barewood cross pieces in which to place the bolts, being off as much as an inch (25 mm) would not be catastrophic as would be the case if the lag bolts were to be screwed into the rafters.

Drilling Through The Roof and Cross Pieces

Having marked the approximate leg placement positions on the roof, I then proceeded to cut the cross members into 2-foot (0.61-m) sections. This would give me a leeway of 4 inches (102 mm) on each side to span the beams if, in fact, I was off center. A 24-inch (0.61-m) piece to span a 16-inch (406-mm) width should leave 8 inches (203 mm) or 4 inches (102 mm) on either side.

I paired the six pieces and placed them each under a different leg. Using the holes in the metal feet as guides, I drilled through the wooden pairs in unison to guarantee a perfect spacing of the three critical pieces for accepting the bolts. Although the legs were made to accept three bolts each, I used only two per leg. I felt that the spacing was too close and that drilling through the roof in that fashion would weaken the roof more than supply extra strength for support.

Each of the six pieces was marked "top" and "bottom," and each pair was labeled A, B and C, respectively. Half of each set went into the attic for later use. The other half was brought up to the roof along with the tower. A small screw, inserted in the middle hole of each metal foot, held the 2 × 6s in place. Moving the tower onto the rough chalk marks previously made on the roof became the next step, followed by suspending a plumb line from the top of the tower to indicate when the precise position over the peak of the roof had been reached.

The first hole drilled also served to check how near it came to the center of the beam span. Fortunately, it was right on target. The other five holes then were quickly made. The borders of the 2 × 6s were outlined in chalk on the roof so that the tower could be moved aside for application of a coat of tar to the roof for a watertight seal.

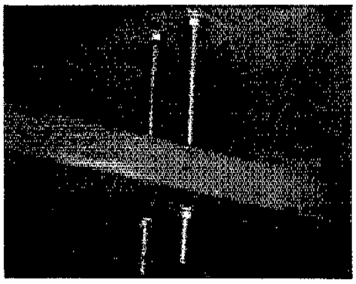


Fig. 4 — The strengthened anchoring for the tripod. Bolts are placed through a 2 × 6 on the underside of the roof and through the 2 × 6 on the top of the roof, as shown in Fig. 3.

With the tower off to one side, we tarred outlines of the three 2 × 6s, being careful to leave a 1/8-inch (3-mm) clear border around the newly drilled holes. That ensured the free passage of the bolts through the roof. We tarred the rest of the outline thickly.

The two needed bolts were made by cutting the threaded rod into two 12-inch (305-mm) lengths. Two nuts, placed near the top of each bolt and turned against one another for maximum pressure, and a washer for each bolt formed the "head."

The Home Stretch

With the six bolts placed in the metal feet and cross pieces, we then lifted the tower above the receiving holes. Each bolt was then inserted through the roof and tightened. The tower seemed immovable, but of course it lacked all the heavy equipment (rotator, mast and antenna) to make that judgment final. The lower 2 × 6s were next nailed onto the beams they spanned.

Back on the roof, we tarred around the legs and wooden supports, including the bolts. The rest of the installation followed rather routinely — mast, rotator, support pole and antenna. We took one further precaution. Much like the OM who wears a belt and suspenders, we secured the tower with four guy wires anchored to the frame of the house.

Epilogue

I wish to give special thanks to my brother, Rich, WB2EYI, who not only gave me valuable advice but also the use of his back during the installation. I am happy to report that there has been no damage from the winds. The attic remains dry, even my XYL hasn't complained. Everything worked out as anticipated until my neighbor came up to me the other day and asked, "Hear anything from Mars yet?" QST

Converting Power-Line Transformers for Transmitter Service

A surplus or junked power-line transformer can be converted easily into a superb plate transformer for a homemade kilowatt linear amplifier. Here's how!

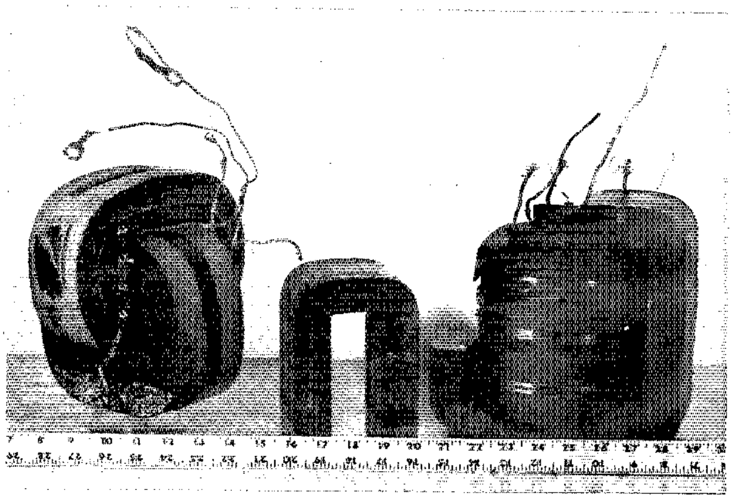
By James Seawright,* AE2Q

The urge to build a high-power linear amplifier led me on a search for suitable components. Clearly, a substantial part of the cost would be the "tab" for a plate transformer. Would I be fortunate enough to find one I could afford?

I remembered two excellent transformer articles in *QST* in 1967 and 1970 written by Lew McCoy, W1ICP.[1] These articles, containing much valuable information, stirred thoughts of winding or rewinding my own transformer. Lew described inexpensive transformers that could be paralleled and used with voltage doublers to reach the kilowatt level. Alternatively, junk transformers with a large enough core could be rewound completely. I made many trips to surplus dealers but failed to turn up either type of transformer.

Lou Cates, a long-time friend and surplus dealer on Canal Street in New York, suggested the use of a power-line distribution transformer. As he described it, a single-phase transformer, intended for step-down from 2400 V to 117/235 V can be removed from its tank, drained of oil,[2] dried out in an oven and connected backwards. He'd heard of amateurs who had tried this idea with complete satisfaction.

Inasmuch as there are not many pole transformers in Manhattan, I waited for my annual trip to visit my parents in rural Mississippi before continuing my quest. I was rewarded by finding a plentiful supply of used distribution transformers which could be converted easily. Many were available for as little as $3 per kVA. Fig. 1 shows a typical transformer of this type.



Windings and cores of a 1.5-kVA transformer (left) and a 3.0-kVA transformer (right). In most cases the windings can be separated easily for rewinding. The outer low-voltage windings have been removed. Counting the layers and the number of turns per layer is not difficult.

Finding the "Raw" Material

Most of the transformers I found provided a stepdown from 7620 to 117/235 volts. These transformers, available in various sizes, are rated from hundreds of kVA down to 1.5 kVA. The latter are ideal for use by amateurs.

As the chief engineer of a large rural electric-utility company explained to me, a transformer which has been in service for 10 or more years is weather-beaten and rusty, requiring a complete overhaul before being put back into service. While the larger size transformers are worth restoring, the smaller ones are sold for scrap, even though in many cases they are in good working order.

The engineering office of the local utility is a good place to begin the search for a used transformer. If the company is unwilling or unable to sell or give you a transformer, they may tell you who buys their scrap units. In my hometown, two

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[1]References appear on page 42.

small companies overhaul such transformers. This enabled me to obtain 1.5-kVA units for $4.50 each and 3.0-kVA transformers for $6 each. These were in working order. Fortunately, they had already been removed from the tanks, drained and dried out.

If a transformer is out of the tank when you are choosing one, carefully examine it for evidence of overheating or other damage. The low-voltage winding must be in good condition, but the state of the high-voltage winding is of less consequence since it will be rewound anyway.

Other materials needed for rewinding the transformer are the wire, insulating paper and insulating varnish. Although I used magnet wire I had on hand, I realized later that I could have rewound a new lower-voltage (but higher current) winding on a 1.5-kVA transformer with the no. 24 B & S gauge wire from a 3.0-kVA transformer. Electrical-grade kraft paper usually insulates transformer windings, along with various thicknesses of fiberboard. I obtained kraft paper through the company which sold me the transformer.[3] Useful thicknesses are 0.005 inch (0.13 mm) and 0.010 inch (0.25 mm). For fiberboard, the thickness should be 1/16 inch (1.6 mm)

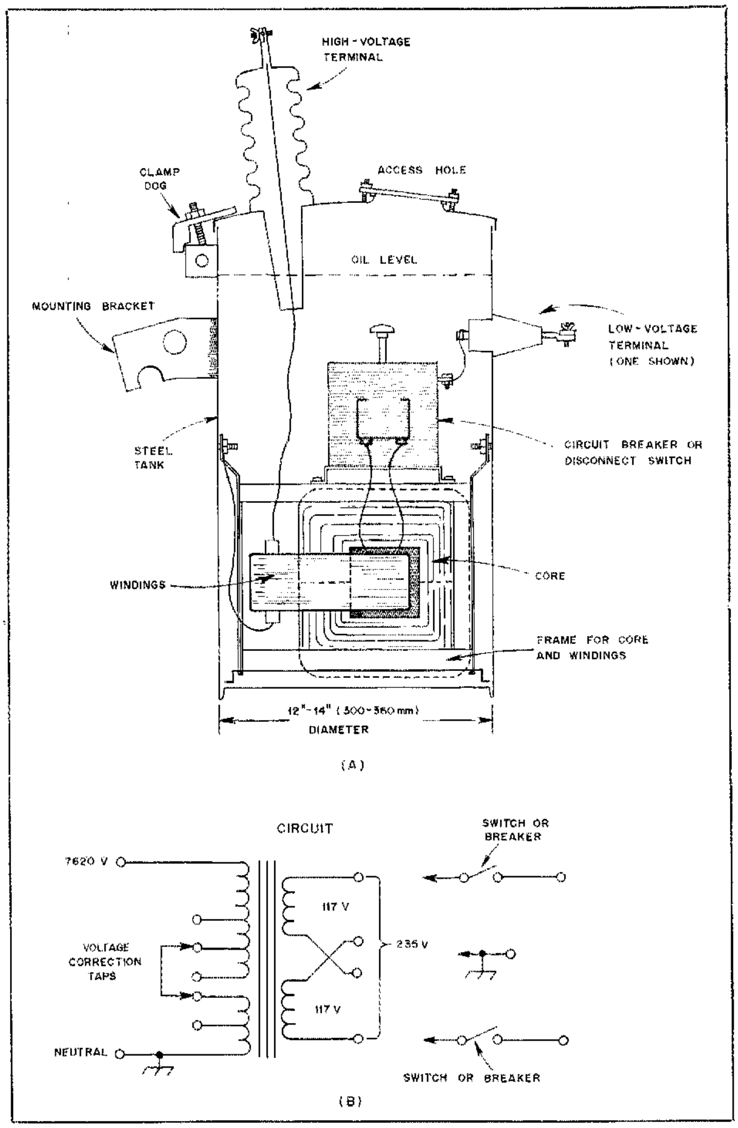

Fig. 1 — A typical small power-line transformer. The inner construction is shown at A. Part B illustrates the transformer circuit. See reference no. 7 for information about delta and Y or star configurations.

Impregnation

Usually, commercially made transformers are wound dry, then impregnated with either an insulating varnish or wax. The home-style approach to transformer winding is to impregnate one layer at a time. Therefore, we must choose material that lends itself to this method. This requires extra precautions to exclude moisture. A small amount of moisture can lead quickly to insulation breakdown.

William Liscusi of General Electric's Insulating Materials Division pointed out that hand coating each layer calls for an impregnating substance that will finish polymerizing or set in the absence of air. That led me to choose polyurethane. While this substance is not the best from the heat-resistance standpoint (good to 125° C), it is adequate for our purpose and will begin to set as each layer is applied. I purchased a good grade of satin finish polyurethane floor varnish because it has a better "tooth" than the glossy type and provides a better bond between coats. Less than a quart is required.

Disassembling the Old Transformer

If the transformer is still in the tank, the oil must be drained. The task is messy and you have to be careful how you dispose of the oil, which is a very unpleasant pollutant.[4]

The core and windings will be held in a frame of steel channels wedged into the bottom of the tank. To get the core and winding out, it may be necessary to remove the low-voltage terminals from the tank, as well as the circuit breaker or disconnect switch if either is present. Once the windings and the core are out of the tank, let them drain for several days. When draining is complete, remove the frame holding the core and windings. Dry the core and windings in the oven at 80° C for several hours. The title photo is an example of how the core and windings should appear.

Cores are made by winding a strip of grain-oriented silicon steel around a mandrel and then bonding it into a solid mass. This is then cut into two C-shaped half cores. The mating faces are ground precisely flat. These two halves can then be reassembled through the windings and strapped together with steel bands. This style of core construction simplifies rewinding. Avoid any transformer that does not have this form of construction.

Pry the core strap open or cut it close to the clamp with tin snips. Save it for reassembly. Give the joint between the core halves a sharp rap with a mallet to break the film of varnish that may be present. Remove the core sections from the coil. It may be necessary first to drive out the shims of fiberboard which have been used to wedge the core tightly inside the winding coil. Save these shims, especially the sleeve of fiberboard that surrounds the high-voltage winding at the point where it passes through the core. Put the core sections aside for now, keeping them carefully paired just as they were in the transformer. Protect the mating surface from damage such as denting or nicking.

In most cases the windings can be separated easily since they were originally wound separately, then nested together. Corrugated fiberboard or wooden strips are wedged in between the high- and low-voltage windings. Carefully drive these wedges out to release the windings from each other. My 1.5-kVA transformer had eight layers of 19 turns each of heavy rectangular copper strip (152 turns in all) for the low-voltage winding.

Rather than cutting through the high-voltage windings with a hacksaw, I judiciously elected to unwind it. This gave me about a mile and a half of no. 27 wire. Most importantly, I was able to learn exactly how the insulating layers were overlapped, how joints and tapes in the wire were dealt with and, of course, the number of turns. Having a close estimate of the number of turns required for the new winding is essential.

There were 4560 turns in all for the high-voltage coil, showing that the core flux was sufficient to yield 1.66 volts for each turn. Another way to estimate the turns needed is to count the turns in the low-voltage winding. By using the turns ratio, as explained in *The Radio Amateur's Handbook* (available from the ARRL for $10), you can determine the number of turns required for the secondary.

Designing the New Winding

The starting point in designing a new winding is to specify a voltage and current level.[5] I wanted 1800-volts rms in order to yield a peak dc voltage of 2500 V with a full-wave bridge. An output of 2-kW PEP would call for a peak current of 800 mA. But as is often pointed out, the lower average power of speech-modulated signals will ease the average current demand considerably.[6]

Once the size of wire and a close estimate of the number of turns have been determined, the next step is to see if the winding will fit into the space available. Fortunately power-line transformers have enough space in the core "window" to accommodate just about any winding need for an amateur transmitter. To develop 1800 volts would require about 1100 turns, allowing a little extra for voltage drop in the secondary. A first choice of wire size might be no. 22 B & S gauge. (Data for no. 22 wire taken from the copper wire table in *The Radio Amateur's Handbook* is shown in Table 1.) The current-carrying capacity of this wire is based on 700 circular mils (cross-sectional area) per ampere. This is a good design figure for small transformers, but for a unit as big as 1.5 kVA, you should allow more wire area since the heat must follow a longer path to get out of the windings. Since our real average-current demand will be less than 500 mA, this should be a good start. An examination of the old transformer will give us the window dimensions. In my case, the high-voltage winding was 2-1/2 inches (64 mm) wide, had a radial depth of 1 inch (25 mm) and an average circumference of 17 inches (430 mm).

Insulation

Requirements for insulation are the next items for consideration. Transformer windings usually consist of layers wound in alternate directions across the width of the winding. (All turns are wound in the same direction around the core.) Thus, the first turn of one layer will be directly underneath the last turn of the next layer, and the maximum voltage between layers will be present at this point. This voltage will depend on how many turns are present in both layers and on the volts-per-turn factor. Books on transformer design give a typical insulation thickness of 50 volts per mil (a mil is 0.001 inch or 0.025 mm) for impregnated kraft paper. We also have to consider turn-to-turn insulation, but as this will be less than 2 volts, we can safely leave this to the enamel or Formvar coating on the wire.

We must, of course, be very careful to avoid kinks and scrapes during the winding process, for a shorted turn would be a serious matter. Heavy currents would flow, overheating the winding and causing an open circuit or further breakdown. The new winding has to be insulated not only from the low-voltage winding inside it, but also from the core it will pass through. In the first case, we must build up the fiber center of the high-voltage winding to a thickness sufficient to withstand the entire secondary voltage with considerable safety factor. In the case of the winding-to-core insulation, the easiest way is to allow a generous margin at each edge of each layer where there will be no turns. On the outside of the finished winding there will also have to be a layer of insulation thick enough to resist the full secondary voltage.

How the manufacturer dealt with these problems was revealed by the details of the original winding. Paper between the layers was 0.005 inch (0.13 mm) thick. Additionally, there was an extra 0.005-inch strip, half the width of each layer, placed between the starting side of one layer and the finishing side of the next. The margin was 1/4 inch (6 mm) on each edge. The inner end of the original winding was grounded to the transformer tank. Because in normal operation this part is at ground potential, there was no extra thickness of insulation apart from the fiber spool itself. However, at the outside of the winding there were many layers of extra paper. The fiber sleeve mentioned earlier (fully 1/8 inch or 3 mm) served to provide additional insulation between the winding and the core.

More Than Normal Paper Thickness

Concerned as I was about the possible shortcomings of varnishing each layer by hand, I decided to install more than a normal thickness of paper between the layers. I made one layer 0.010 inch (0.25 mm) thick, full width with an additional 0.005-inch (0.13 mm) layer between the high-potential edges of adjacent layers. I provided a 1/4-inch (6-mm) margin that left two inches (50 mm) of width for each layer. At 37 turns per inch (from the wire table) or approximately 1.5 turns per mm, I would have 74 turns per layer. Thus, between two layers, the maximum voltage difference would be 250 V. At 1.66 volts per turn, 148 turns should produce approximately 250 V. With 0.015 inch (0.38 mm) of paper, this would be less than 20 volts per mil. Since the wire thickness was 0.025 inch (0.64 mm) the insulation

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Polychlorinated Biphenyls (PCBs)

Regulations established in 1979 prohibit the manufacture of transformers containing oil with PCBs, chemicals which may be hazardous to one's health. Prior to that time such transformer oil was mainly placed in very large transformers and in transformers to be located in buildings where fire would have serious consequences. To a much lesser degree PCB-containing oil was used in pole transformers. Nevertheless, amateurs are advised for safety reasons to treat transformer oil as though it were contaminated. Avoid getting it on hands and body, or in the mouth. Wash hands thoroughly before eating. Detailed information on PCB use and disposal is available from the Environmental Protection Agency, Washington DC 20460. — *Stu Leland, W1JEC*

Table 1

Copper Wire Data (Enamel or Formvar Covered Wire)

Size	*Diameter*	*Turns per Unit Length*	*Length per Unit Weight*	*Resistance*	*Current Capacity*
No. 22	0.0253 inch 0.643 mm	37 per inch 1.46 per mm	514.2 feet/lb 71.3 m/kg	16.46 Ω/1000 feet 5.40 Ω/100 m	918 mA

thickness of 0.015 inch would make each layer 0.040 inch (1 mm). At 74 turns per layer, 1100 turns would call for slightly less than 15 layers, and at 0.040 inch per layer would add up to 0.6 inch (15.2 mm) total. I could then use 0.2 inch (5 mm) both on the inside and outside of the winding which, at 20 volts per mil, would be enough for 4000 V.

Seeing How the Trade-Offs Work

By going through this procedure a couple of times for different sets of specifications, it will quickly be seen how the trade-offs will work. Using no. 24 wire, for example, will reduce the average current capability but more layers can be added to give a higher voltage. The increased voltage per layer, because of the the greater number of turns, might call for more insulation but already we are allowing a huge safety margin. Remember that the original transformer was designed for 1.5 kVA in continuous operation 24 hours per day, with only 55° C temperature rise. Even though we will be giving up the advantage of oil cooling, we should be able to draw a kilowatt for amateur service without the slightest problem.

There are two final points about design to keep in mind. The circumference of the winding will tell you how many feet of wire will be needed (in my case around 1800 feet or about 4 pounds — 1.8 kg — of no. 22 wire). The resistance, from the ohms-per-1000-feet figure of the wire table, will allow you to predict the regulation or voltage drop under load.

To wind the new coil, you will need a fixture similar to the one shown in Fig. 2, a simple device made from scrap wood and Masonite. Stay away from lathes, drill presses or other motor-driven contraptions unless you are sure you know what you are doing. Kinks and tangles are almost inevitable if you don't have a lot of experience. The winding is best done *slowly*, one *layer per day*. This makes the task considerably more pleasant and allows time for each layer to dry properly.

See Fig. 3. Begin by precutting the kraft paper to proper width and in convenient lengths. The paper should be dried by placing it in an oven (set for 80° C) for an hour or so.

I kept thinned and unthinned polyurethane in separate cans. The thinned varnish served to saturate the paper while the unthinned liquid was reserved for coating each layer after it was wound. This work is best done with rubber gloves.

Scotch electrical tape will hold surprisingly well on wet or sticky polyurethane, keeping ends of paper strips in place or holding the last turn of wire in the layer. Peel it off, however, before each new layer is added.

During the initial paper winding, the joints may be butted together, but when insulating the layers of wire windings, joints must be lapped and they must fall at the ends of the long oval of the winding. Otherwise you will have extra thickness where you don't want it. You must also remember to start and finish the winding and bring out any taps at the ends and at positions outside the core. Bring the high-voltage ends and taps out on the side of the winding opposite where the low-voltage lead is dressed. The layers of wire are wound fairly tight, the turns being placed side by side with no gaps (close-wound). If the first few turns are smooth and tight, the layer will wind quickly and neatly.

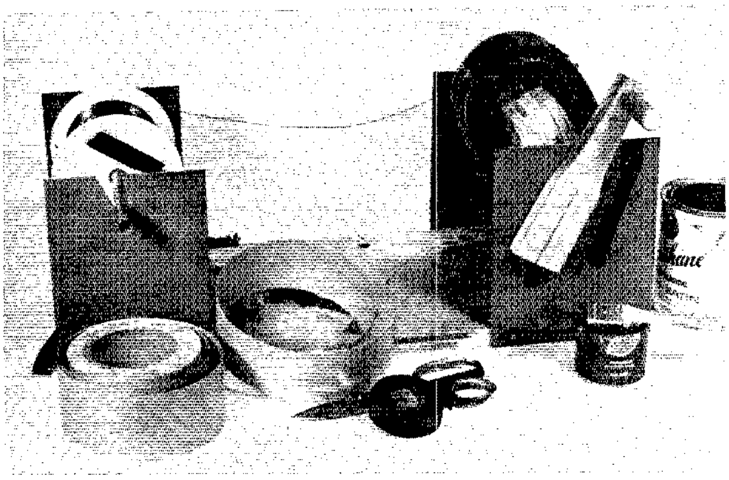


Fig. 2 — This winding jig can be made from odds and ends likely to be found in nearly any home workshop. Shown is a coil being wound on the original fiber spool which is supported by the low-voltage winding. The latter winding is mounted on a crank driven wooden mandrel. A fairly close fit is needed to avoid distortion caused by tension of the new winding.

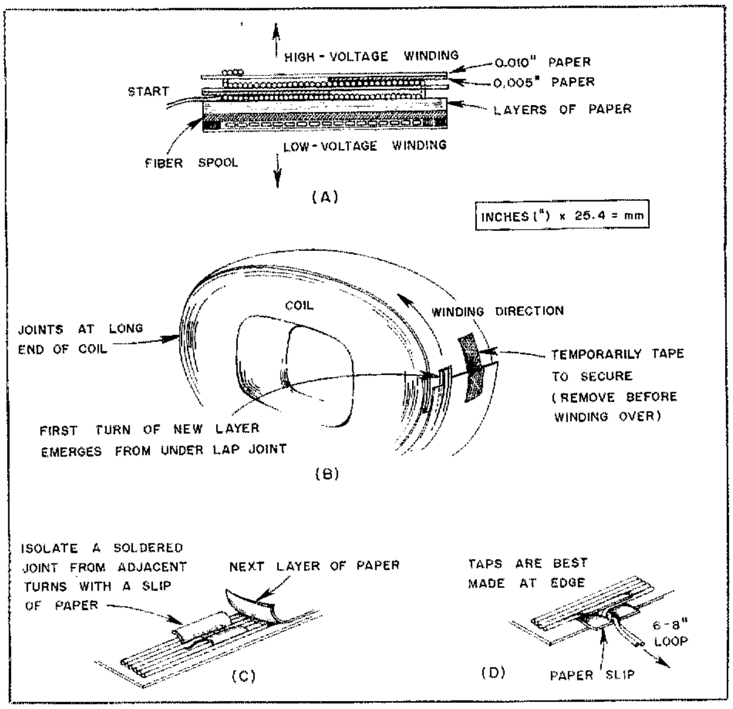


Fig. 3 — Details of the new winding. At A is a cross-sectional view of the winding. B shows how the insulating paper is installed. A soldered joint can be isolated as indicated in C. D illustrates the method of providing taps on the winding. Each layer takes about a half hour to install.

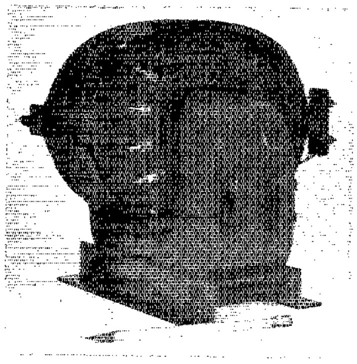


Fig. 4 — A rewound transformer ready to use. The pencil in the photograph gives an idea of the size of the transformer.

Once the winding is finished, including the last 0.2 inch (5 mm) of paper thickness, give it a few extra days to dry. Then bake it for 12 hours at 80° C.

Reassembling the Transformer

Try the core sections to make sure they fit properly. Clean mating surfaces *scrupulously* with solvent. Once the core has been reassembled through the coil, the strap can be threaded through the coil. Bend the strap ends 90° and drill a hole for a bolt to tighten the strap, clamping the core firmly together.

The fiberboard shims can now be reinstated to wedge the core tightly in place. Slip the insulating sleeve around the high-voltage winding to add an additional 1/8 inch (3 mm) of insulation. Apply two coats of Glyptal to improve the appearance of the transformer and seal the windings against moisture. The reassembled transformer is shown in Fig. 4. Under no circumstance attempt to mount the transformer by the metal strap through the core. That could form a shorted turn!

Danger — High Voltage!

Until now, the transformer has been an inert collection of various materials. But once you connect it to a source of power, it becomes *lethal*!

Begin testing with the help of a 3-ampere variable-voltage transformer such as a Variac. Use one or both windings of the primary. A voltage divider consisting of four 1-MΩ, 2-watt resistors in series will permit the use of a VOM or VTVM for measuring the secondary voltage. Even with a VTVM, the readings will be low by a few percent as a result of the loading effect of the meter on the voltage divider. Connect the meter across *one* of the 1-MΩ resistors. *With the power off,* place the string of four resistors across the secondary of your rewound transformer. Set the meter for the 1000-volt ac range. Next, connect your transformer to the Variac and the Variac to the ac line. Bring the primary voltage up slowly. Watch the meter for an indication of the presence of the secondary voltage.

As the voltage on the primary of my transformer reached 120, the magnetizing current was a very satisfactory 1/2 ampere and the secondary voltage (4 times the meter reading) registered as predicted. The core had to be readjusted slightly and additional fiberboard shims wedged into place to reduce the angry buzz of the laminations to a barely perceptible hum.

The point of saturation was apparently reached and core losses increased when the primary voltage was pushed to 145 V, causing a no-load current of 3 amperes. Although the voltage had risen 20% above normal, the insulation did not break down, thus passing the overvoltage test. Under various load-current levels the transformer performed exactly as it should. At 840 watts, the primary current was 7-1/2 amperes with the efficiency above 90%. Best of all, after more than an hour, the transformer remained barely lukewarm.

When the transformer is to be under load, be sure both primary windings are connected in parallel (properly phased) for 117 V or in series for 235 V. Alternatively, the primary windings may also be connected in series for use with any two phases of a 208-V, three-phase service. In the latter case, however, the output voltage will be reduced. The power supply chapter in *The Radio Amateur's Handbook* explains these arrangements.

I fully realize the technique described here is a very rough-and-ready one. But I hope to have shown that a high-power plate transformer can be fashioned from little-known but commonly and inexpensively available things, with a bit of ham ingenuity and labor being the only additional requirement. QST

References

[1] McCoy, "Use $urplus and $ave," *QST*, October 1967, pp. 18-21. Also, "How to Wind Your Own Power Transformer," *QST*, February 1970, pp. 26-29. [Similar information is contained in a more recent article, "Rewinding Transformers," by O'Dell and Shriner, October 1980 *QST* — *Ed.*]

[2] See sidebar story.

[3] *QST* readers unable to obtain a junked transformer or insulating paper locally may write to Mr. Charles Bowman Jr., Bowman and Bowman, Box 518, Greenwood, MS. 38930. Bowman and Bowman can furnish drained and dried cores and windings. Small quantities of insulating kraft paper are also available. Mr. Bowman has made this special arrangement strictly as a favor to *QST* readers and the author.

[4] See sidebar story.

[5] *Reference Data for Radio Engineers*, Chapter 13, Howard W. Sams & Co., Inc. (a complete step-by-step design procedure for transformers).

[6] Orr, *Radio Handbook*, twenty-first edition, Howard W. Sams & Co., Inc., pp. 23.22 ff. (a good discussion of intermittent voice service rating of transformers).

[7] Nilson and Hornung, *Practical Radio Communication*, second edition, 1943, section 6.13.

Strays

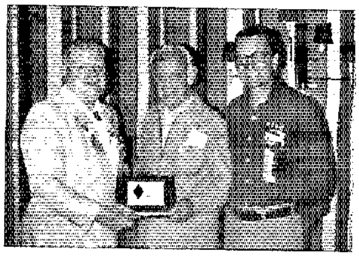
MOVING? UPGRADING?

☐ When you change your address or call sign, be sure to notify the Circulation Department at ARRL hq. Enclose a recent address label from a *QST* wrapper if at all possible. Address your letter to Circulation Department, ARRL, 225 Main St., Newington, CT 06111. Please allow six weeks for the change to take effect. Once we have the information, we'll make sure your records are kept up-to-date so you'll be sure to receive *QST* without interruption. If you're writing to Hq. about something else, please use a separate piece of paper for each separate request.

ANYONE FOR FAX?

☐ JA2OL and a group of Japanese amateurs report that they are active on facsimile near 14.245 MHz using standards somewhat similar to those used for slow-scan television. FAX transmission presently is not allowed in the U.S. below 50.1 MHz, but a one-way receiving test would be possible now. August *QST*, page 57, describes an FCC proposal, supported by ARRL, to permit FAX in the hf phone bands.

Interested? Write Hisataka Sumioku, JA2OL, 1560 Kamiokamoto, Takayama City, Gifu, Japan. — *Dave Sumner, K1ZZ*



Wayne Cooper, AG4R (center), of Miami, Florida, receives the ARRL 50-year member plaque from ARRL President Harry J. Dannals, W2HD (left) and ARRL Southeastern Division Director Frank M. Butler, W4RH, at the 1980 Miami Hamboree.

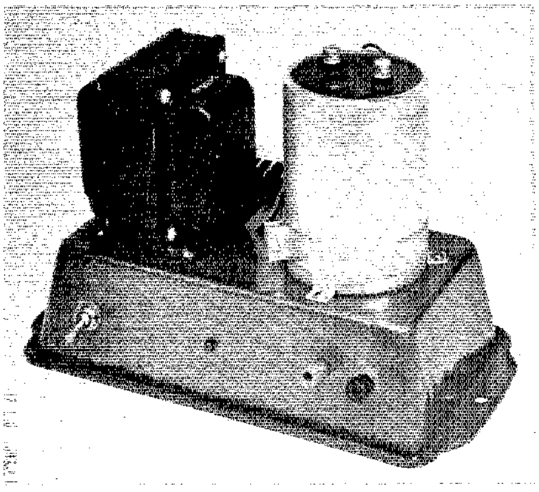
QST congratulates . . .

☐ A. H. "Bud" Waite, W2ZK, formerly of Massachusetts and New Jersey, now of Venice, Florida, who was the guest of honor at the annual banquet of the International Antarctican Society, held recently in Washington, DC.

☐ Charles E. Darrow, K8GZQ, of N. Olmsted, Ohio, who as been appointed to the new post of Product Marketing Administrator with The Antenna Specialists Company, Cleveland Ohio.

• *Basic Amateur Radio*

5-A Loafer



Loafing around? Short on dough? Luck panned out? Need a 12-V, 5-A power supply? This one is inexpensive, quick and easy to breadboard.

By Peter O'Dell,* AE8Q and Robert D. Shriner,** WAØUZO

Long ago, in a state far away from Connecticut, coauthor O'Dell lived happily with his wife, Sally. Even though Sally was an active, licensed amateur, the biggest problem they faced centered around ham radio. Every time that Pete enthusiastically started another building project, he got the same *encouraging* words from Sally, "The things you build usually work, but they are *always ugly!* Why can't you build something pretty like they show in *QST*?" In spite of such fundamental differences of perspective, their marriage endures. But what of the poor home-construction enthusiast married to someone who doesn't like the hobby? One complaint that we receive regularly is that projects coming out of the ARRL lab are *too pretty*. This month's Basic Amateur Radio article is for those of you who have suffered untold abuse when your masterpieces have been invidiously compared to photographs from *QST*.

Please note that we have included photographs of technically sound, high-performance, *ugly* equipment built by ARRL staffers. Even though you may not be interested in duplicating this month's circuit (a 12-V, 5-A power supply), you probably will want to save the photographs for future use — self defense! (The authors tried in vain to persuade the editor to make available 8 × 10 glossy copies of these photographs.)

Is Ugly Better?

Although most of the staffers and others connected with ARRL headquarters tend to place a high value on "building neat," one of the TAs (Technical Advisors) who designs very sophisticated equipment insists that "ugly is better." (Name, address and call withheld by request.) A couple of other TAs build ugly equipment, but make no claims as to the technical merit of ugliness. Then there are those of us (O'Dell included) who admire works of beauty, but who have learned to survive without benefit of artistic talent.

Where most home construction is concerned, beauty (or the lack thereof) is largely irrelevant to the functioning of equipment. Frequently, "neat construction techniques" come with experience; this process is often referred to as learning the "tricks of the trade." The balance of this article will deal with various "tricks" of power supply building. Shriner and DeMaw recently presented an introductory theoretical discussion of power supplies,[1] so theory will be kept to a minimum.

Classy Chassis?

Regardless of whether you build "pretty" or "ugly," you may have been faced with the double-edged problem of the chassis — cost and availability. Those living near a large urban area can probably find any size chassis they want at a commercial electronics distributor. But of course, the price may be a little high. Those not living near a large distributor have an even more fundamental problem — where to find the chassis regardless of price.

In the early days of radio, experimenters built equipment on chunks of wood (frequently breadboards; hence the term, breadboarding). Few people these days would consider constructing a circuit on wood, but the kitchen does offer an often-overlooked source of inexpensive chassis material — bread pans! Depending on the size, shape and store where purchased, the price of a bread pan can range from under one dollar to several dollars. Commercial chassis of similar size start at around four dollars and go up. Although slightly cheaper, breadpans have as their main advantage widespread availability. From a structural strength, durability and aesthetic point of view, a regular chassis is probably superior. But amateurs have long been famous for making do by pressing ordinary items into extraordinary service.

Another advantage to using the bread pan for the chassis is the ease with which the soft metal can be worked. You need only a few simple hand tools and a common electric drill to do the metal work. Aluminum bread pans are somewhat easier to work with than those made of steel.

The photograph of the Accu-Keyer enclosure illustrates another common item that has been pressed into service. The cabinet was originally a one-gallon (3.875 liter) can. After the contents were used, the can was washed thoroughly inside and out. The top of the can with the spout and handle was cut away with a can opener. The keyer was built on a "slightly used" chassis. Holes were then measured

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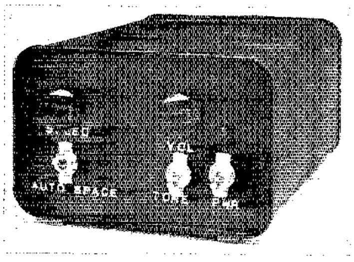
**Box 969, Pueblo, CO 81002

[1]References appear on page 46.



Accu-Keyer mounted inside a cabinet made from a discarded one-gallon can. If you think this is ugly, you should see the "slightly used" chassis on the inside.

and drilled in the bottom of the can for the controls. The bottom of the can became the front panel! A few light coats of spray paint, tape labels and rubber feet added the finishing touches. This cabinet was made six years ago by coauthor O'Dell using nothing more than a drill and a few simple hand tools. It is highly unlikely that anyone looking closely (or not so closely) would ever mistake this for a commercial cabinet; however, it is certainly more appealing than the "slightly used" chassis on the inside. And it was a lot *less expensive* than a "store-bought" cabinet!

Diodes Are a Drop in the Bucket

This month's workshop project is a 5-A, 12-V power supply. The preferred circuit is built around a monolithic three-terminal regulator chip that is rated at 5 A. Unlike the lower current power supply of this series, this supply has a fixed output voltage. Some of you may feel a need for a high current, variable-voltage supply. If that is your need, we suggest you buy a copy of the 1981 *Radio Amateur's Handbook* (available from ARRL for $10) which has new plans for an excellent variable-voltage, high-current supply.

Some of you may be saying to yourself that you do not really need a *variable* voltage supply, but that 12 V is not quite enough for the purpose you have in mind. For instance, some 2-meter fm rigs are designed for optimum performance at 13.8 V; their output is somewhat degraded when run at 12 V. Here is where some of the tricks of the trade can come to your rescue. The ground terminal of this regulator (as well as that of the common 1 A, three-terminal variety) is used for an internal reference and has relatively little current flowing through it. If this leg is raised above ground potential, the regulator chip will continue to supply a regulated output, but that output will be equal to the voltage of the regulator chip plus the amount by which pin 3 is raised above ground. E.g., suppose that pin 3 is raised 1.8 V above ground; the regulated output voltage will now be 13.8 V (12 V plus 1.8 V).

Another way of saying that we want to raise the potential between pin 3 and ground is to say that we want to create a voltage drop. One thing that comes to mind is placing a resistor in series with pin 3. What value? We can experiment with either a bunch of resistors or a potentiometer; we have to experiment because the voltage drop will depend on the amount of current flowing (Ohm's Law). It is not all that difficult to do with a voltmeter and a couple of potentiometers or a good supply of resistors. Being somewhat on the lazy side, the authors looked for another way. Why not use

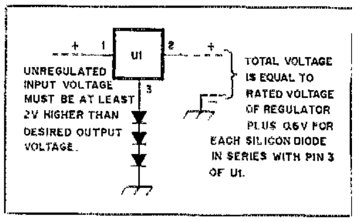


Fig. 1 — Method for altering output voltage of 3-terminal voltage regulator. Although the voltage drop across the diodes does vary slightly with temperature and current density, it can be considered constant for our purposes.

something that has a constant (more or less) voltage drop, regardless of the amount of current flowing through it?

What common, garden-variety device has a constant (more or less) voltage drop? The semiconductor diode. (An explanation of the "hows and whys" can be found in the first section of ARRL's *Solid State Basics* available from ARRL for $5). Suffice it to say here that germanium diodes have a "constant" forward voltage drop of something on the order of 0.2 V and silicon diodes have a "constant" forward voltage drop of something on the order of 0.6 V. If this all sounds just a little vague, relax, because that is the intention. The purist will tell you that the voltage drop across a diode changes with both temperature and current density, which it does. But the changes will be measured in terms of millivolts for semiconductor diodes, while the changes for resistors will be measured in volts. For our purposes it is quite safe to figure on a constant voltage drop of 0.6 V, as long as

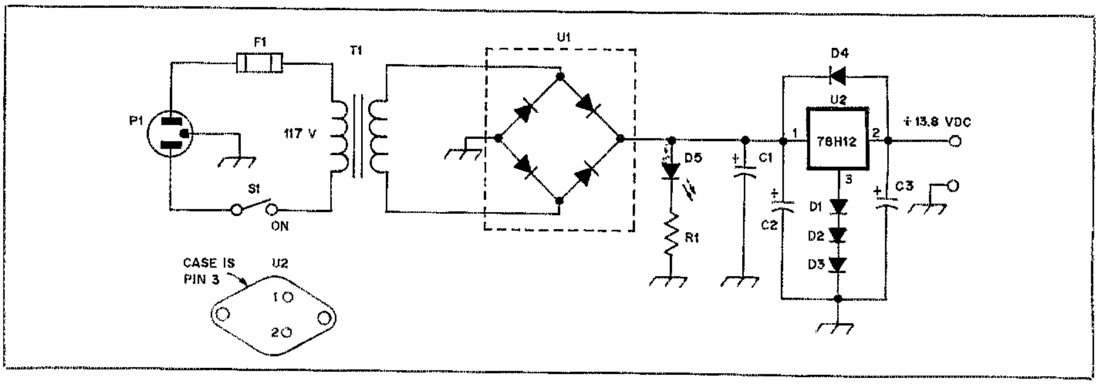


Fig. 2 — Schematic diagram of power supply using a single IC regulator. Capacitors are electrolytic and polarized. R1 is a carbon composition, 1/2-watt. Suggested sources for components are parts dealers at flea markets or those advertising in electronics magazines. Some parts (including the 78H12) are available from Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81002. Part numbers inside parentheses are Radio Shack parts suitable for use in this circuit.

C1 — See text.
C2, C3 — 3.3 µF, 35 V tantalum or equivalent (272-1408).
D1-D4, incl. — 1N4000 series or equivalent (276-1101).
D5 — LED (276-1622).
F1 — 2 A, fast-acting fuse (270-1275).
P1 — 3-conductor plug and cord; 2-conductor cord (suicide cord) should be avoided.
R1 — See text.
S1 — Spst switch (275-602).
T1 — See text.
U1 — 25-A, full-wave-bridge rectifier, 50 PIV minimum, 100 PIV or greater recommended.
U2 — 5-A, 12-V regulator.
Miscellaneous — fuse holder, heat sink, heat-sink compound, output terminals, grommets, hardware.

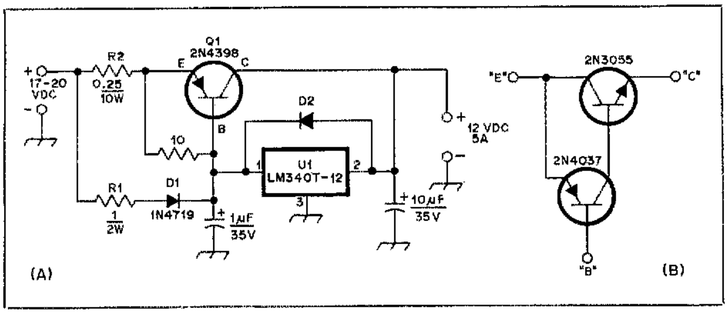


Fig. 3 — An alternative regulator circuit is shown at A. Unlike some regulator circuits using pass transistors, this circuit retains the current-limiting action of the 3-terminal regulator chip. Q1 should be rated to handle two to three times the maximum current to be drawn from the supply. Resistances are in ohms. Resistors are carbon composition, 1/2-watt or greater except where marked otherwise. Capacitors are tantalum. The circuit at B is used to fabricate a pnp pass transistor from an npn pass transistor.

the current capabilities of the diodes are large with respect to the amount of current actually flowing.

Fig. 1 shows a positive-voltage, three-teminal regulator chip with three diodes connected to the reference pin. This system will also work for a negative regulator if the polarities are reversed. The positive output terminal (pin 2) becomes common and both connections shown as chassis common become the negative output bus. The regulated output voltage will be the sum of the voltage drops across the diodes (D1, D2 and D3) plus the nominal voltage of the regulator chip. One word of caution: If the diodes are reversed, the output of the regulator will be approximately equal to the input; i.e., if there is 17 V at the output of the filter section (and the input of the regulator), that is the approximate voltage that will appear at the output of the regulator. Therefore, it is wise to check the connections, check the voltage, and check the connections again while construction is in progress.

Ugly is Only Skin Deep

The bottom view of the power supply reveals that there are only a few components mounted inside the chassis. The circuit (Fig. 2) is a simple straightforward design of few components, but most of those are large and bulky.

With the TO-3 style case, pin 3 of the regulator is the housing itself. Thus, to raise pin 3 above ground, you must isolate it electrically from the heat sink (or isolate the heat sink from ground). A mica washer, nylon bushings and screws (metal or nylon), along with a good heat-sink compound, can be used to insulate the device from the heat sink while allowing the heat to be conducted away safely. Radio Shack sells mounting hardware kits (276-1371) and heat-sink compound (276-1372), so most builders should have little trouble locating these items. If the mounting hardware kit is not available, however, you can make do with Teflon tape in place of the mica washer and nylon (only) screws. The Teflon tape can be obtained at most hardware stores; it is used to seal threaded-pipe joints.

The transformer that was rewound last month[2] provides 17 V at better than 5 A on the secondary. Any 117-V-primary transformer having a secondary that will provide at least 17 V at 5 A will work, as long as the 35-V maximum input-voltage limit of the regulator chip is not exceeded. But keep in mind that increases in input voltage translate into increases in power (heat) dissipation.

U1 is a monolithic bridge rectifier. Even though we are building a 5-A supply, we have specified a 25-A bridge. There are a couple of valid reasons for using a higher rating than necessary. At the instant that the supply is turned on, C1 (a very large capacitor) has no charge and looks like a dead short. Until C1 is partially charged, the current will go somewhat above 5 A. Even though this is only for an instant, it might be enough to damage the bridge, if it were not "hefty." Another drawback has to do with the voltage drop of a diode (U1 is four diodes in one package) as the current density approaches the diode rating. This was mentioned above and is quite a bit deeper water than we want to go wading through now. If you want more detailed information on the theory of power supplies see ARRL's *Understanding Amateur Radio* (available from ARRL for $5) or the 1981 edition of *The Radio Amateur's Handbook*.

D5 is an LED that serves as a power-on indicator. A neon lamp and dropping resistor wired in parallel with the primary of T1 would have served the same function. The diode was from a grab-bag source, so it was necessary to experimentally determine the value of the current-limiting resistor. A 1-kΩ potentiometer was used in place of the fixed resistor. The potentiometer was adjusted until the LED shone at the desired brightness. The resistance of the potentiometer was then measured for that setting and a fixed-value resistor of comparable value was selected.

C1 is a *large* capacitor. The one used in the prototype built in the ARRL Lab is 18,000 µF at 35 V. There is nothing sacred about the 18,000 µF value. If you have one in your junk box that is rated between 15,000 and 25,000 µF it will probably work — as will two rated at 10,000 µF wired in parallel.

O'Dell once built a comparable power supply that specified 2000 µF for a similarly used capacitor (there was an error in the schematic; it should have read *20,000 µF*). Flipping the power switch produced a hum unmatched since the last general warm-up exercise at the National Convention of Barber Shop Quartets. O'Dell began adding 2000-µF capacitors in parallel until the hum disappeared. Paralleling small-value capacitors to produce a large value is effective, but it is not cost effective!

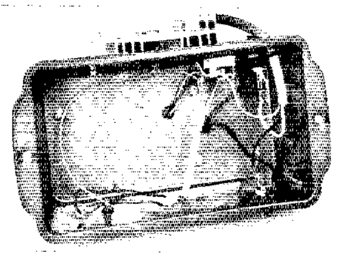
The critical factor for C1 is the voltage rating. When C1 is fully charged, the peak voltage will rise to something over 20 V depending upon the transformer used. Although it is probably okay to use 35-V capacitors, you will be safer using 50-V (or higher) devices.

The regulator circuit is the same as that of Fig. 1 discussed earlier, except that two capacitors have been added (C2 and C3). Both capacitors should be placed as near the regulator chip as possible; 3 inches away should be maximum. C2 helps stabilize the voltage regulator while C3 serves to suppress transients. Without these two capacitors, there is a good chance that your regulator will not produce a pure dc voltage. D4, the diode strapped across the input and output of the regulator chip, U2, is there to protect the chip from reverse voltage breakdown. Most heat sinks have enough space so that the entire regulator circuit can be built on the heat sink and then assembled to the chassis as a unit.

Alternative Regulator Circuit

The 5-A regulator chips are not found quite so easily as the 1-A variety, although we have listed one known source. The circuit using the 5-A chip is the preferred one, but we are including an alternative which features a 1-A chip with a pass transistor "wrapped around" it. The circuit in Fig. 3 is adapted from one presented by DeMaw and Hayward in ARRL's *Solid State Design* (available from ARRL for $7).

We will not attempt a detailed explanation of the inner workings of the circuit; however, a few salient features are worth pointing out. The voltage drop across R1 and R2 will be equal; therefore, the current in each branch will be inversely proportional to the resistances. In other words, four times as much current will



Ugly is only skin deep! Most of the components for the power supply are mounted on the outside of the bread pan chassis. Note that the heat sink is a relatively large one. Additionally, it is mounted with the fins in a vertical position during normal operation, to facilitate cooling. Because of the conservative design approach, this power supply "loafs" along at its 5-A rated output.

flow through Q1 as through U1. This means that the regulator circuit retains the current-limiting characteristic of the chip. Q1 is a pnp power transistor capable of handling the 5-A current. Since npn power transistors sometimes seem to be more abundant than pnps, we have included a gimmick for turning an npn into a pseudo-pnp. The circuit of Fig. 3B may be used in place of Q1.

Another important characteristic of voltage-regulator chips that usually disappears when a pass transistor is used is thermal shutdown. Most regulator chips have circuitry built in that sense a dangerous rise in temperature. When that happens, the chip automatically reduces output until the temperature falls to a safer level. This is something else that we can "gimmick," although not as accurately as the current-limiting action. If we install the regulator chip and the pass transistor on separate heat sinks, and if we make the heat sink for the pass transistor about four times the size of the one for the regulator, then we will retain some semblance of thermal shutdown.

Should we desire a voltage slightly higher than the nominal output voltage of U1, we can use the same techniques as described earlier. The circuit in Fig. 3 just replaces the regulator portion of the power supply. You will still need the rectifier and filter.

Making Do and Making Better

Either way you build this supply, it should "loaf" along at the 5-A level. There is a beauty and an elegance in building something right, whether it looks like something store-bought or not. Much of the "building right" knowledge comes from experience. Where do you get experience? The journey of a thousand miles begins with the first step.

References

[1]DeMaw and Shriner, "A Simple Utility Power Supply," *QST*, November 1979, p. 22.
[2]O'Dell and Shriner, "Rewinding Transformers," *QST*, October 1980, p. 34.

Amateur Radio at Iditarod, 1980

The Iditarod Trail Race is a 1049-mile dogsled race that begins at Nancy Lake, north of Anchorage, Alaska, and finishes in Nome. The race was established to commemorate a 1925 race against time when Leonard Seppala carried diphtheria vaccine to Nome, where a diphtheria epidemic had broken out.

Amateur Radio had been used extensively in past races, but this year the Iditarod Committee decided to place total responsibility for communications in the hands of Amateur Radio operators. A team of Anchorage hams, headed by Tom Moore, KL7Q, spent eight months preparing and organizing a communications plan. Their plan would not only provide race progress information to Anchorage and Nome race headquarters, but would also provide emergency communications, search-and-rescue coordination and personal third-party traffic handling for the dogsled drivers (mushers) and race-support people on the trail.

We felt that the communications effort should serve two purposes. The first was to cover the race and pass information as quickly as possible. A second and more important purpose was to provide an exercise in extended communications under emergency conditions.

The Alaska Division of Emergency Services donated the use of their communications center in downtown Anchorage. They agreed that the Iditarod would be a good RACES exercise to demonstrate Amateur Radio's ability to provide sustained communications from remote areas of the state. Area amateurs augmented the equipment already at the communication center's RACES position so that the station would have simultaneous capability on 75, 40, and 20 meters as well as vhf links to checkpoints within 140 miles of Anchorage.

Amateurs manned 29 checkpoints along the race route. There were also four shifts of four hours each to be filled at communications headquarters in Anchorage and Nome. Volunteers from Anchorage ARC, Matanuska ARA, Fairbanks and Nome manned the checkpoints.

Part of our program was getting hams out to their checkpoints in the bush. At the same time we kept Nome and Anchorage updated with race information, delivered traffic and kept tabs on who was doing what and where. Many of the hams going out on the trail had their own planes. The "Ham Air Force" consisted of five light aircraft. They spent the better part of their time ferrying other hams to the various checkpoints along the race route.

It was most important to keep our message traffic in order. We opted to pass traffic using standard ARRL message blanks. Each operator had a pad of these blanks and wrote out all traffic before sending it on to Anchorage where it was copied in message form for relay, via RTTY, to the Iditarod race headquarters.

Our communications plan was developed in close cooperation with the Iditarod Race Committee, the Alaska State Troopers, the Rescue Coordination Center (RCC) at Elmendorf Air Force Base and other official agencies. Each of the amateur operators received a pre-race briefing on emergency procedures and weather observation in the event such information was needed.

In one instance the advance planning saved a great deal of anguish and helped to quell rumors. A light plane carrying three members of a Spanish television film crew crashed about 800 miles uptrail from Anchorage. When word of the crash reached his checkpoint, Dave Goodyear, KL7JKC, set the emergency plan in motion. Both Nome and Anchorage were notified of the accident. Nome headquarters alerted the State Troopers, who immediately dispatched a helicopter to the scene. Anchorage coordinated traffic to RCC and Anchorage race headquarters.

At the time of the crash the identification of the plane was not known. It was known, however, that at least three other Iditarod planes were in the area. Identification became a priority matter. When the tail number of the downed aircraft was brought to KL7JKC he quickly transmitted it to Anchorage. Because the number closely resembled that of one of the other planes, a priority search was initiated to locate all the other planes in the area. Within 10 minutes of the original request, all other aircraft were located.

As the evening wore on, more information was relayed from the trail to Anchorage and Nome as to the location of the crash site and the victims who had been brought in. Weather conditions and other information were passed to the State Trooper helicopter, RCC, the Federal Aviation Administration and the National Transportation Safety Board were kept up-to-date on events as they occurred. The amateurs involved performed perfectly. They passed accurate information quickly and efficiently.

At 5 P.M. on March 15 Joe May, of Trapper Creek, crossed the finish line in Nome, setting a new Iditarod record of 14 days, 4 hours. The last musher crossed the finish line 11 days later. Only then were the last of the hams brought back to Anchorage for a party, debriefing and congratulations on a communications effort that once again showed that Amateur Radio is a vital communications service unsurpassed in efficiency of operation, ingenuity and willingness to assist wherever needed. — *Chip Lee, KL7IUI, Anchorage, Alaska*

Product Review

Conducted By Paul K. Pagel,* N1FB

Optoelectronics TRMS:5000 DMM/Thermometer

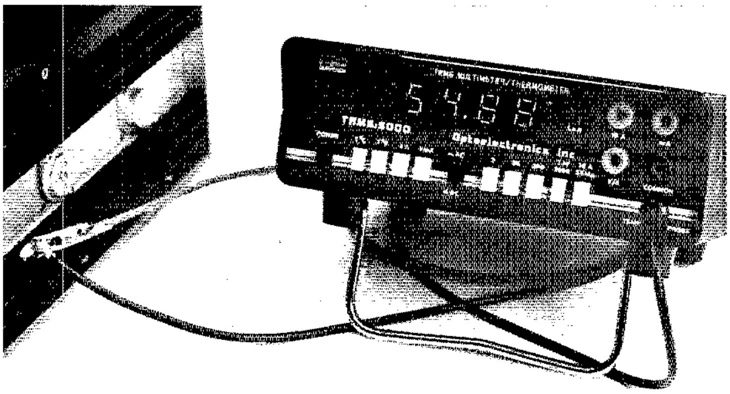
The TRMS:5000 is a digital VOM and thermometer having 4-1/2 digits of resolution. The "half" means that the most significant digit can only be a "one" or a "zero," and if it's a zero, it's blanked. It can measure voltages up to 1-kV dc or ac (pk-pk), currents up to 10 A, resistances up to 20 mΩ, and temperatures from −50 to +150° C (−67 to 200° F). The '5000 is a laboratory-grade instrument and is guaranteed to hold calibration for one year.

The letters in the model designation mean "true root-mean-square." Typical VOMs have rectifier circuits to convert ac to dc for measurement and display. These circuits usually produce a dc voltage equal to the *average* ac amplitude. For a pure sine wave, rms and average are the same thing. In other waveforms, that's not the case. The ratio of the peak voltage to the rms voltage is called the *crest factor*. A sine wave has a crest factor of $\sqrt{2}$. The TRMS:5000 displays the true rms voltage of waveforms having crest factors up to three.

An abbreviated table of specifications appears with this review, but if you're not familiar with DMMs, the specs can be confusing. Several factors affect the accuracy of the meter, including errors in the voltage reference source, the A/D converter, the time base and the attenuator network. An accuracy specification (such as ±0.04% + one count) accounts for all of the possible sources of error. If the meter reads 1.5000 V, the actual voltage could be as low as 1.4993 or as high as 1.5007. The *resolution* (100 μV) exceeds the accuracy of the measurement. If somebody offers you a meter having 1 microvolt resolution, don't get excited, because unless it has comparable accuracy, the last few digits are worthless. The last digit of the TRMS:5000 is useful for monitoring relative voltage changes. A meter having one more meaningful digit would cost at least twice as much as the TRMS:5000 because it would need a temperature-controlled reference element and a TCXO or crystal oven in the counter time base.

Successful use of test equipment requires an understanding of its limitations. For current measurements, Optoelectronics specifies a *burden* of 2 volts, meaning the TRMS:5000 may introduce 2 volts of potential drop in a series circuit. You couldn't use a 10-A range to monitor the current drain of your mobile transceiver, because the voltage drop would radically alter the ouput impedance match and cause the transceiver to draw less current and possibly malfunction. A better way to employ the TRMS:5000 in this application would be to install a calibrated brass shunt in the power lead and monitor the voltage across it. A couple of volts won't make much difference when measuring the plate current of a tube type of transmitter, but you can run into trouble here too if you're not careful. The "common" measurement terminal is floating with respect to the chassis.

*Assistant Technical Editor



A tilt-up bail brings the TRMS:5000 readout to a convenient level during use. In this photograph, the unit is being used to measure the heat sink temperature of a 25-A power supply. The display indicates 54.88° C.

Optoelectronics TRMS:5000

Abbreviated Manufacturer's Claimed Specifications

Dc voltage

Range	*Accuracy*
2 V	± (0.04% + 1 count)
up to 1000 V	± (0.04% + 2 counts)

Ac voltage (45 Hz - 10 kHz)

Range	*Accuracy*
all up to 1000 V	± (0.35% + 15 counts)

Crest Factor: 3
Useful frequency range: 45 Hz to 250 kHz

Current

Frequency Range	*Accuracy*
Dc	± (0.6% + 2 counts)
45 Hz to 10 kHz	± (1% + 2 counts)
10 kHz to 40 kHz	± (1.5% + 2 counts)

Temperature

Range	*Resolution*	*Accuracy*
−50 to +150° C	0.01°	±0.5°
−67 to +199° F	0.01°	±0.9°

General

Maximum input voltage: 1040 V pk-pk
Input impedance: 10 MΩ in parallel with 80 pF
Temperature and time range for rated accuracy: 18 to 28° C for one year.
Power requirements: 9 to 12 V dc @ 300 mA (wall-plug supply comes with meter)
Dimensions: 3-1/4 × 7-1/4 × 6-3/4 inches (83 × 184 × 171 mm) (H × W × D)
Weight: 2 lb (0.9 kg)
Price class: $300
rechargeable battery option: $25
Supplier: Optoelectronics, Inc., 5821 N.E. 14 Ave., Ft. Lauderdale, FL 33334, Tel. 1-800-327-5912.

You can ground the chassis for noise reduction purposes, but the common terminal can withstand only 600 V with respect to the chassis. If you measure current in a high-voltage lead, enclose the meter in a plastic bag and power it with batteries.

Resistance measurements on the 20-MΩ range call for some patience, because the settling time is about 10 seconds. Readings taken on the lower ranges stabilize in two seconds or less. A rear-panel switch selects resistance probe potentials of 0.5 and 1.5 volts. The high-voltage position provides the greatest accuracy, but the low-voltage feature is useful for in-circuit measurements without forward-biasing silicon semiconductor junctions. A front-panel LED alerts the operator to the low-voltage condition.

The thermometer function is fairly simple but not completely goof proof. The case of the temperature transducer can survive 200 volts with respect to the voltmeter common. To use the probe over its full rated temperature range, you should replace the cable with a Teflon one. The owner's manual advises avoiding strong acids when using the temperature probe. I assume this means don't dunk it in your pc-board etching tank.

Checkout

What about the meter's electromagnetic compatibility — how will it get along in your ham shack? The time base for the A/D converter and counter begins with a 3.84-MHz crystal oscillator. (They could have picked a better frequency!) The signal radiation isn't strong though, and grounding the DMM chassis to my transceiver made the signal drop into the noise. My real concern was the 555 timer operating at 20 kHz for the negative power supply. I searched for 20-kHz markers throughout the hf bands but didn't hear any. I *did* hear some white noise, but that too disappeared when I connected the DMM chassis to the transceiver. The meter wasn't disturbed by 50 watts of rf on all hf bands.

A DMM can't replace your old, trusty analog VOM in every application, but it can certainly increase the number and accuracy of the electrical measurements you make. If you acquire an Optoelectronics TRMS:5000, you will have a professional instrument with which to advance the state of the amateur art. — *George Woodward, W1RN*

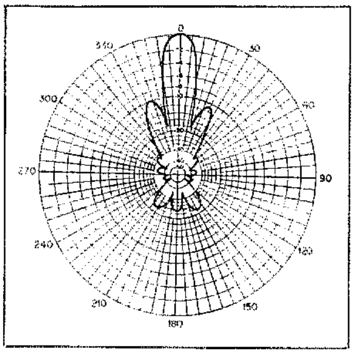
[Editor's Note: The instrument submitted for review was in kit form. Shortly before the review was originally scheduled to appear in this column, we were informed that, because of several engineering and other changes, the kit version was being discontinued. Optoelectronics has offered buyers who reference this *QST* review a discount price of $270 for the factory assembled TRMS:5000, complete with a one year parts and labor guarantee.]

CUSHCRAFT 32-19 "BOOMER" AND 324-QK STACKING KIT

☐ Moonbounce, or EME (earth-moon-earth) communication, requires a transmitting, receiving and antenna setup which can bridge a round-trip distance of about 450,000 miles (725,000 km) and also make up for the losses caused by the moon's surface being a very imperfect reflector. Also, as I was about to discover, it requires a great deal of patience.

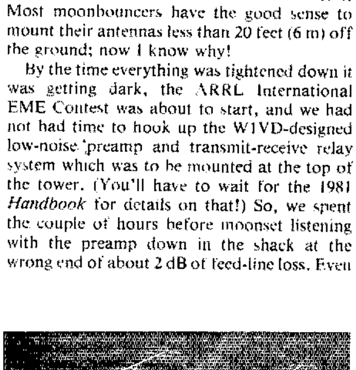
Cushcraft supplied four 19-element antennas and a 324-QK stacking kit, which consists of an "H" frame of 2-inch (51-mm) and 1-7/8-inch (47.6-mm) aluminum tubing and an RG-8/U coaxial cable harness and power divider for combining and phasing the four antennas. The frame spaces the antennas 14 ft (4.25 m) horizontally and 12 ft (3.66 m) vertically. Materials are furnished for weatherproofing the cable connectors, which is a very nice touch. The cables are all precut and terminated in male uhf connectors. Each antenna weighs about 12 pounds (5.5 kg). The hardware is all stainless steel, and all of the elements (with the exception of the driven element) are 3/16-inch (4.76 mm) solid aluminum rod. On the driven element, which is made from 1/2-inch (12.7 mm) aluminum tubing, a T match replaces the old gamma match used on earlier Cushcraft designs. The boom of each antenna is 3.2 λ long, or 22 feet (6.7 meters), and is made from 1-1/8-inch (28.6-mm) and 1-inch (25.4-mm) dia tubing. Fifteen directors, the driven element, and one reflector are spaced evenly along this boom, and two more reflectors are mounted above and below the boom at the rear of the antenna. A boom brace is provided to keep the boom from sagging. Presence of the brace means you cannot mount the antenna for vertical polarization, but Cushcraft has other models for the fm operator. The 32-19 is not intended to be used above 146 MHz.

Assembling the first antenna took more than two hours, but by the time the third and fourth were being put together our time was down to 1-1/4 hours unassisted and 45 minutes with two of us working together. That was the easy part; the difficult part was getting the whole assembly to the top of the 70-foot guyed tower. After that, we had a 90-pound (45.4 kg) aluminum array, occupying almost 5000 cubic feet (140 m³) of air space, to wrestle into place on the elevation rotator which was already bolted to the mast. (As supplied, the "H" frame is designed for mounting on a vertical pipe with a diameter of up to 2 inches (50.8 mm). Some additional tubing and brackets are needed to mount it on an elevation rotator.) Most moonbouncers have the good sense to mount their antennas less than 20 feet (6 m) off the ground; now I know why!



This diagram shows the radiation pattern at 144.15 MHz of the array of four Cushcraft 32-19 "Boomers" as installed at K1ZZ. For this test, a signal was fed into a 3-element Yagi mounted at the same height as the center of the array (72 feet, or 22 meters), and about 30 wavelengths away. Then a laboratory 1-dB step attenuator was used to maintain a constant S-meter reading on a receiver connected to the array under test as the array was rotated. The pattern shown is reasonably representative of the array's performance, but tests performed under different conditions might yield slightly different results. Numbers around the perimeter indicate degrees; the concentric scale represents dB relative to the peak of the major lobe. See July 1980 *QST*, page 26, for an explanation of this method of depicting antenna patterns.

By the time everything was tightened down it was getting dark, the ARRL International EME Contest was about to start, and we had not had time to hook up the W1VD-designed low-noise preamp and transmit-receive relay system which was to be mounted at the top of the tower. (You'll have to wait for the 1981 *Handbook* for details on that!) So, we spent the couple of hours before moonset listening with the preamp down in the shack at the wrong end of about 2 dB of feed-line loss. Even with that handicap, we were elated to hear W7FN in Washington and a couple of other stations which could not be positively identified because of fading. About the only problem we had with the antenna was that it was not perfectly balanced mechanically; the elevation rotator could go up but had a tough time coming back down to the horizon. This was remedied by adding a counterweight on the front of the array.



This view of the four Cushcraft 32-19 "Boomers" as installed at K1ZZ was taken from the 90-foot level of another tower on the property. Two 6-foot (1.8 m) lengths of 2-inch (50.8 mm) aluminum tubing (not supplied with the 324-QK stacking kit) are used to mount the array on the elevation rotator. *(W1VD photo)*

From the first, we were hearing signals very well — once the preamp was put at the antenna where it belonged, part-time listening over the two contest weekends yielded positive identification of a dozen stations, and partial calls on a number of others which we could have deciphered had we known who was active on the band. However, with more than 500 watts at the antenna we had heard our own echoes just once and had made no QSOs, though we had answered some CQs during the contest. The problem was *fading*, caused by changes in polarization as the signal passed through the ionosphere (Faraday rotation). Somewhat disappointed, we checked in with the 2-meter EME group that meets on 14.345 MHz at 1700 UTC on weekends. The welcome we received could not have been warmer. Conditions aren't very good at the moment, we were told; the fact that you're hearing *anything* means the system is working. A couple of people who obviously did not need Connecticut volunteered to run schedules, and on the third try we had a solid exchange with VE7BQH in the log and on tape, followed almost immediately by W7FN. Then K4PKV (who also uses four Boomers) asked for a sked on the fourth of July, and we celebrated the day with another QSO — our first with a station using an antenna as "small" as ours. EME provides "the ultimate antenna test range" — and, obviously, our tests with the Boomer show that it works!

Not too many people are going to make an investment like this just to try 2-meter moonbounce, so we wanted to see how well the antenna would work in normal terrestrial operation. We were a bit skeptical because of the narrow beamwidth: As you can see from Fig. 1, if the antenna is pointed more than 5° off the mark, you're well down the side of the major lobe. From Hartford, this means that if the array is pointed toward northern New Jersey you don't hear much from southern New Jersey, and vice versa. This makes round-table QSOs a bit tricky! On the other hand, for weak-signal DXing there is no substitute for antenna gain, and there's not way to *get* gain without compressing the main lobe. We didn't have time for a full effort in the June VHF QSO Party, but two hours of multiplier hunting on cw late Saturday afternoon yielded 21 sections. And K8NXI in Ohio popped through with his 100 watts the following morning. The only other New England station he worked on 2 meters in the contest was W2SZ/1, a station with a 3400-foot (1036-m) height advantage! The disappointment of the weekend was missing what should have been an easy North Carolina multiplier, probably because the antenna was seldom pointed that far south.

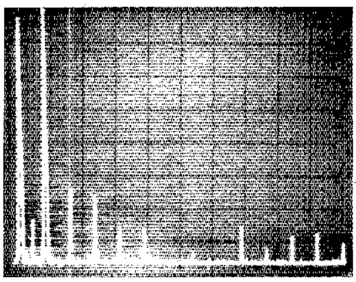
For most of us, one or two Yagis is all that's manageable for 144 MHz. We haven't tried the Boomer in that configuration, but for a four-bay array to work this well, each antenna must be an effective performer by itself. Of course, the mechanical problems of installing and rotating a smaller array would be much less, and the expense of the H frame would be eliminated. As supplied, the T match is set up for 50-ohm unbalanced feed, but it could be readjusted for 75-ohm feed if there were some reason for doing so. Incidentally, as installed the antenna met the manufacturer's SWR claims of 1.2:1 or less, and it was essentially flat across the 2-MHz bandwidth.

The 32-19 Boomer is a high-performance antenna made with high-quality hardware which, if properly installed, should give years of effective service. You don't need to work moonbounce to appreciate its performance, but the fact that four of them make an effective EME system should remove any doubts as to its capabilities!

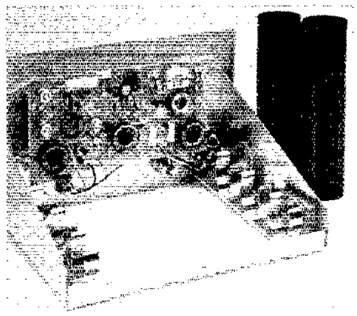
Retail price class of the individual antennas is $100, and of the stacking kit, $440. Manufacturer: Cushcraft Corporation, P. O. Box 4680, Manchester, NH 03108. — *David Sumner, K1ZZ*

TEDCO MODEL 1

☐ Tedco's Model 1 is a QRP cw-only transceiver that operates within the Novice portion of the 80-meter band. The unit covers the frequency range of 3685 to 3755 kHz. As may be seen in the photograph, the entire transceiver, with the exception of the battery supply, is contained on a single glass-epoxy pc board. The unit is housed in a wooden enclosure covered with wood-grained vinyl. Nine D-cell batteries (not supplied) are divided among three cardboard tubes and placed in the three rows of battery clips provided on the chassis rear. The instruction manual is lengthy and includes a complete circuit description, initial checkout procedures, operational hints, and maintenance and troubleshooting information.



Spectral output of the Tedco Model 1. Vertical divisions are 10 dB; horizontal divisions are 5 MHz each. Indicated power output is 1 watt at a frequency of 3750 kHz. The second harmonic is approximately 54 dB down from the fundamental. The Model 1 complies with current FCC specifications regarding spectral purity.



The inside of the Tedco Model 1. The complete transceiver is on the single pc board. To the right of the unit are the tubes into which the batteries are placed and set inside the chassis battery clips.

Tedco Model 1

Manufacturer's Claimed Specifications	*Measured in ARRL lab*
Rf power output: 0.5 watt.	1 watt into 50-ohm load.
Harmonics: More than 30 dB down.	More than 54 dB down.
Frequency drift: Less than 30 ppm/° C	Less than 30 ppm at room temperature.
Chirp: Less than 10 Hz.	30 Hz.
Receiver sensitivity at 50 ohms: Less than 1 μV for 10 dB S + N/N	≤1 μV @ 50 ohms.
Size: 5 × 9 × 8 inches (127 × 229 × 203 mm) HWD.	
Weight: 1 pound.	
Price class: $80.	
Manufacturer: Tedco, 9 Canonicus Ave., Newport, RI 02840.	

The Receiver Section

The receiver is a direct-conversion type employing a total of six transistors: Two operate as a common-base differential-pair rf amplifier, two are in a similar configuration as a product detector and the last two comprise the audio amplifier stages. A simple L-C audio filter is centered at a frequency of 750 Hz. A BEAT SELECT control (RIT) permits tuning the receiver independently ±750 Hz from the transmitted (center) frequency. The tuning of this control is quite smooth.

Headphone operation is dictated because of the low audio power output (5 mW) available. Monaural 'phones with each earpiece presenting an 8-ohm impedance are recommended to be used with a 1/4-inch (2.5 mm), three-conductor plug (not provided). If a two-conductor plug is used, it is inserted only part way into the jack. This is inconvenient, however, as the plug will not fit snugly into the jack, and movement of the headphone cord causes the plug to lose contact. The result: no audio. After a while, this can become quite aggravating. The T-R switching is arranged so that the built-in sidetone signal will be heard in the headphones during transmitter keying.

The Transmitter Section

A single FET is used in the master-oscillator circuit, which operates as both the VFO for the transmitter and the BFO for the receiver. One pole of the toggle switch used for the T-R switch selects either one of two capacitors to ensure that the receive and transmit frequencies are the same when the receiver BEAT SELECT control is set at zero (mid-position).

Following the VFO is a single IC (CA3020A) which furnishes both the buffer and final amplifier stages for the transmitter. The output transistors of the IC will deliver 1/2 watt of output power. A single transistor is used to generate a 750-Hz sidetone signal during keying.

The antenna output coupling is geared toward balanced loads with a 300-ohm impedance; the operator is cautioned against creating an unbalanced condition. (Such a restriction appears to be an inconvenience to most station operations since the use of low-impedance unbalanced coaxial lines is quite prevalent today. There is a way to accommodate the use of coax, however, which will be explained later.) Components to construct a peak-reading rf voltmeter are included with the transceiver to aid in transmitter tune-up.

Operation

Tedco advises not to use an ac-operated power supply with the Model 1 because of the susceptibility of the unit to hum pickup. This was verified at my station. When an attempt was made to use such a supply, the audible hum in the headphones masked most of the incoming signals and made operating intolerable. Attempting to connect everything to one common station ground resulted in ground loops which made conditions even worse. Battery operation eliminated the hum problem entirely.

Since my station is geared to the use of 50-ohm coaxial cable, it was necessary to change the 300-ohm balanced output to 50-ohm unbalanced. This was accomplished by unwinding 6 turns of the output link from the toroid and using a 1:1 balun. (This procedure does add another lossy element to the picture, however — an undesirable circumstance when QRP operation is contemplated.) There is no antenna-connection jack at the rear of the cabinet: The antenna connecting leads must pass through the rear of the cabinet to thumb-screw terminals on the pc board; the key-lead connections have to be similarly made.

It was noted that hand capacitance affected the VFO frequency slightly. Attaching a station ground to the chassis reduced this effect. Main-dial accuracy is quite good, well within 1 kHz. The transmitter will transmit with the T-R switch in the receive position, but this is immediately noticeable since there is no sidetone audible and keying clicks (because of receiver overload) are evidenced in the headphones.

Observations

Operating in the Novice portion of the 80-meter band on a weekend evening with this amount of power and a direct-conversion receiver is quite a challenge. Although this unit is intended for the Novice operator, I'd definitely not recommend it for the *beginning* Novice — he or she usually has enough things to think about during the first 100 or so QSOs without having to resort to as-yet-unlearned QRP operating skills. Skilled, "bare bones" QRP operators might like the challenge. — *Paul K. Pagel, N1FB*

HEATH SA-2040 ANTENNA TUNER

☐ It took approximately eight hours to bring the SA-2040 from shipping carton to finished product. Before assembly began, a number of corrections had to be transferred from the errata sheet and pages had to be added to the manual. From that point on, the whole process flowed smoothly. Nary a nut or bolt was missing from the kit; in fact, a few extra parts were included. Even an extra capacitor-mounting insulator is supplied in case you fail to heed the frequent warnings about tightening the hardware and manage to break an insulator in the process. The two capacitors and some of the roller coils require assembly.

The front-panel mask has a self-adhesive backing and is made of a material called "matte clear vinylite." It really dressed up the tuner and has provisions for adding the station call letters and control-position information, which may be jotted down on an erasable logging scale. The decor is black and gray, not the usual Heath green you've been used to seeing.

Large knobs on the capacitor and inductor shafts, along with well-lubricated bearing surfaces and tension adjustments on the capacitors and inductor make control tuning quite smooth. A three-digit turns counter is coupled to the rotary inductor and driven by a pair of right-angle nylon gears attached to the controlling shafts. The rotary inductor is factory wound on a fiberglass form, and the interconnecting strapping between the major components is silver plated. Two cores, fiberglass tape and Teflon-covered wire are supplied to construct a 4:1 balun. Large feed-through insulators are provided for balanced-wire and single-wire outputs in addition to SO-239 coaxial input and output connectors. No internal bypass switching is provided.

Putting It To Use

Heath frequently stresses (in bold print) the use of control settings which use the most capacitance of both capacitors; this delivers the best harmonic attenuation. With certain antenna systems, one may find several different control combinations which produce a matched condition. However, one or more of these settings may provide little harmonic attenuation. Approximate control positions for each band (80 through 10 meters) are given in the manual for use as a starting point.

Heath's advertised specifications state that the '2040 has a "wide range" of output impedance-matching capabilities. During some initial testing, two "soft spots" showed up. Arcing occurred between the capacitor plates when attempting to match a load on 80 meters at the high-power level. The arcing was traced to improper rotor and stator plate alignment, not a fault of the tuner. After readjustment, no arcing occurred during a similar test. (The load, as was later discovered, was not within the range of impedances Heath had in mind.)

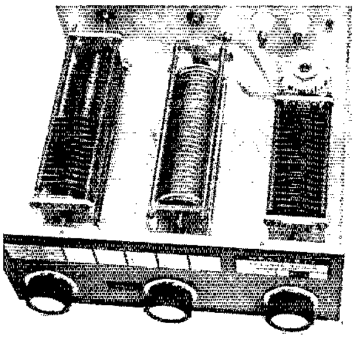
During a check of balun operation on 10 meters, the unused coaxial-output-connector insultion melted and burned briefly with a visible flame during a prolonged key-down, high-power test. Heath was notified of the situation. Simultaneously, I requested more-specific information about the impedance-matching range of the tuner. The persons to whom I spoke were quite helpful. It was learned that a similar coaxial connector failure had occurred during a field testing of another unit by one of the Heath employees and that the coaxial connectors to be supplied with later production units would have Teflon insulation. Units still in stock are supplied with the other type of connector, however, so it would behoove the prospective owner of a '2040 to check the output connector and replace it if necessary with the Teflon-insulated type as a precaution.

The detailed specifications for the SA-2040 provided by Heath are shown in the accompanying table. Lab tests showed that the Heath specifications are met. On 80 meters, insertion loss measured 0.24 dB with a 50-ohm resistive load, and the balanced-line output showed 0.6 dB of imbalance with a 250-ohm load at the terminals.

Depending upon the amount of reactance encountered with the antenna system in use and the transmitter output power level, the matching ranges of the '2040 may be exceeded without harm to the unit. Large mismatches should be avoided in any case, as they tend to increase losses within the matching network. — *Paul K. Pagel, N1FB*

Heath SA-2040 Antenna Tuner

SA-2040 Manufacturer's Claimed Specifications	*ARRL Lab Results*
Frequency range: 3 to 30 MHz. Power-handling capability: Full legal limit. Input impedance: 50 ohms (at matched conditions). Impedance transformation, 4:1 balanced line output: 100 to 1000 ohms; unbalanced output: a maximum SWR of 10:1, or impedance-matching range of 50 to 500 ohms; single-wire output: 6:1 SWR, using an odd-multiple 1/4 wavelength of wire. Size: 5-5/8 × 14-13/16 × 13-15/16 inches (143 × 556 × 354 mm) HWD. Price class: $150. Manufacturer: Heath Company, Benton Harbor, MI 49022.	All specifications met or exceeded (see text).



The interior of the Heath SA-2040 is neat and uncluttered. A heavy-duty ceramic insulator is used to support the balun, visible at the rear of the chassis.

DATAK TITLES

□ Have you ever wondered how the fellows in the ARRL lab manage to make the *Handbook* and *QST* projects look so good? Wish you could do it at home in your own workshop? You can! A simple paint job using spray paint goes a long way toward producing a professional-looking job. The final touch, labeling the controls and switches, is a cinch — if you use dry-transfer labels and titles. While a number of different manufacturers are marketing dry-transfer letters, Datak Corporation has a line of letter sets and titles especially suited to Amateur Radio and other electronic projects.

After using Datak dry transfers on several new projects for the 1981 ARRL *Handbook*, I find Datak's "Titles for Electronic Equipment" (cat. no. 9581 and 9591), "Meter, Dial and Switch Marking Set" (cat. no. 968) and the 1/8-inch (3.2-mm) alphabet sets to be the most useful for general work. Alphabet sets are also available in 1/4- and 1/2-inch (6.4- and 12.7-mm) sizes in white, black and gold.

Using the dry-transfer letters is easy if you work carefully. They must be aligned properly the first time. Once they have been pressed in place, moving them is impossible. They are best applied after painting but before any controls or switches are mounted. I place a sheet of paper over the panel, taped to the unpainted edges. This protects the paint and serves as an alignment guide. With the letter in position, rubbing it lightly will transfer it to the panel. When all the labels have been applied, burnishing them by placing a sheet of paper over them and rubbing the surface will fix them firmly in place.

In addition to the letter and title sets, Datak has a wide variety of other useful products, such as dry-transfer, etch-resist patterns and tapes, as well as etchant for making printed-circuit boards.

The process for making a board with these products is simple. A copper-clad board is first carefully cleaned, then the required patterns for transistors and ICs are applied directly to the copper surface. This is done in the same manner that letters are applied to a panel. Inter-connections are formed by applying etch-resist tape between the pads. When the circuit layout is complete, the board is placed in the etchant bath. Half an hour later, the finished board, ready for drilling, is removed. The only difficulty I have had with this method of making circuit boards is a slight under-cutting of the etch-resist tape. Careful application of the tape will minimize the problem.

All of these products are described in the Datak catalog in addition to many other marking sets, drafting aids and materials for making your next workshop project look as good as it works. Datak products are available at many electronic parts suppliers and through most major mail-order supply houses. Price range for the title and letter sets: $1.50 to $6. Datak Corporation, 65 71st St., Guttenberg, NJ 07093. — *George Collins, ADØW*

Some of the Datak products designed to help your latest project acquire a professional appearance.

Hints and Kinks

Conducted By Stuart Leland,* W1JEC

UPDATING THE EXTENDED FREQUENCY RANGE MODIFICATION FOR THE COLLINS 75S-1

☐ In a previous article, "An Extended Frequency Range for the Collins 75-S-1" (October 1977 *QST*), I presented a method of extending the frequency range of the 75S-1 through an external crystal oscillator plug-in unit. The following additional modification of that circuit, providing coverage from 3.4 to 30.0 MHz, has no effect on the cosmetics of the set and the few wiring changes are so simple that the circuitry can be restored to the original state in a few minutes.

To begin the update project, carefully remove the aluminum angle shield covering the OFF-STDBY-OPER-CAL switch (S5) after unfastening the two nuts that hold the shield in place. Lay out and drill two holes to accommodate a miniature spdt toggle switch (S_{MOD}) and miniature audio jack (J_{MOD}). Make the mounting hole for the jack large enough for an insulated washer to be placed over the shaft, a necessary precaution because the jack is to be connected to the screen lead of the 75S-1 crystal oscillator, V2. The accompanying drawings will assist you in this work.

A 50-ohm miniature coaxial lead connects pin 2 of V2 to S2. Carefully unsolder the lead from S2. Then install a small terminal lug (TB_{MOD}) just in front of the crystal board in the 75S-1. Solder the lead removed from S2 to the lug. Cut and install four insulated wires, routing them as follows: Solder one lead to the terminal lug you installed and the other end to the center contact on the added toggle switch (S_{MOD}). Refer to Fig. 1C.

Solder a lead to one pole of the toggle switch and route to a point on S2 where the miniature coaxial lead was removed. Solder a lead to the other pole of the switch (S_{MOD}) and route it to one contact of the audio jack (J_{MOD}). Connect a lead to the other contact of J_{MOD} and route it to the common side of the crystals in the crystal-oscillator circuit of the 75S-1.

In order to reduce stray capacitance in the oscillator circuit, keep the leads as short as possible. Avoid movement of the leads by securing them with tie wraps or lacing cord. Do not use coaxial cable or shielded leads, which will add too much capacitance to the circuit.

After the modification is completed, touch up the oscillator alignment following the instructions in the 75S-1 manual. Peform only the oscillator trimmer adjustments if you do not wish to peak all the rf circuits. You will need to connect a 47-ohm carbon resistor from the antenna jack to ground. Also, make a signal attenuator by connecting a 0.001-µF capacitor in series with a 5000-ohm potentiometer between pin 5 of the crystal calibrator and ground. For all of these adjustments maintain an S-meter rading no greater than S3.

For general-coverage reception with this modification, place the crystal switch S_{MOD} in the general-coverage position and peak the receiver preselector. To return the receiver to the internal crystals simply throw the switch to the normal position. With the proper selection of crystals, the range of the 75S-1 will cover the frequencies within the limits I've mentioned. The only restriction is that a few "birdies" will be found from 5.0 to 6.6 MHz. — *Vernon L. Gibbs, W4JTL, Mount Sterling, Kentucky*

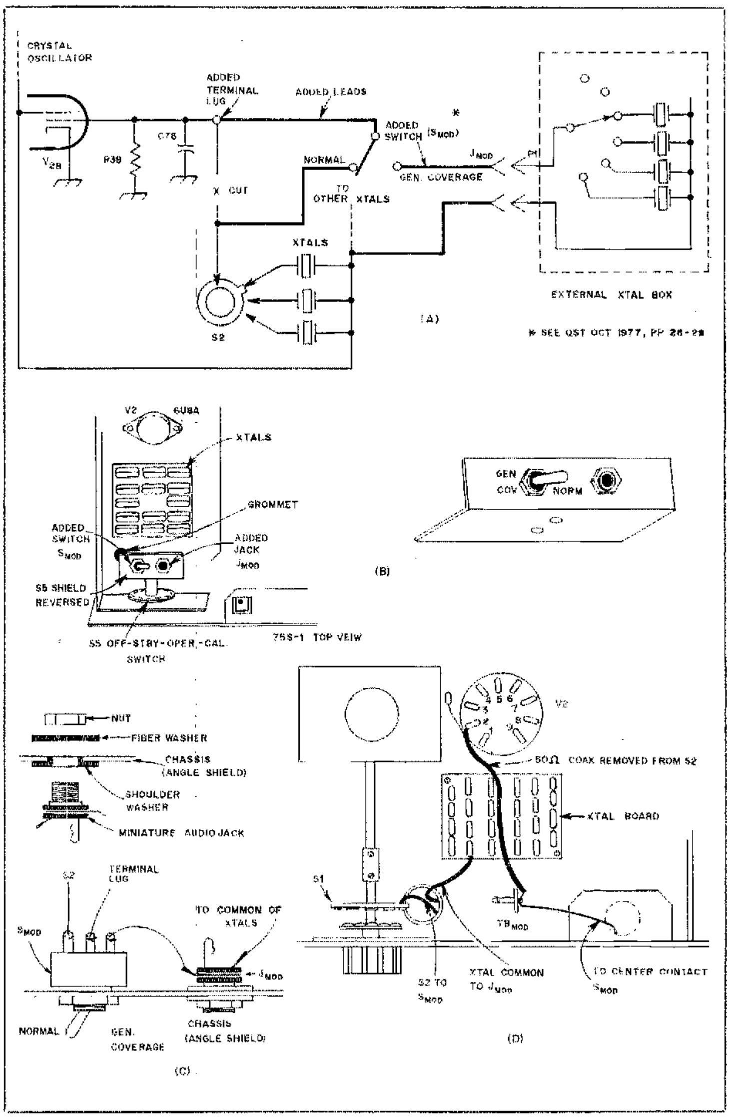


Fig. 1 — The circuit diagram at A is an expansion of the extended frequency range modification of the Collins 75S-1 described by Vernon Gibbs, W4JTL, in October 1977 *QST*. B illustrates how he installed the switch and jack for this additional modification. The jack, part of the oscillator screen circuit, is insulated from the chassis by the washers shown in C. Details for the remaining part of the modification are shown at D. Related information appears on page 94 of October 1978 *Ham Radio*.

TELEPHONE RFI

☐ When telephone company installers failed to cure RFI on my telephone line by means of the customary company capacitors and inductors, I came up with a solution to the two-year old problem that also bothered my neighbor's

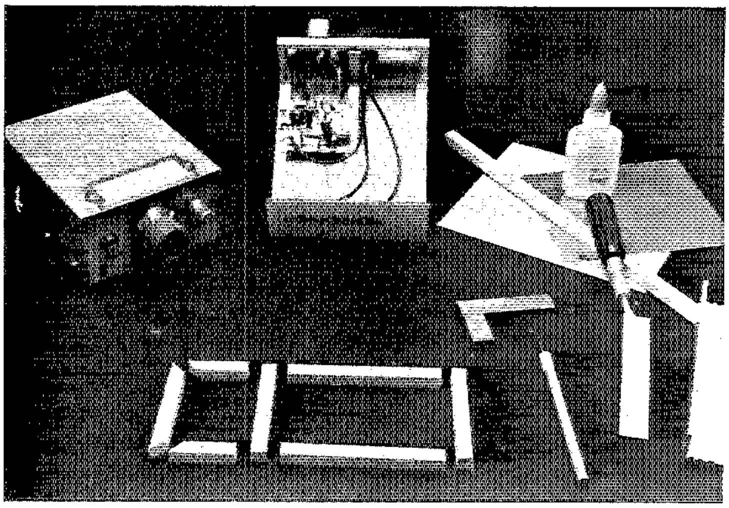
*Assistant Technical Editor

line. The inexpensive remedy is to insert ferrite beads in the line at the terminal block. With the rf field generated by my Swan 700-CX, I needed only one bead on each wire going to the various extension outlets in the house. Where the rf field is very strong, three beads may be necessary. Beads that are suitable for this purpose are Amidon's no. FB-75B-101.

Convinced of the effectiveness of the beads on my telephone line, the company agreed to try a set on my neighbor's phone. Again the little "jewels" did the job. — *Lee F. Blodgett, WØTGQ, President, Lee de Forest Chapter, QCWA, Marion, Iowa*

TAILOR-MADE ENCLOSURES FOR PROJECTS

☐ Strong, attractive tailor-made enclosures for projects are easy to fabricate using cookie-sheet aluminum plus readily available hobby materials and tools. I use 3/8-inch (10-mm)-square hardwood strips for enclosure frames, thin plywood for bottoms and aluminum for panels and covers. Form the frame to project size and match the bottom plate and panels. Use glue and brads for rigidity. Shape the cover and screw the circuit board modules to the bottom frame with small screws. Upon completion, you will have a strong, lightweight and economical unit. The accompanying photograph illustrates the tools, materials and a frame in preparation. Also shown are a partially completed transmitter and a receiver using the aforementioned technique. — *Richard McIntyre, K4BNI, Cape Coral, Florida*



Richard McIntyre, K4BNI, submitted this photograph to illustrate the simple materials he uses to make very inexpensive enclosures for his projects. See text for explanation.

VARACTOR TUNING THE MINI-MISER'S RECEIVER

☐ I built the Mini-Miser's Dream receiver from May 1978 *QST* using a pc board from Circuit Board Specialists. The local oscillator in my unit was very unstable. I traced the cause to a faulty variable capacitor. Rather than locate a new one, I chose to modify the local-oscillator circuit to a voltage-variable capacitance (varactor) type. The results were outstanding.

The drawing shows the circuit I developed. With the values shown, the tuning range is 6990 kHz to 7160 kHz. R1 is the tuning control. It is a 10-turn Helipot, thereby giving me plenty of vernier action. Performance is excellent: I am unable to measure any drift from a cold start to a period much later. The diodes I used are MSI Electronics no. ZC-808. Other brands of tuning diodes should work equally well in this circuit, provided the capacitance range is selected for the frequency spread desired. — *Kit Kohlmoos, W6ISO, Palo Alto, California*

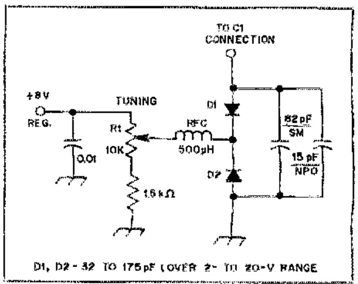


Fig. 2 — Excellent stability is provided in the Mini-Miser's Dream Receiver (May 1978 *QST*) by installing varactor tuning of the local oscillator. The circuit is the work of Kit Kohlmoos, W6ISO. Resistance is in ohms. Capacitance is in picofarads except for the decimal value, which is in microfarads.

TS-180S SEMI BREAK-IN CW

☐ A number of TS-180S transceivers I have heard on the air have a more or less severe dwell on the first cw character when the VOX relays activate. The owner can diagnose the fault by 'scoping the rf envelope or by listening with a separate receiver (agc off). The dwell is aggravated if less than full power is used.

My transceiver was severely affected, probably as a result of worst-case component tolerances. Comments about my signal from other hams were quite positive until a ham neighbor broke the news to me after a late-evening test on a dead band where we worked semi break-in.

The heart of the matter is the slow recovery of switching transistor Q18 from hard saturation. It is located on the i-f board and is responsible for changing the operating point of FETs Q16 and Q17 between transmit and receive (see "Speech Processor" in section 6.6 of the operating manual). In receive mode, Q18 is hard saturated and you might find the V_{CE} near zero volts. In the transmit mode, Q18 has no base drive and the V_{CE} is about 2 volts as the product of the combined currents of Q16 and Q17 across R94 (470 ohms).

The cure is to bring Q18 out of hard saturation by changing the base-to-ground resistor R75 (on the far side of the i-f board) from 10 kΩ to a lower value. This diverts base drive and changes the discharge time constant of C170 (3.3 µF) and R75. The new value of R75 is found in the receive mode. Decrease R75 until Q18 shows between 50 and 100 mV V_{CE}, an indication that it is out of hard saturation. The new value may be as low as 1.8 kΩ.

This modification fully cures the changeover problem and does not affect the normal keying waveform. Neither does it affect ssb or normal cw operating conditions. — *W. F. Kohlrausch, KB2FS, Woodstock, New York*

HINTS

☐ Nuts and bolts that become loosened by vibration can be secured by applying a drop of Loctite liquid to the threads. — *John C. Nelson, W2FW, Rotterdam, New York*, Hints and Kinks for the Radio Amateur (1968)

☐ After giving my Accu-Keyer the initial test, I noticed the first dit or dah of a string was longer than the rest. As it states in *The Radio Amateur's Handbook*, the problem can be solved by changing the value of R5. Instead of digging through the junk box for resistors close to the original value, I installed a 500-ohm miniature potentiometer directly on the board. By repeatedly starting a string of dits or dahs, the first lock pulse can be set to equal the rest by listening to it. The mini-pot does not obstruct the mounting scheme, as it is not too large. — *Rick Dolinsky, WB3JZA, Tamaqua, Pennsylvania*

REMEDY FOR CRYSTAL CALIBRATOR

☐ When I completed the "Weekender Crystal Calibrator" project (July 1979 *QST*), I encountered a slight harmonic difficulty. The 1-MHz harmonics were present at the output upon depressing S1. When S1 was released and S2 was activated, however, the output contained harmonics of 200 kHz instead of the expected 100 kHz. Furthermore, 20-kHz harmonics instead of 10 kHz appeared at the output with S3 depressed.

I traced the problem to a glitch in the 1-MHz waveform that caused the first decade counter (U2) to be clocked at a 2-MHz rate. By connecting a 0.01-µF disc capacitor across U1B (pin 4 to pin 6), the problem was eliminated. A smaller value of capacitance would probably work, but the results with the 0.01-µF capacitor were so complete that I made no further experiments with other values. I now enjoy the luxury of those 10-kHz calibration points. — *Donald R. Stickle, K2OX, Lake Hopatcong, New Jersey* QST

Feedback

☐ I wish to apologize for my error in the schematic diagram of "An Optimized QRP Transceiver" (August 1980 *QST*). The phasing of T1 is incorrect as shown. Since writing the article I have developed an improved buffer that uses fewer parts, is insensitive to phasing, and is less critical with regard to output transformer choice. In addition, it will work as shown from 160 to 10 meters. I encourage builders to use it instead of the one shown in the schematic.

Other comments: For people who aren't trying for extremely small size, T3 and T4 may each be more easily wound with five trifilar turns on a T37-72 core. D1 was not identified on the parts list. It is a 15-volt, 400-mW Zener, 1N965 or equivalent. — *Roy W. Lewallen, W7EL*

☐ The foil-side view of the FT-101ZD final amplifier board shown in "Hints and Kinks" (May 1980) is incorrect; a corrected layout is shown here.

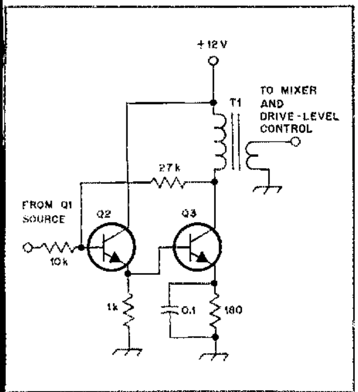
☐ The coil winding data for Fig. 4 of "A High-Performance Synthesized 2-Meter Transmitter," September 1980 *QST*, was inadvertently omitted.

L1 — 2 turns no. 20, 1/4-in. (6-mm) ID.
L2 — 5 turns no. 20, 1/4-in. (6-mm) ID.
L3 — 1 turn no. 18, 1/4-in. (6-mm) ID.
L4 — 2-1/2 turns no. 18, 3/8-in. (9.5-mm) ID.
L5 — 1 turn no. 18, 3/8-in. (9.5-mm) ID.
L6, L8 — 5-1/2 turns no. 18, 3/16-in. (4.8-mm) ID.
L7 — 4-1/2 turns no. 18, 3/16-in. (4.8-mm) ID.

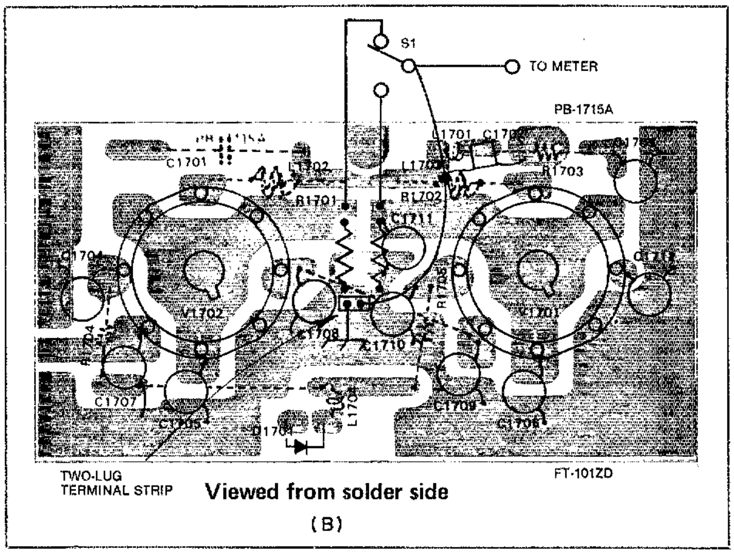
☐ The address of Communications Specialists was inadvertently omitted from the product review of the TE-64 tone encoder in September *QST*. That address is: Communications Specialists, 426 West Taft Ave., Orange, CA 92667.

☐ The address of Maurice A. Knight, Jr., ex-8AOK, was incorrectly listed in September "Silent Keys." It should have read Akron, OH.

☐ Apologies to Guido Emiliani, whose last name we misspelled as first author of the article, "An S-band Receiving System for Weather Satellites." The caption for Fig. 7 on page 30 for that article should read "The triplers Q8 and Q9 . . .," not Q7 and Q8.



An improved VFO buffer for Lewallen's "Optimized QRP Transceiver." Cores listed below are available from Amidon Associates, 12033 Otsego St., North Hollywood, CA 91607, or from Radiokit, Box 411, Greenville, NH 03048.
Q1, Q2 — General-purpose, silicon npn, 310 mW; 2N3904 or equiv.
T1 — Pri. 15 t., sec. 3 t. on T37-72 core, or pri. 10 t., sec. 2 t. on BLN-43-2402 core. Phasing is unimportant.



Corrected parts layout for the FT-101ZD final-amplifier board.

Strays

COMPUTER NET INFO

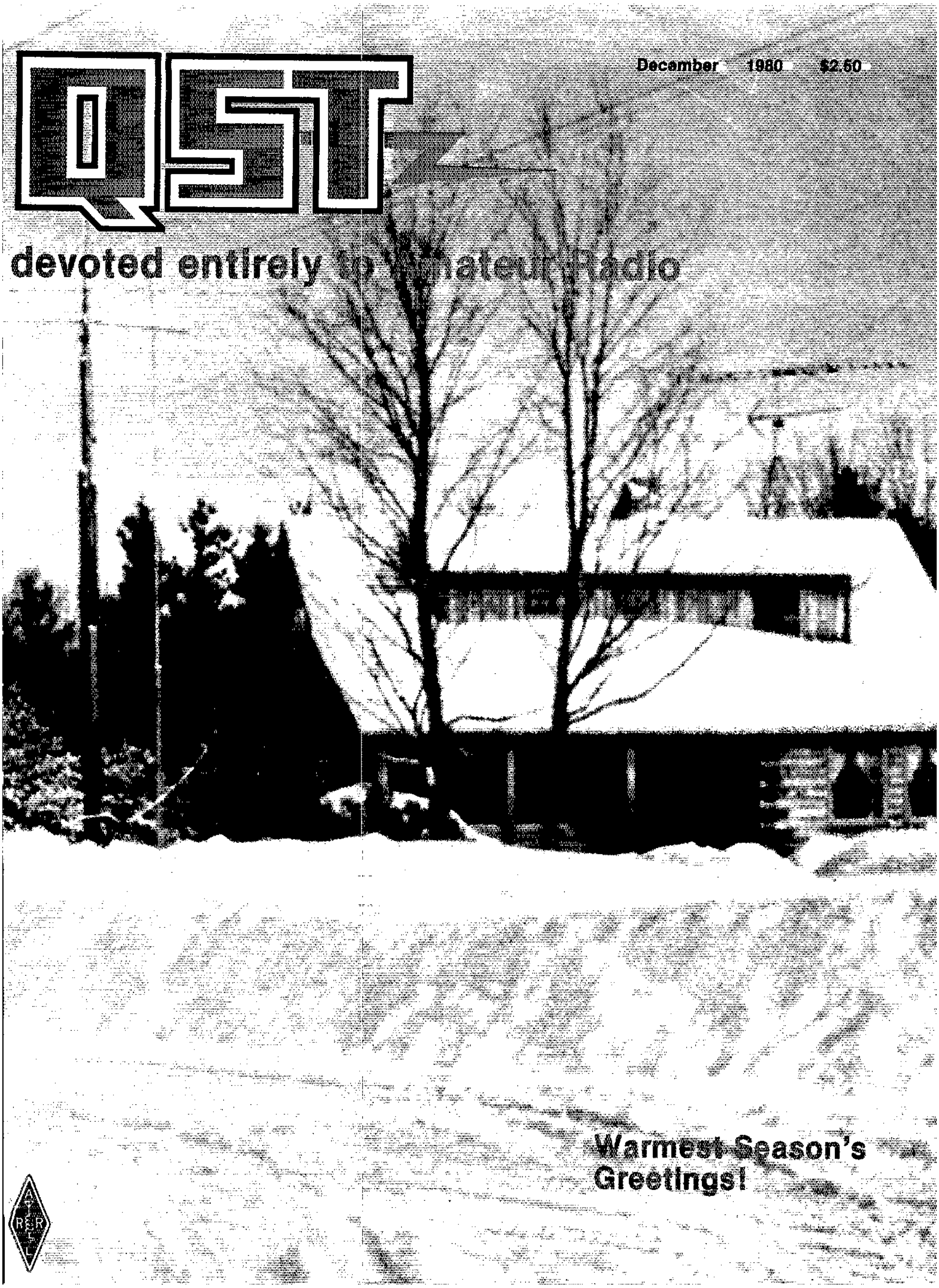
☐ David P. Allen, W1UKZ, of Scituate, Massachusetts, serves as NCS on three computer nets. An East Coast Apple net meets at 1300 UTC on Saturdays on or near 7260 kHz, lsb. In the Boston area there is a 2-meter Apple net on the Norwell (65/25) repeater at 8 P.M. local time on Wednesdays. A new Atari international net meets at 0100 UTC on Tuesdays on 20 meters, near 14,329 kHz, usb.

SEANET CONVENTION

☐ The annual SeaNet convention will be held in Manila, Philippines, November 27 to 29. Information about convention details can be obtained from the SeaNet, which meets daily at 1200 UTC on 14,320 kHz, or by writing Earl Hornbostel, Box 445, Greenhills Post Office, Metro Manila, Philippines 3113. Radiograms (telegrams) may be sent to "Valex" Manila, Philippines, and Telex to RCA (722) 27840, Answerback: FEW PH, Attn: Hornbostel.

ROBINS USE MORSE CODE

☐ No, not the birds — Morse code is making a comeback at the 5th Combat Communications Group at Robins Air Force Base, Georgia, where radio operators are dusting off code keys and learning to send and receive the code. Morse is being revived at the direction of higher headquarters because it is an effective means of communications during periods of jamming. Any prospective hams there? — *Edward F. Warren, K8RD, Torrance, California*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THE COVER

A crisp winter's day at W1NH, Newport, New Hampshire. As the snow flies, Bill's triband, 2-el quad on a homebuilt, foldover tower will likely once again bring in his share of DX. *(photo courtesy W1NH)*

Contents

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General

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Organizational and Regulatory

Departments

Organizing Amateur Communications for Public Events

Want your activity to get off to a good start? Follow these proven steps and Amateur Radio will stand out in the crowd.

by Robert C. Diefenbach,* W4NEK

Photo courtesy The Atlanta Journal and Constitution

Congratulations! If you have taken on the job of organizing a group of amateurs to provide communications for a public event, you are in an opportunity-filled position. Trouble is, some problems come along with the opportunities.

If things go right, you stand to get well-deserved applause from your fellow hams and the organizers of the event. But if you organize poorly, you have an equally good opportunity to wind up on everyone's blacklist. By going about your organizing chores *professionally* you will just about guarantee a successful project.

"Winging" a public service effort is the absolute tops in unprofessionalism. If you organize ham activities without careful planning, sooner or later you will wind up publicly embarrassed — like the organizer who talked a dozen or so well-intentioned hams into working a military air show without first discussing amateur participation with the officials involved.

The volunteer hams, asked to report to the host Air Force base at 8 A.M., waited without instructions for three hours in a parking lot. Finally, the organizer assigned them to various spots around the base, including a control tower where the Deputy Base Commander was surprised to see a civilian communicator appear. Clearly annoyed, the officer borrowed the ham's radio to give the hapless organizer (and all the others listening on the frequency) a few facts he should have checked beforehand. The hams' assistance was not needed and had not been officially requested. The military "official" who had initiated the project, a sergeant friend of the embarrassed organizer, had no authority to invite the hams to participate! Color several faces red.

The Essentials

Professional organization of a public-event project is built on these essentials:

1) Assurance that amateurs' participation is considered important by the event organizers and the local ham community.

2) Participating hams' anticipation that working the event will be hassle-free, interesting and, hopefully, fun.

3) Agreement with the event organizers on exactly what the amateur communicators' roles can and will be.

4) Careful advance planning of every facet of the operation — in detail. This includes identifying and defusing potential problems.

5) Understanding and endorsement of the operational plan by everyone involved.

6) Appropriate recognition of each participating amateur's contribution.

Without the foundation formed by these organizational "musts," you may not have a workable project. Until it is *known* that all the essentials are established or attainable, an organizer should be very cautious about accepting a project or recruiting volunteers. Instead of going naively ahead hoping that loose ends will come together, it may be wiser to decline the project. Our friend at the air show could have avoided having his wings clipped in public.

Did I hear you ask, "How will I know if those 'essentials' are established or attainable?" Good question. The answer is: Be a pro! Do what a professional in any field would do. Start by collecting the

*2402 Lauderdale Dr. N.E., Atlanta, GA 30345

Getting Organized

Although it doesn't cover all possible questions for every type of event, this checklist addresses some key steps in the organizing process.

Justification for Project

☐ Has amateur participation been requested or okayed by the appropriate authority?
☐ Is the requested ham involvement considered important to the success of the event by the event organizers?
☐ Among the event organizers, who has what authority?

Resources

☐ What is the least number of volunteers needed to do the job?
☐ How will volunteers be recruited?
☐ Is each volunteer's equipment appropriate? Frequency selection? Portability? Power supply? Antennas?
☐ Are certain frequencies generally too popular for dedication to the project without inconveniencing non-participating hams?
☐ Can one or more repeaters be dedicated to the event?
☐ Are special vehicles such as four-wheel drive and pickup trucks needed for some assignments?

Priorities

☐ If you have too few volunteer operators to fill all assignments, which assignments are least and most important to the project?
☐ If you have more volunteers than needed to fill all assignments, can the "extra" operators be assigned acceptably?

Logistics

☐ During the event, who must hear what?
☐ Should more than one frequency be used? If so, should they be interfaced somehow?
☐ Do assignments call for vehicle-mounted radios? Portable radios? Special power or antennas?
☐ Could bad weather or other factors cancel the event? If so, how will cancellation be announced?
☐ How will participating amateurs receive information and materials?
☐ Who has authority to okay necessary access, parking and so on?
☐ Are special passes or other credentials needed?
☐ Are earphones, noise-canceling microphones or other special equipment required?

Legal/Regulatory

☐ Who is liable for personal injury, equipment loss or damage, etc., suffered or caused by amateurs during the event?
☐ Do event organizers realize that hams must operate within FCC regulations and should not be asked to violate those regulations?
☐ Do participating hams understand that they are individually responsible for operating within FCC regulations?
☐ Will participating amateurs be reimbursed for non Amateur Radio-related expenses?*

Recognition

☐ Are all involved organizations aware of amateurs' participation in the event?
☐ Will the event publicity include mention of ham radio?
☐ Will the event organizers originate individual "thank you" letters or similar personalized recognition?
☐ If souvenirs are to be given to others involved with the event, will amateurs be included?

Miscellaneous

☐ Are there conflicts among event organizers that may affect amateur participation?
☐ Do certain amateurs prefer to work, or not work, together?
☐ Will participating amateurs allow others, such as news media personnel, to listen to QSOs for the purpose of publicizing the event?

Most, if not all, of these questions will apply to whatever project you are organizing. And there will be other questions too, specific to your project, which will need answering before and while you make your plans.

*[Editor's Note: It is best to be cautious about accepting any type of compensation from event organizers, as §97.112 of the U.S. Amateur Regulations prohibits operation of an amateur station "for material compensation, direct or indirect, paid or promised."]

Volunteer work can be fun. Careful and thorough advance planning of a public event will ensure that participating amateurs, like these in North Carolina, serve a useful and productive role.

relative information. Use that information, and other peoples' expertise if necessary, to decide: (1) What are the objectives of the amateur involvement? (2) Given the resources available, what, realistically, can be done to reach the objectives? and (3) What actual or potential obstacles exist, and how can they be avoided?

What information relates to these decisions, and where it can be found, depends on the event. Most is readily available simply by talking with event officials, looking over the site(s), checking maps, and reading promotional brochures or newspaper stories about the event or similar ones. Other information, particularly that which depends on other peoples' actions and decisions, may be more difficult to gather but is often important to your decision making. For example: You can't decide whether hams can use vehicle-mounted radios while parked on Main Street until someone else (the event organizer? the police? the mayor?) decides whether or not hams will be authorized to park on Main Street during the parade.

If you've recruited volunteers without portable capability, only to learn on parade day that all parking on Main Street is banned, your project is in trouble. But if you had thought of a last-minute parking ban as a potential obstacle during your early planning, and had hedged against it by insisting that each ham assigned to Main Street have a hand-held transceiver available, you are still in business!

Smooth The Way

As an organizer your role is to facilitate — to smooth the way. If you do your job well the hams working on the event will have a minimum of hassle because you will have prearranged everything possible and planned for every important possibility. By the end of the event, the participating amateurs will feel they have performed an important community service, worked well as a team, and had a good time doing it!

You can't do your job — facilitating others' participation — if you get too involved in participating yourself. Name other reliable amateurs to key assignments. Leave yourself free to monitor the operation and "put out fires." If you *must* assume an on-the-air role, make it an expendable one that you can abandon if you must.

Many a well-planned operation has been arrested by Murphy's Law. You need to protect yours by having alternate plans ready to substitute for those that don't work out, and by having extra operators and backup equipment available in case of no-shows and breakdowns.

But don't overdo it! Overcomplicating a project is almost as risky as "winging" one. Inexperienced organizers sometimes *over*plan events with disastrous results. Enthusiastic ham volunteers often want to use more, or more complex, equipment than is necessary. Experienced organizers avoid these traps by keeping every facet of their operations as simple as possible.

Your aim should be: (1) to put together an easily understood and executed plan, one that is just detailed enough to do the job, with appropriate extra attention given to *critical* objectives only, and (2) to line up just enough operators and equipment to handle all the assignments in your plan, with standby operators and backup equipment at *necessary* points only.

Circulate the Plan

Once you have worked out the plan for your operation, share it with everyone involved in whatever detail *each needs to* know. At the very least, hold a meeting (on the air or off) of all the amateur volunteers to describe the plan, the ham assignments and what the volunteers can expect on the day of the event. The plan should also be explained to the event organizers and others (police, media, property owners) whose cooperation is important. Give everyone a chance to ask questions. Be receptive to suggestions: Someone may very well think of something you have overlooked.

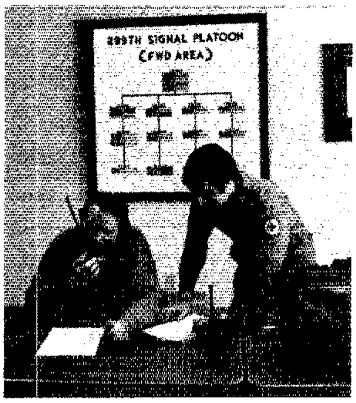
If the size and complexity of the project warrants it — and funds are available — you might distribute a printed operational plan.[1] This can include maps, traffic procedures, emergency and contingency plans, and the like. You may wish to add background information on the event, letters of thanks for the hams' participation, or a statement disclaiming liability in case of injury, damage or loss during the event.

If you have done a professional organizational job and your amateur volunteers perform with equal professionalism on E (Event) Day, you will share a satisfying experience. The entire Amateur Radio community will applaud and benefit from your efforts. You will gain an enviable personal reputation as an organizer. Hams will want to work with you on other projects, and organizers of other events will seek your help.

But before you ride off into the golden sunset of self-adulation, remember to clear up the loose ends. Ask for criticism and suggestions from the people involved in your operation. Solicited while memories are still fresh, these will be immensely helpful when you plan the next similar communications project. If the suggestions you receive include some valid ones related to the event itself, rather than to the communications effort, pass these suggestions on to the event organizers.

Be prompt and generous in thanking everyone who helped on the project. Individual letters are preferable to "Dear Volunteer" ones, and reference to a specific contribution is always a nice touch. If you receive thanks that belongs to others, too, pass them along.

While you are organizing your project, and especially on the day it all happens, remember that this is a *hobby* activity. Planning and performing like professionals doesn't take away any of the pleasure and excitement we get from Amateur Radio. To the contrary, it adds!



This Red Cross official (right), arranging an emergency fuel delivery, relies heavily on experienced amateurs for communications support. Typically, event organizers will welcome assistance from "professionally" trained amateurs.

The author is an experienced organizer of large public events and the communications supporting them. His professional and volunteer credits include two "world's largest" events.

[1]Copies of an 18-page operational plan, covering communications for a road race and parade, are available from the author at his cost ($3).

Strays

SOLAR ENERGY HELPS KEEP PITCAIRN ON THE AIR

☐ The high cost of fuel oil nearly forced Tom Christian, VR6TC, off the air recently — until a fellow amateur came to the rescue with a solar-power unit. By late 1979 the cost of fuel oil to run Pitcairn Island's diesel generators had risen to nearly $200 per barrel. At that price, the islanders could only afford to have electric power about two hours a day, and Christian's operating time was limited.

Escalating fuel cost and the fact that only a few ships call at the island each year have been frequent subjects of conversation between Christian and the amateurs who talk to him. One of those amateurs is Thorn Mayes, W7HWA, of Phoenix, Arizona. Mayes and his wife were planning a visit to Pitcairn via an island-hopping ship out of the Fiji Islands and wanted to help Christian with his power problem.

Solar energy seemed like a reasonable long-term solution, so Mayes contacted the Semiconductor Group at Motorola, Inc. Solar systems personnel agreed to help, and three 2-foot-square solar-power modules were assembled and packaged so that Mayes and his wife could take them to Tom Christian.

The Mayes's left Phoenix in late October 1979 and a month later the three solar panels were installed on Christian's antenna tower on Pitcairn. The modules contain 36 solid-state photovoltaic cells, which convert sunlight directly into electricity. Christian can store the sun-generated power in batteries, which allows him to use his rig at almost anytime of the day or night.

Christian hopes that all the island's power needs eventually can be provided through solar power. Even at today's high cost, photovoltaic power, when amortized over a 20-year period, is almost competitive with the island's cost of generating power by diesel generator. The cost of a solar-power unit of that size is more, at present, than the islanders can afford. But maybe one day Pitcairn will get all its power from electricity from the sun. — *Motorola corporate press release*


Tom Christian, VR6TC, adjusts a solar-power module on his Pitcairn Island antenna tower. The solar assembly is an alternative power source to the island's costly diesel-powered generator. *(photo courtesy Motorola, Inc.)*

Modern Design of a CW Filter Using 88- and 44-mH Surplus Inductors

Pick the values from a table, tack together some readily available (and inexpensive) components, and you've got a filter that'll aid your cw "hearability."

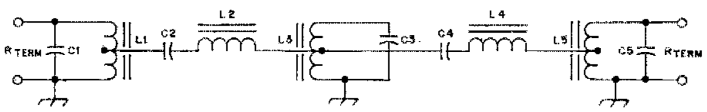
By Edward E. Wetherhold,* W3NQN

One of the most popular and frequently used circuits in Amateur Radio is the cw audio filter. Formerly, the passive LC filter was employed almost exclusively; however, the low cost of integrated circuits now makes the active cw filter economically practical and many such devices are now commercially available. The passive LC filter nevertheless has many important advantages. For example, passive filters are inherently stable whereas active filters are prone to instability and are more sensitive to component value changes and tolerances.[1] Passive filters require no power supply whereas active filters do, and passive filters are less susceptible to signal overload than are active filters. For the individual amateur, the passive LC filter is easier to build and is less expensive (because of the availability of low-cost surplus toroidal inductors) than the active filter.

An excellent technical discussion of the passive LC filter was presented by Rife.[2] Rife's Butterworth bandpass cw filter used three 44-mH surplus toroidal inductors and a number of capacitors arranged in accordance with Norton's transformation to match the selected 600-ohm termination resistances to an impedance level required by the 44-mH inductor values. The three-resonator Butterworth filter had a calculated 3-dB bandwidth of about 40% of the center frequency, and a 36/3-dB bandwidth ratio of about 4. Although the calculated 3-dB bandwidth of 353 Hz was greater than necessary (for a center frequency of 875 Hz), Rife used

Table 1

Design and Performance Parameters and Component Values for 5-Resonator Chebyshev Band-pass Filters Using 88-and 44-mH Surplus Toroidal Inductors



Fixed Inductor Values

L1, 5 = 88 mH
L2, 4 = 4(88 mH) = 352 mH
L3 = 44 mH
BW_{3dB} = 32.8% F_{MEAN}

Low-pass Filter Design Parameters

R.C. = 6.3%
A_p = 0.0173 dB
ϵ = 0.0631253968
$F_{3dB}F_{A_p}$ = 1.248

G1, 5 = 0.8265
G2, 4 = 1.3375
G3 = 1.653
G3/G1 = 2.000

F-MEAN (HZ)	C1,5 (UF)	C3 (UF)	C2,4 (UF)	R-TERM (OHMS)	BW-AP (HZ)	BW-3DB (HZ)	F-LO(3DB) (HZ)	F-HI(3DB) (HZ)
1014.	.28	.56	.0700	1763.	267.	333.	861.	1194.
996.	.29	.58	.0725	1732.	262.	327.	846.	1173.
964.	.31	.62	.0775	1675.	253.	316.	818.	1135.
948.	.32	.64	.0800	1649.	249.	311.	806.	1117.
934.	.33	.66	.0825	1624.	245.	306.	793.	1100.
920.	.34	.68	.0850	1600.	242.	302.	781.	1083.
800.	.45	.90	.1125	1390.	210.	262.	679.	942.
791.	.46	.92	.1150	1375.	208.	259.	672.	931.
783.	.47	.94	.1175	1361.	206.	257.	665.	921.
774.	.48	.96	.1200	1346.	204.	254.	658.	912.
723.	.55	1.10	.1375	1258.	190.	237.	614.	852.
717.	.56	1.12	.1400	1246.	188.	235.	609.	844.
711.	.57	1.14	.1425	1235.	187.	233.	604.	837.
655.	.67	1.34	.1675	1140.	172.	215.	557.	772.
651.	.68	1.36	.1700	1131.	171.	213.	553.	766.
646.	.69	1.38	.1725	1123.	170.	212.	549.	760.
596.	.81	1.62	.2025	1036.	157.	196.	506.	702.
592.	.82	1.64	.2050	1030.	156.	194.	503.	698.
589.	.83	1.66	.2075	1024.	155.	193.	500.	693.
548.	.96	1.92	.2400	952.	144.	180.	465.	645.
542.	.98	1.96	.2450	942.	142.	178.	460.	638.
537.	1.00	2.00	.2500	933.	141.	176.	456.	632.
531.	1.02	2.04	.2550	924.	140.	174.	451.	625.

Note: Equations and definitions of F-MEAN, C1, C3, C2, R-TERM, BW-AP, BW-3DB, F-LOW(3DB) and F-HI(3DB) are given in Appendices.

*Honeywell Inc., Defense Electronics Division, Signal Analysis Center, P. O. Box 391, Annapolis, MD 21404, Tel. 301-224-4500, Ext. 243.

[1]Notes appear on page

the filter with gratifying results. An appendix in Rife's article listed design equations for other center frequencies.

Since Rife's paper was published, many other articles on both passive and active cw filters have appeared in *QST* and *Ham Radio.* Noble discussed the application of a single-series LC combination for cw reception.[3] Most recently, Bartlett presented a similar 2-element passive LC filter with some additional circuit refinements.[4] Although these articles were useful, the design techniques presented did not significantly advance the amateur state-of-the-art filter design or use the full capabilities of the surplus toroidal inductors.

A Simple, Selective Cw Filter

The passive LC cw filter discussed here has selectivity that is equal to the best of the commercial active filters. It is easy and inexpensive to construct using surplus 88-mH inductors in their original stack form of five inductors per stack. Detailed lowpass-to-bandpass design procedures previously unpublished in amateur circles are explained, and a tabulation of component values and performance parameters are provided for those who wish to omit the discussion of the design equations. This cw band-pass filter is based on the transformation of the 5-element Chebyshev low-pass filter with a reflection coefficient of 6.3%. All inductive elements use unmodified surplus toroidal inductors — ten 88 mH and one 44 mH. To further simplify construction, all wiring interconnections are made using the terminal strips of the two inductor stacks. This 5-resonator filter has a fixed 3-dB bandwidth equal to 32.8% of any selected geometric mean center frequency, and the ratio of the 36/3-dB bandwidths is about 2.0, or twice as selective as the previously mentioned 3-resonator Butterworth filter.

For those interested only in construction of the filter, 23 precalculated designs with mean center frequencies from 531 to 1014 Hz are tabulated with component values and performance parameters. Standard capacitor values are used for C1 and C5, with additional values just on either side of the standard value. Because of the design technique used, the termination resistance is not a constant, but varies from 1763 to 924 ohms, depending on which center frequency is selected. If the center taps of the input and output inductors are used, the termination resistance will be one-quarter of those values, or about 441 to 231 ohms. The actual termination resistance is not critical and the filter will function satisfactorily if a termination resistance within about ±20% is provided.

Computer-Tabulated Band-pass Filter Values

Table I shows the filter schematic diagram and lists the filter performance parameters for C1 and C5 values from 0.28 to 1.02 μF, with corresponding center frequencies (F-Mean) of 1014 to 531 Hz. The fixed inductor values and the low-pass filter prototype design parameters are listed directly under the filter schematic diagram. The low-pass filter design parameters were used to computer-calculate all of the tabulated data for the band-pass filter. The procedures are explained in Appendix C for those who may wish to calculate new designs for different inductor values of L1 and L3.

A Chebyshev low-pass prototype design having a 6.3% reflection coefficient was used so the transformed band-pass filter value of L3 would be exactly one-half that of L1. Thus, unmodified 88- and 44-mH surplus toroidal inductors can be used for L1, L5 and L3, respectively. The bandwidth of the band-pass filter is a constant 32.8% of the mean center frequency. This particular percentage bandwidth was selected so L2 and L4 each could be made from four 88-mH inductors. Consequently, the total number of 88-mH inductors is 10, or two five-inductor stacks. By using the center taps of L1, L3, and L5 instead of the customary connections at the maximum impedance points of the tuned circuits, the inductance of L2 and L4 is reduced by 75%, from 1.408 H to 0.352 H, which is much more practical.[5] The 88-mH value was selected for use in the filter construction because this value is much more commonly available than the 44-mH value.

An alternate band-pass design based on a 5-element Butterworth low-pass prototype is also possible. In this case, the 3-dB bandwidth is 25% of the mean center frequency. Although this design is more selective than the 32.8% bandwidth of the 6.3% reflection coefficient Chebyshev filter, the design is less convenient to construct. In the Butterworth band-pass filter, L3 has a value of 27.2 mH, which requires the removal of about 56 turns from each of the two windings of

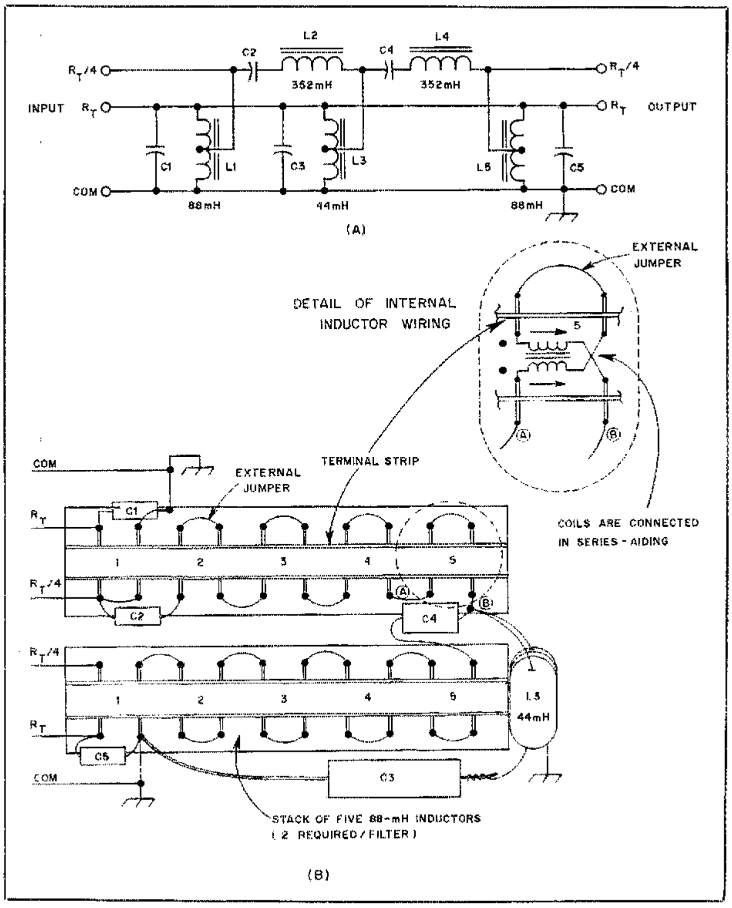


Fig. 1 — The schematic and pictorial diagrams of a 5-resonator cw filter using surplus telephone company toroids.

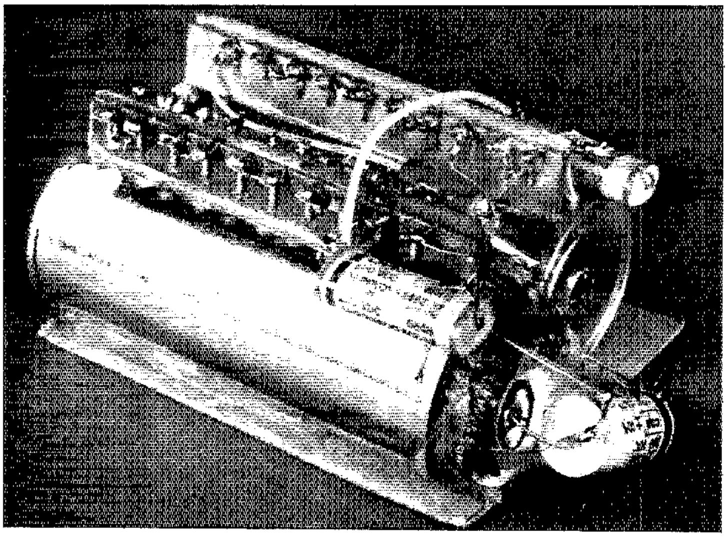


Fig. 2 — An assembled cw filter showing two 88-mH inductor stacks with the externally mounted 44-mH inductor, L3.

the 44-mH inductor, and the capacitance and physical size of C3 increase. Because the disadvantages of implementing the Butterworth band-pass design appeared to outweigh any advantages gained by the slight improvement in selectivity, the Chebyshev design was chosen.

Note that the capacitance of C1 is exactly half of C3 and four times that of C2. Thus, if the desired value of C1 is not listed in Table 1, it is easy to find the values of the other capacitors. For best results, the actual capacitance values should be within 2% of the design value; how this matching may be accomplished is discussed later. The other five tabulated parameters (R-TERM, BW-AP, etc.) are less important from a construction standpoint, and they can be approximated for any nontabulated capacitance values by interpolation of the tabulated data.

Filter Wiring and Construction

The schematic and pictorial diagrams of the bandpass filter are shown in Fig. 1. The schematic diagram is redrawn differently from the schematic diagram above Table 1 to more clearly indicate the alternate input and output quarter-impedance terminations that may be used. A suggested method of filter wiring is depicted in the pictorial diagram. Inductor interconnections and the mounting of the capacitors are greatly facilitated by using the terminal-strip lugs of the inductor stacks. The single 44-mH inductor (L3) is fastened to the rear of one of the stacks with RTV silicone rubber adhesive, and its wire leads are connected to the terminal lugs as shown.

An assembled filter is shown in Fig. 2. Inductor stacks with tinned sheet-metal covers were used; they were fastened together for stability by tack-soldering the metal cases at a few points. Inductor stacks manufactured with only a cardboard cover require a different fastening method. In this assembly, C3 was mounted on top of L3, but the method shown in Fig. 1B appears more convenient. Capacitors C1, C5 and part of C3 are metallized Mylar types; because of their physical size, they are more conveniently mounted on the inductor case. C2 and C4 are much lower in capacitance and may consist of standard Mylar capacitors paralleled to produce the design capacitance value within 2%. All inductors and capacitors will fit into a 3- × 4- × 5-in. (76- × 101- × 127-mm) aluminum box with room to spare for mounting a phone jack and dpdt switch.

Filter Performance

Fig. 3 shows the measured relative attenuation response of a band-pass filter designed for a mean center frequency of 537 Hz (see the second-to-last entry in Table 1 for the corresponding design and performance parameters of this filter). For comparison, several design (calculated) response points are also plotted and are indicated by an X. The close agreement between the measured and the calculated response values confirms that the filter was assembled correctly, and demonstrates that the inductor losses are not significant for this particular application. The effect of the inductor Q is most obvious from the response curve between the frequencies of F_m and F_{3-}; F_{3-} is the lower 3-dB frequency of the filter passband.

The rounding of the response curve at the low end of the passband is more pro-

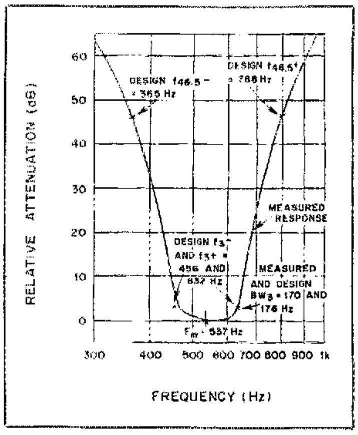


Fig. 3 — Measured relative attenuation of a 5-resonator surplus toroid cw filter.

nounced than at the high end because of the lower inductor Q. Details of the filter attenuation versus frequency calculations are discussed in Appendix D. The insertion loss of the filter is about 3 dB, typical of filters having this many elements using surplus toroidal inductors.

Installation and Operation

For best results, the filter input and output ports should be terminated in the correct resistance, either R_T or $R_T/4$, whichever value is easier to approximate. If the filter is to be installed in a low-impedance audio system, resistors should be installed in series with the filter input and output to approximate the design termination resistance. If this results in excessive signal loss or other problems caused by the extreme impedance mismatch between the filter and the low impedance of the receiver output and the headset, then transformer matching should be considered. The penalty for a gross mismatch is a narrowing of the filter attenuation skirts and the introduction of two attenuation peaks in the passband. For example, if a filter designed for termination resistance of 1000 ohms is placed in a 50-ohm system (a mismatch of 20:1), the bandwidth below 30 dB will be slightly narrower, and there will be two 8-dB attenuation peaks on each side of the center frequency.

A simple and inexpensive way of accomplishing transformer impedance matching is to use two Radio Shack no. 273-1380 (8:1000 ohm ct) audio transformers or two 300 mA, 115/6.3-volt filament transformers. Connect the low-voltage winding of the first filament transformer to the receiver headset output, and the high-voltage winding to the filter input. The high-voltage winding of the second transformer is connected to the filter output, and the low-voltage winding to the headset. Use the filter taps that give the best match. Filament transformers are recommended for this application because of their availability and low cost, and because their impedance transformation ratio approximates that required between a 4-ohm audio system and the filter termination resistance. Because this application is for a narrowband audio function, the limited frequency response of the transformer is not important.

If the source resistance (R_S) of the receiver audio output amplifier (the output that will drive the cw filter) is not known, it can be measured with an ac VOM using the following procedure.

1) Adjust the receiver BFO and audio gain control to obtain a suitable audio output tone and voltage level. The necessary receiver rf input can be provided by a crystal calibrator, a GDO or an rf signal generator.

2) Disconnect the headset or speaker load and measure the unloaded source voltage (V_S) of the audio output amplifier.

3) Connect a known resistance (R_L) across the audio output, which causes the output voltage level to drop slightly by one or two dB, and measure the loaded output voltage, V_L.

4) Calculate the source resistance (R_S) using the equation

$$R_S = R_L (V_S - V_L)/V_L$$

where R and V are in ohms and volts. For example, if $R_L = 5400$ ohms, $V_S = 1.0$ V and $V_L = 0.9$ V, then $R_S = 5400(1 - 0.9)/0.9 = 600$ ohms.

In this procedure, the output voltage is reduced slightly to ensure that the output stage is operating in its linear range and is not overloaded; overload might occur if too low a resistance is used. Also, note that this procedure is suitable only if the source impedance is predominantly resistive, as it is in this case. Take care to see that the audio output stage does not become unstable and go into self-oscillation when the headset of speaker load is removed. This will be indicated by a high output-voltage level which may not respond to the audio gain control. If this happens, connect a high-value resistance (about 20 kΩ) across the output tap having the highest impedance level, and reduce the resistance until the self-oscillation is damped out. This condition is more likely to occur in the old, tube-type receivers (such as the author's GPR-90 receiver) than in the modern transistor receivers.

For the lower mean frequencies, such as 600 Hz or below, the 3-dB bandwidth will be less than 200 Hz; this will be satisfactory for most operators. However, the bandwidth for the higher mean frequencies (above 800 Hz) will be greater than 260 Hz. If this is found to be too wide for good selectivity, then the filters of Noble and Bartlett, mentioned previously, should be considered for addition to the 5-resonator filter. Although these simple two-element filters have poor skirt selectivity, they do have a relatively sharp response at their center frequency. Thus, the combination of the 5-resonator filter with its excellent skirt response, and the single-resonator filter with its sharp center frequency response, makes for a combined filter with optimum performance. The 5-resonator filter probably will work best if it is placed between the receiver output and Bartlett's circuit. Bartlett's active input circuit will provide the desired isolation between the two filters, and the input circuit can be adjusted to provide the proper resistive loading for the 5-resonator filter.

Some users may desire a switch-selectable, broader response for general tuning across the band of operation, while reserving the maximum selectivity for use during a QSO. In this case, some experimentation can be tried, such as reducing the inductance of L2 and L4 by half with a 4-pole, 2-position rotary switch to broaden the passband response. If this is done, the proper amount of capacitance will have to be added simultaneously to maintain the LC product of the tuned circuit. I tried this, and measurements show that this change increases the 3-dB bandwidth by half again as much as before, while still maintaining a relatively flat passband response. If a sharper skirt response is desired, it can be obtained by using a 7-element low-pass Chebyshev prototype design for a 7-resonator band-pass filter. The availability of low-cost toroidal inductors and the application of the design procedures discussed in this article make such a filter quite feasible. The 7-element Chebyshev design that appears most suitable has a reflection coefficient of 8.1%, which provides an L1/L3 ratio of exactly 2/1. Thus, 88- and 44-mH inductors can again be used without modification. If the two series inductors either side of center are made to be 352 mH, and the center series inductor is made to be 396 mH (design value of 402 mH), a 32% bandwidth will result with improved skirt response. For example, the measured 36/3-dB ratio of the 5-resonator band-pass filter is about 2, while that of the 7-resonator filter is about 1.6.

Where to Get the Inductors and Capacitors

The 88-mH inductor stacks are available from Typetronics at a cost of $3 per stack with a shipping charge of $1.75 for the first stack and 80 cents for each additional stack.[6] A single order for two of the 88-mH stacks to duplicate the 5-resonator filter is $8.55. Be sure to specify "inductor stack required *with terminal board*." Also specify the preferred inductor style as "scramble-wound red and green wires." This winding style provides 99.8% coupling between the two windings, which is preferred for applications using the center-tap connection.

The 44-mH inductor is not available from Typetronics; it must be ordered from M. Reed at a cost of five for $5, prepaid.[7] At this time, M. Reed is the only known source of the 44-mH inductors.

If the 44-mH inductor is not available, an 88-mH inductor may be used instead, after removing enough turns to obtain the proper inductance. For the red/green-colored wire scramble-wound inductor, remove 110 turns from each winding (total turns removed = 220). For the inductor with two separate windings on opposite halves of the core and with the same color wire, remove 109 turns from each winding (total turns removed = 218). In either case, the windings must be connected in series aiding. For the scramble-wound inductor, connect the red wire of the start pair to the green wire of the finish pair. With the other inductor type, connect the "finish" end of one winding to the "start" end of the other winding. The inductor center tap is available at the junction of the two windings. The 88-mH inductors are also available from Reed at the same price as the 44-mH inductor, but the order must specify "88-mH, 5-inductor stack *with terminal board*"; otherwise, the inductors will be disconnected from the terminal board and removed from the container before shipping to minimize shipping weight and mailing cost.

If the reader is a member of a radio club affiliated with the ARRL, and lives in Virginia, West Virginia, Maryland or Washington, DC, there is another way to obtain the 88-mH inductor stacks. Through the cooperation of the Chesapeake and Potomac Telephone Company of Maryland, I have been able to obtain a limited number of 88-mH inductor stacks that are no longer usable by the telephone company. These surplus inductors are being made available to those amateurs living within the area serviced by the C&P Telephone Company with the understanding that they will be distributed by me at no charge (except for packing and shipping expenses) to those who will use the inductors in Amateur Radio applications. Those amateurs who have use for these inductors but live outside the area serviced by the C&P Telephone Company are advised to write to the Director of Public Relations of their local telephone company and request that surplus inductors be made available for those club activities and projects that will serve the public need in some manner.

To distribute the inductor stacks now on hand in the most expeditious and efficient manner, I will accept requests for up to 20 stacks from any ARRL-affiliated radio club located within the area serviced by the C&P Telephone Company. Once received, these inductors may not be sold for cash as this is contrary to the wishes of the C&P Telephone Company. To obtain a shipment, an officer of the radio club should write to the author and request a specific number of 88-mH inductor stacks. The names and call signs of the individual members of the club who are to receive the stacks must be listed along with the intended applications. A business-sized s.a.s.e. must be included for a reply and further instructions. All shipments will be made via UPS, so a geographical location (street number, city and state) must be provided; a P. O. Box number is not acceptable. If more requests are received than there are inductors now available, the requests and return envelopes will be held until more surplus inductors are received from the C&P Telephone Company.

Quality Mylar capacitors are available at reasonable prices from several sources.[8,9,10] The best source I have been able to find for low-cost metallized polyester capacitors is Allied Electronics.[10] These capacitors are listed on page 75 of the Allied 1980 *Engineering Manual and Purchasing Guide,* no. 800. Metallized polyester capacitors are available in values from 0.33 to 2.2 µF/250 V dc, with noninductive construction and a 10% tolerance (type ECQ-E).

It is important that all capacitor values be within 2% of the design value to ensure proper operation of the filter. The simplest and least expensive procedure to obtain the correct value capacitors for the filter is to purchase a large number of capacitors and measure each to an accuracy of about 0.5%. Years ago, this was a tedious job using an impedance bridge, but today it is simple when you use one of the many capacitance-measuring meters that are now priced as low as $130.[11] The C-meter I prefer is the Data Precision Model 938, which has an accuracy of 0.1% and a 3-1/2-digit liquid crystal display (for longer battery life).[12] The cost of such a C-meter is within the budget of most radio clubs, and the use of such a meter will allow the proper selection of capacitors for all projects that the members may wish to undertake.

Conclusion

Rife's statements — that the design techniques used in his article are not new; they are routinely used by filter designers, but amateurs have made little use of them — are certainly still applicable to the present.[13] But perhaps with this second demonstration other amateurs will find new applications for both the modern design technique and the surplus toroidal inductors.

I gratefully acknowledge the cooperation of John Kirby, N3AAZ, Frank Noble, W3MT, and Bill Robert Jr., N5BON, for providing comments on the filter performance under actual operating conditions. The assistance of Rex Cox, of Honeywell Inc., and Joseph Gutowski, of EWC, Inc. is also gratefully acknowledged for their review of this article. QST

Appendix A
Definitions and Equations

(Refer to Figs. 6 and 7.)

F-mean — geometric mean or center frequency (Hz) of the band-pass filter attenuation response.

R-term — filter termination resistance in ohms.

A_p — peak amplitude (dB) of the passband attenuation ripple.

A_s — stopband attenuation (dB).

F_{Ap} — frequency (Hz) where the passband attenuation level first exceeds the A_p level (denotes the end of the passband).

F_{As} — frequency (Hz) corresponding to a stopband attenuation level of A_s.

BW_{Ap} — bandwidth (Hz) between upper and lower frequencies at the A_p(dB) level on the attenuation response curve.

BW_x — bandwidth (Hz) between upper and lower frequencies at x attenuation level.

$F\text{-}HI_{(x)}$, $F\text{-}LO_{(x)}$ — upper and lower frequencies (Hz) at the x dB attenuation level on the attenuation response curve.

R.C. — reflection coefficient (%).

ρ — absolute value of R.C. in decimal form (used in following equations).

ε — ripple factor, a parameter <1 related to the ripple amplitude.

n — number of branches in a ladder network (equal to number of reactive elements in the low-pass prototype filter discussed in this article).

T — Chebyshev polynomial (T used instead of C to prevent confusing with capacitance).

Ω — normalized frequency $= F_{As}/F_{Ap}$.

G1-5 — normalized element values (1-5).

(*1*) $\rho = (1 - 0.1^{0.1A_p})^{0.5}$

(*2a*) $A_p = -10 \cdot \log(1 - \rho^2)$ dB

(*2b*) $A_p = 10 \cdot \log(1 + \varepsilon^2)$ dB

(*3a*) $\varepsilon = (10^{0.1}A_p - 1)^{0.5}$

(*3b*) $\varepsilon = \rho/(1 - \rho^2)^{0.5}$

For example, if R.C. = 6.3%, then ρ = 0.063, A_p = 0.0172714 and ε = 0.0631254.

Appendix B
Calculation of F_3/F_{Ap} ratio (or BW_3/BW_{Ap} ratio)

Where F_3 is the 3-dB cutoff frequency (BW_3 is the 3-dB BW), F_{Ap} is the A_p-dB cutoff frequency (BW_{Ap} is the A_p-dB BW),

A_p is the max. passband attenuation, n = number of filter elements, $1/\varepsilon = [(1-\rho^2)/\rho^2]^{0.5}$, and ρ = (R.C.%)/100.

(*1*) $F_3/F_{Ap} = \cosh[(\cosh^{-1} 1/\varepsilon)/n]$
For R.C. = 6.3%, $1/\varepsilon$ = 15.841485.
Let n = 5.

Hyperbolic functions in terms of natural logs and exponents:

$\cosh^{-1}x = \ln[x + (x^2 - 1)^{0.5}]$, $\cosh y = 0.5[e^y + e^{-y}]$, e = 2.718282.

Let $x = 1/\varepsilon$, then $\cosh^{-1}x$ = 3.4547816;
Let y = (3.4547816)/5 = 0.6909563,
then cosh y = 0.5[1.995623 + 0.501097],
F_3/F_{Ap} = 1.24836 or 1.248.

(Note: For band-pass design, $BW_{Ap} = F_{Ap}$ and $BW_3 = F_3$.
Thus, $BW_{Ap} = BW_3/1.248$ for ρ = 0.063 and n = 5.)

Simplified equations to find F_3/F_{Ap} when A_p < 0.1dB (R.C. < 15%).

(*2a*) $F_3/F_{Ap} \approx 0.5(K + 1/K)$, where.

(*2b*) $K = (2/\varepsilon)^{1/n}$.

For example, if A_p = 0.0172714, ε = 0.063125 and n = 5, then K = 1.99602 and F_3/F_{Ap} = 1.2485.

Appendix C
Design Equations for Five-Resonator Chebyshev Band-pass Filters

In the following equations, F_{mean}, BW_{Ap}, BW_3, F_{LO} and F_{HI} are in Hz, and all capacitances and inductances are in farads and henrys unless otherwise stated. Fig. 4 (below) shows the schematic diagram of the band-pass filter.

(*1a*) $F_{mean} = 1/[2\pi(L1 \cdot C1)^{0.5}]$

(*1b*) $F_{mean} = 536.51/(C1)^{0.5}$,
for L1 = 0.088H with C1 in µF.

(*1c*) $F_{mean} = [F_{LO_x} \cdot F_{HI_x}]^{0.5}$, where x is any attenuation level in dB, and F_{LO} and F_{HI} are the low and high band-pass frequencies at the x attenuation level.

(*2a*) $BW_{Ap} = F_m[(G1 \cdot G2)L1/L2]^{0.5}$, the basic equation for calculating BW_{Ap}. See Appendix D for G1, 2 values.

(*2b*) $BW_{Ap} = 0.25 \cdot F_m[G1 \cdot G2)^{0.5}]$,
for L1/L2 = 0.088H/1.408H = 0.0625.

(*2c*) $BW_{Ap} = 0.26285 \cdot F_m$, for R.C. = 6.3%, G1 = 0.8265 and G2 = 1.3375.

(*3a*) $BW_3 = 1.248 \cdot BW_{Ap}$, for R.C. = 6.3% and BW_3 = 3-dB bandwidth of BP filter.

(*3b*) $BW_3 = 0.328 \cdot F_m$.

(*4a*) $R_{term} = 2\pi(BW_{Ap})L2/G2$, where R_{term} is the filter source and load resistance in ohms.

(*4b*) $R_{term} = 6.6144 \cdot BW_{Ap}$,
for L2 = 1.408H and G2 = 1.3375.

(*4c*) $R_{term} = 932.773/(C1)^{0.5}$, for C1 in µF.

(*5a*) C3 = 2(C1), L3 = 0.5(L1).

(*5b*) C2 = (C1)/16, L2 = 16(L1).

(*6a*) $F_{LO_x} = -BW_x/2 + [F_m^2 + (BW_x/2)^2]^{0.5}$

(*6b*) $F_{HI_x} = F_{LO_x} + BW_x$

All resonant circuits are tuned to F_m.

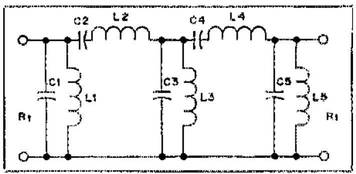


Fig. 4 — Schematic diagram of a 5-resonator band-pass filter.

Appendix D
Calculation of Filter Stop-band Attenuation and Lowpass-to-Bandpass Transformation Procedure

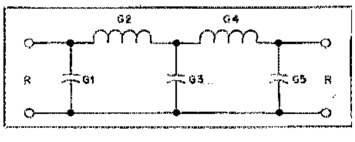


Fig. 5 — Low-pass prototype schematic diagram.

F_{Ap} = 1 rad/sec, R = 1 ohm.
Normalized Values: G1, 5 = 0.8265 F, G2, 4 = 1.3375 H, G3 = 1.6531 F, ρ = 0.063, A_p = 0.0173 dB, F_3/F_{Ap} = 1.248, ε = 0.0631254.

Equations used in the calculation of the stopband attenuation (A_s) of a five-element low-pass filter with ρ 0.063.

(*1*) $A_s = 10 \cdot \log[1 + (\varepsilon \cdot T_\Omega)^2]$ dB

(*2*) $T_\Omega = 16\Omega^5 - 20\Omega^3 + 5\Omega$,
$\Omega = F_{As}/F_{Ap}$

(*3*) $\varepsilon = \rho/(1 - \rho^2)^{0.5}$

For example, if F_{Ap} = 1 kHz, find A_s @ 2 kHz.

(*From Eq. 3*): ε = 0.0631254

(*From Eq. 2*): $T_\Omega = 16 \cdot 2^5 - 20 \cdot 2^3 + 5 \cdot 2$, $\Omega = 2$.

(*From Eq. 1*): $A_{s2kHz} = 10 \cdot \log[1 + (\varepsilon \cdot T_\Omega)^2]$ dB where T_Ω = 362.

$A_{s2kHz} = 10 \cdot \log[1 + 522.2]$ dB

$A_{s2kHz} = 10(2.719)$ dB = 27.2 dB.

In a similar manner the stopband attenuation can be found for any value of F_{As}. Table 2 lists the calculated values of $T_{(\Omega)}$ and A_s versus normalized frequency. Fig. 6 shows the attenuation response of a typical LP filter.

The LP-to-BP Transformation Procedure for Designing a Chebyshev Band-pass Filter

1) Select the desired filter F_m, the 3-dB BW and the R_t design values.

2) Select a specific reflection coefficient (ρ) and calculate the corresponding BW_{Ap} (see Appendix B). See Table 3 for normalized component values (G1-G5).

3) Use the following equations to calculate the component values of an LP filter having an A_p-cutoff frequency *equal to the BW_{Ap} of the BP filter*, and having the same R_t and ρ as the BP filter: $L' = L \cdot R_t/\omega$ and $C' = C/(R_t \cdot \omega)$, where L' and C' are the component values and L and C are the normalized values in henrys and farads, and $\omega = 2\pi \cdot F_{Ap}$.

4) Transform the LP filter into a BP filter by resonating all capacitors and inductors to F_m. For example, let F_m = 536.5, BW_3 = 176, R_t = 932.8 & ρ = 0.063. From Appendix B, F_3/F_{Ap} = 1.248, F_{Ap} = 176/1.248 = 141 Hz. Normalized values of G1, 5, G3 and G2, 4 = 0.8265, 1.653 and 1.3375. C1, 5 = $0.8265/(2\pi \cdot 141 \cdot 932.8)$ = 1.00 µF, L2, 4 = $1.3375\ (932.8)/(2\pi \cdot 141)$ = 1.408 H and C3 = 2.00 µF. Resonate all C's to F_m with shunt inductors and all L's with series capacitors using the following equations: $L_{sh} = 1/[2\pi \cdot F_m)^2C]$ and $C_s = 1/[2\pi \cdot F_m)^2L]$. L1, 5 = 88 mH, L3 = 44 mH and C2, 4 = 62.5 nF. The transformed BP filter schematic is shown in Fig. 4 and the filter attenuation values and other parameters are listed in Table 2.

Table 2

LP and BP Filter Parameters vs. Normalized Frequency for R.C. = 6.3%, F_m = 536.5 Hz & BW_{Ap} = 141 Hz

NORMALIZED FREQ. (Ω)	$T_{(\Omega)}$	ATTEN. AS (DB)	BW (HZ)	F-LO (HZ)	F-HI (HZ)
1.000	1.0	.0173	141.	471.	612.
1.200	11.3	1.7742	169.	459.	628.
1.248	15.8	3.0000	176.	456.	632.
1.300	22.0	4.6580	183.	453.	636.
1.338	27.4	6.0000	189.	450.	639.
1.40	38.2	8.3	197.	447.	644.
1.50	51.5	12.1	212.	441.	653.
1.60	83.9	15.6	226.	435.	661.
1.80	194.7	21.8	254.	424.	678.
2.00	362.0	27.2	282.	414.	696.
2.50	1262.5	38.0	353.	388.	741.
3.00	3363.0	46.5	423.	365.	788.
4.00	15124.0	59.6	564.	324.	888.
4.50	27724.5	64.9	635.	306.	941.

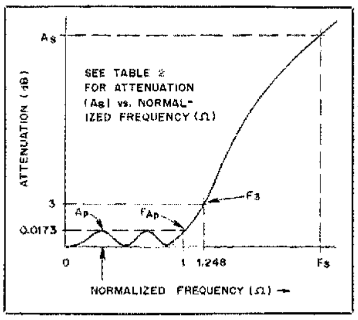


Fig. 6 — Attenuation vs. frequency for a 5-element Chebyshev low-pass filter (R.C. = 6.3%).

Table 3

Normalized Component Values (G1-G5) for 5-Element Chebyshev Low-pass Filters

R.C. (%)	F3/FAP RATIO	A-P (D B)	(G1&G5) (F)	(G3) (F)	(G2&G4) (H)
.80	1.674	.00028	.4604	1.182	1.011
1.00	1.616	.00043	.4871	1.226	1.050
1.20	1.571	.00063	.5103	1.262	1.081
1.40	1.534	.00085	.5311	1.293	1.108
1.60	1.504	.00111	.5503	1.321	1.131
1.80	1.478	.00141	.5682	1.346	1.151
2.00	1.455	.00174	.5848	1.369	1.169
2.40	1.417	.00250	.6153	1.409	1.200
2.80	1.387	.00341	.6430	1.445	1.225
3.20	1.362	.00445	.6686	1.476	1.246
3.60	1.340	.00563	.6924	1.504	1.264
4.00	1.322	.00695	.7148	1.530	1.280
4.50	1.302	.00880	.7414	1.561	1.296
5.00	1.284	.01087	.7664	1.588	1.310
5.50	1.269	.01316	.7903	1.614	1.322
6.00	1.256	.01566	.8132	1.639	1.332
6.30	1.248	.01727	.8265	1.653	1.337
6.50	1.244	.01839	.8353	1.662	1.341
7.00	1.233	.02133	.8565	1.685	1.348
8.00	1.214	.02788	.8973	1.727	1.359
10.00	1.184	.04365	.9732	1.803	1.372

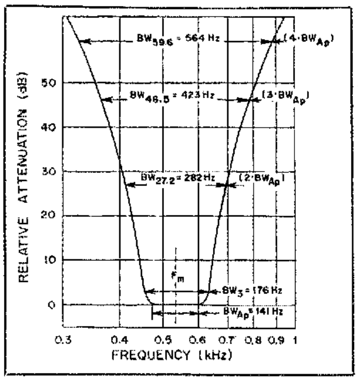


Fig. 7 — Calculated attenuation of a 5-resonator band-pass filter with R.C. = 6.3%, F_m = 536.5 Hz, and BW_{Ap} = 141 Hz.

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[1]Saal, *The Design of Filters Using the Catalog of Normalized Lowpass Filters*, Telefunken, 1966.

[2]Zverev, *Handbook of Filter Synthesis*, John Wiley and Sons, 1967.

[3]Geffe, *Simplified Modern Filter Design*, John F. Rider Publisher, Inc., 1963.

[4]Daniels, *Approximation Methods for Electronic Filter Design*, McGraw-Hill, 1974.

[5]Blinchikoff and Zverev, *Filtering in the Time and Frequency Domains*, John Wiley and Sons, 1976.

[6]Wetherhold, "Inductance and Q of Modified Surplus Toroidal Inductors," *QST*, September 1968.

[7]DeMaw, "The Practical Side of Toroids," *QST*, June 1979.

[8]Wetherhold, "Low-Pass Filters for Amateur Radio Transmitters," *QST*, December 1979.

[9]Wetherhold, "7-Element 50-ohm Chebyshev Filters Using Standard-Value Capacitors," *RF Design*, Vol. 3, No. 2, February 1980.

[10]Wetherhold, "Lowpass Chebyshev filters use standard-value capacitors," *Electronics*, June 19, 1980, Engineer's Notebook, pp. 160-161.

Notes

[1]Su, "Active Filters," *IEEE Circuits and Systems*, October 1976.

[2]Rife, "Low-loss Passive Bandpass CW Filters," *QST*, September 1971.

[3]Noble, "A Passive CW Filter to Improve Selectivity," *QST*, November 1977.

[4]Bartlett, "A Simple CW Audio Filter," *QST*, April 1979.

[5]Wetherhold, "Low-loss Passive Bandpass CW Filters," Technical Correspondence, *QST*, January 1972.

[6]Box 8873, Fort Lauderdale, FL 33310.

[7]Box 74, Soquel, CA 96073.

[8]Electronic Distributors, Inc., 4900 N. Elston Ave., Chicago, IL 60630.

[9]Edlie Electronics, Inc. 2700 Hempstead Tpke., Levittown, NY 11756.

[10]Allied Electronics, 401 East 8th St., Fort Worth, TX 76102.

[11]"Comparing Hand-held Capacitance Meters," *Electronic Design*, April 12, 1979, p. 161.

[12]"Product Review," *QST*, November 1979, p. 51.

[13]See note 2.

Strays

SIXTEENTH ANNUAL TELEPHONE PIONEERS QSO PARTY

☐ The Telephone Pioneers QSO Party will be held from 1900 UTC, Saturday, December 6 until 0500 UTC, Monday, December 8. Phone users call "CQ Telephone Pioneers." Cw users call CQTP. Suggested phone frequencies (plus or minus 10 kHz) 3.965, 7.275, 14.295, 21.365, 28.675, 50.1 to 50.25, 144.275 to 145.5 and 146.52 MHz; cw — 3.565, 7.065, 14.065, 21.065, 28.065; Novice and Technician — 3.725, 7.125, 21.125 and 28.125 MHz. Complete rules, scoring, exchange and reporting information available from Ted Phelps, W8TP, John D. Burlie Chapter no. 89, Telephone Pioneers of America, c/o Western Electric, Dept. 45160, 6200 East Broad St., Columbus, OH 43213.

I would like to get in touch with . . .

☐ North American amateurs, to set up skeds in French, English or Russian. Ilieff Svetozar, LZ1A-1021, 1126 Sofia, P. O. Box 33, Bulgaria.

☐ people who are interested in, or have working model of, radio-controlled or microprocessor-controlled humanoid robots. Natt Beha, N8BPI, 3752 Lane Court, St. Joseph, MI 49085.

A State-of-the-Art Terminal Unit for RTTY

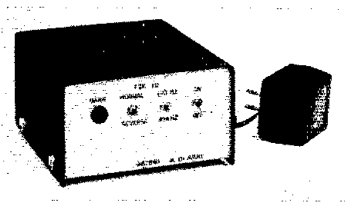
Update your RTTY installation with this two-chip terminal unit. It accommodates both your new video unit and that model 15, interfaces with a simplex loop and handles both narrow and wide shift. Try it!

By Michael J. Di Julio,* WB2BWJ

A modern reliable fsk terminal unit can be built with just two chips and a handful of parts. It will work equally well on the low bands with narrow-shift fsk or on vhf with wide shift. The device interfaces with the standard 60-mA simplex loop.

The circuit is designed around two chips manufactured by Exar Integrated Systems. These chips are the XR-2206 function generator and the XR-2211 fsk demodulator. The XR-2206 is capable of generating stable, low-distortion sine waves, the frequency of which are determined by simply varying the resistance of the circuit. Switching in different values determines the mark and space frequencies.

When pin 9 of the XR-2206 is grounded, the resistance at pin 8 determines the output frequency. With pin 9 open, the resistance at pin 7 determines the frequency. Since a low at pin 9 corresponds to a mark, R1 is set to the mark frequency of 2125 Hz and R2 and R3 are set to produce tones of 2975 Hz and 2295 Hz, respectively. These frequencies correspond to the space tones for the wide-shift standard of 850 Hz and the narrow-shift standard of 170 Hz. S1 selects the shift. R4 controls the peak-to-peak output of the sine wave available at pin 2. The output of pin 2 is fed to the microphone input of your ssb or fm radio or to a tape recorder for storage of afsk data. Keying of the chip is accomplished by the presence or absence of current in the loop via the optoisolator, U1. When current is flowing, the LED in the isolator lights, turning on the phototransistor and grounding pin 9 initiating a mark tone. When current is not flowing, the phototransistor is off and pin 9 goes high via an internal pull-up resistor and a space tone is generated. D1, R11 and C3 protect the isolator from spikes produced from the teleprinter magnets. D3 through D6 form a bridge that permits the loop supply to be connected to J1 with either polarity.



The fsk RTTY terminal unit designed and built by Michael Di Julio, WB2BWJ. At the right of this professional-appearing device is the 9-V battery eliminator that powers the unit.

PLL Determines Mark or Space

The fsk demodulation is performed by the XR-2211, a phase-locked loop (PLL) decoder similar to the popular LM565 demodulator. The VCO in the chip is tuned via R21 to $F_O = (f_1 + f_2)/2$ where f_1 is the mark frequency of 2125 Hz and f_2 is the narrow-shift space frequency of 2295 Hz. Therefore, F_O = 2210 Hz. C7, R20 and R21 determine this frequency and the values listed were chosen appropriately. R12, R17, R18, R19, C5, C8 and C9 are all elements associated with the filtering of the PLL and were selected by means of the formulas in Ref. 1 to allow optimum operation with amateur standard 60- or 100-wpm signals, both wide and narrow shift.

When a mark is detected, the PLL locks and pins 6 and 7 go high, turning on Q1, and permitting current to flow in the loop. In the absence of a mark tone, the PLL error voltage changes. Under this condition, a space is assumed by the internal voltage comparator and pins 6 and 7 go low, turning off Q1 which then stops the flow of current in the loop. Q2 and associated components form an inverter to reverse the polarity of the mark to accommodate stations transmitting contrary to the conventional mark/hold technique. Pin 5 of the chip goes low when a mark tone is detected and the LED, D2, is illuminated by means of Q3, Q4 and associated components. Audio from a receiver or tape recorder is fed to pin 2 via C4.

Pc Board, a Builder's Choice

Pc board construction is optional. The layout is not critical. S1, S2, S3 and D2 should be front-panel mounted, while J1, J2 and J3 should be mounted in the rear. J1 must be insulated from the chassis as a loop supply approaching 120 volts may be present in mechanical teleprinter equipment. For a power supply, I recommend a battery eliminator, of the type sold for tape recorders and radios, capable of supplying 9 volts at 300 mA.

Tuning Adjustment is Easy

Tuning the unit is extremely simple. Apply 9 volts to the device and ground pin 9 of U2 simulating a mark. With a frequency counter connected to the afsk

[Editor's Note: As a convenience to those wishing to avail themselves, the author offers ready-made circuit boards for this TU for $10. The ARRL and *QST* in no way warrant this offer.]

*97 Woodside Rd., Maplewood, NJ 07040

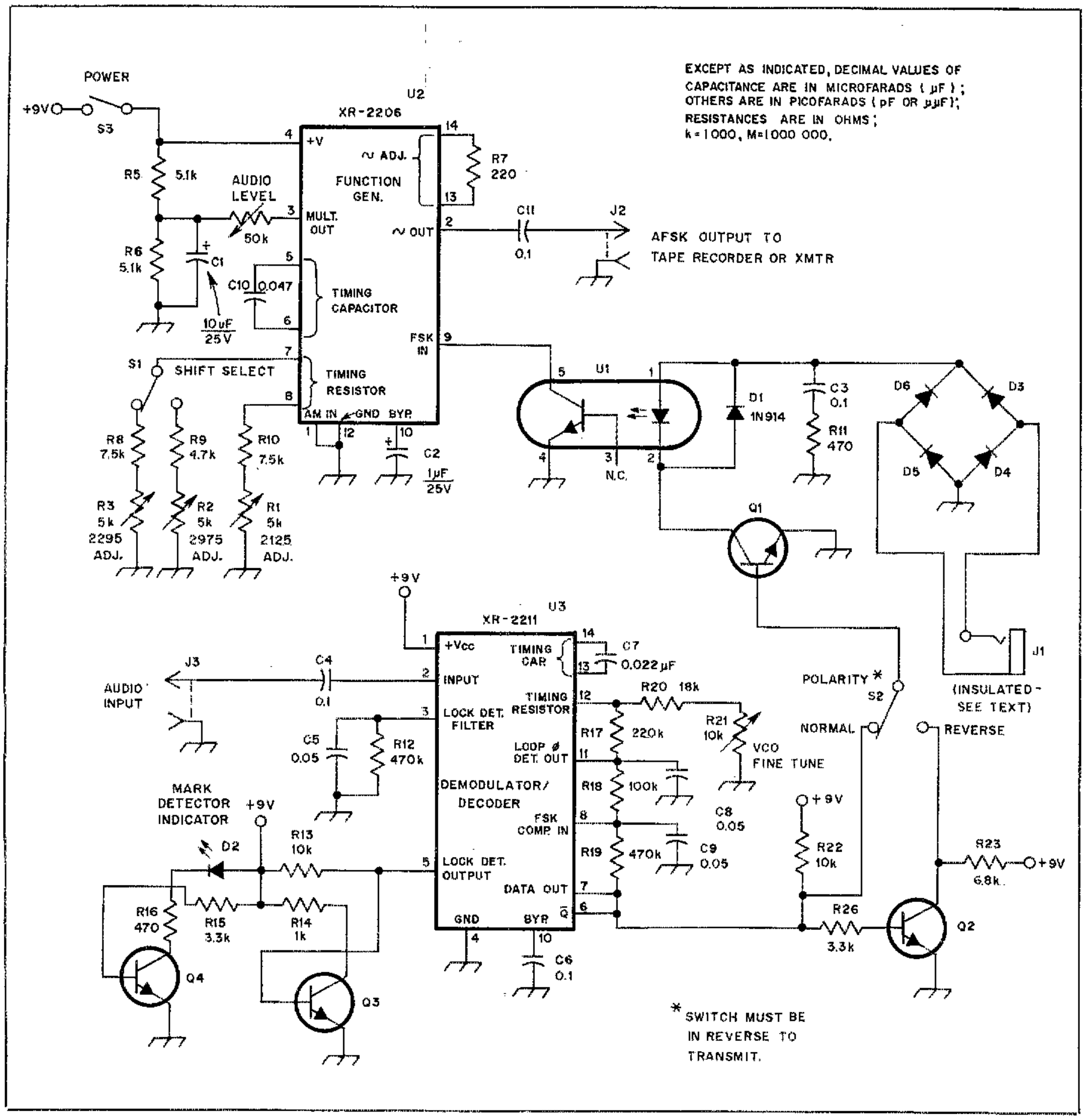


Fig. 1 — Circuit diagram for the State-of-the-Art Terminal Unit. This arrangement is compatible with both wide and narrow fsk. U2 is the function generator. U3, a PLL decoder, serves as the fsk demodulator. When current flows through the optoisolator, U1, it initiates a mark tone through U2. Because 120 V from the loop supply may be present in mechanical teleprinter equipment, J1 must be insulated from the chassis. S1 is shown in the 170-Hz position. All resistors are 5%, 1/4 watt. Pc boards are available from the author for $10 postpaid. Most other parts are available from Jameco Electronics, 1021 Howard Ave., San Carlos, CA 94070.

C1 — 10 μF, 25-V tantalum.
C2 — 1 μF, 25-V tantalum.
C3, C4, C6, C11 — 0.1 μF, 50-V ceramic disc.
C5, C9 — 0.05 μF, 50-V ceramic.
C7 — 0.022 μF, Mylar.
C8 — 0.005 μF, 50 V, ceramic disc.
C10 — 0.047 μF Mylar.
D1 — 1N914.
D2 — LED.
D3-D6, incl. — 1N4003.
J1 — 1/4-inch phone jack.
J2, J3 — Miniature phone jacks or the type of jack that interfaces with your equipment.
Q1 — 2N5655, MJE340 or TIP-48.
Q2, Q3, Q4 — 2N2222.
R1, 2, 3 — 5-kΩ 10-turn Trimpot.
R4 — 50-kΩ, single-turn Trimpot.
R5, 6 — 5.1 kΩ.
R7 — 220 Ω.
R8, 10 — 7.5 kΩ.
R9 — 4.7 kΩ.
R11, 16 — 470 Ω.
R12, 19 — 470 kΩ.
R13, 22 — 10 kΩ.
R14 — 1 kΩ.
R15, R26 — 3.3 kΩ.
R17 — 220 kΩ.
R18 — 100 kΩ.
R20 — 18 kΩ.
R21 — 10-kΩ 10-turn Trimpot.
R23 — 6.8 kΩ.
S1, S2 — Spdt switch.
S3 — Spst switch.
S4 — Dpdt switch.
U1 — OPI-2150, HEP-P5000, Motorola 4N28 or equivalent.
U2 — XR-2206 (Exar Integrated Systems, Sunnyvale, CA).
U3 — XR-2211 (Exar Integrated Systems, Sunnyvale, CA).
Misc.: One 14-pin IC socket; 9-V, 300-mA battery eliminator; one 16-pin IC socket; cabinet and pc board.

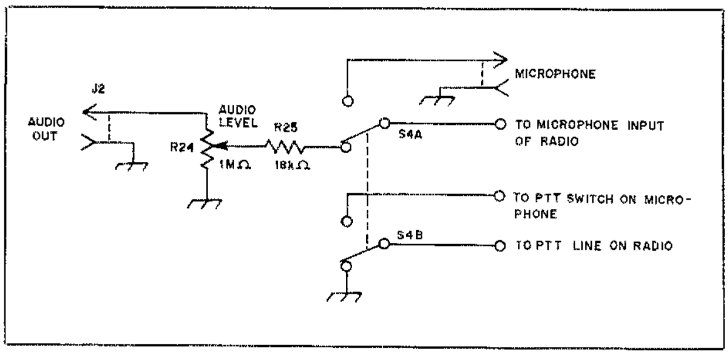


Fig. 2 — Use of the above circuit is recommended by the author as a means of connecting the microphone to the transmitter when the TU output is fed directly to the microphone input of the transmitter.

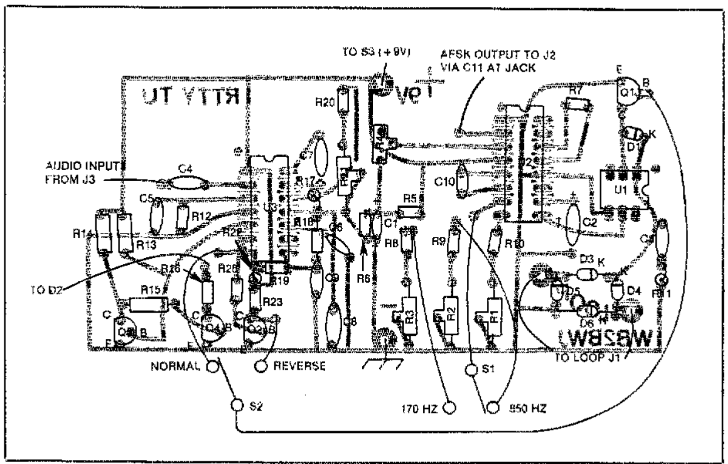


Fig. 3 — Parts-placement guide for the State-of-the-Art Terminal Unit. Parts are placed on the non-foil side of the board; the shaded area represents an X-ray view of the copper pattern. (The etching pattern appears in the "Hints and Kinks" section of this issue.)

output jack, J2, adjust R1 to read 2125 Hz on the display. Lift the ground from pin 9 and with S1 in the 170 Hz position, adjust R3 for a reading of 2295 Hz. Finally, switch S1 to the 850-Hz position and adjust R2 for a reading of 2975 Hz. To adjust the demodulator, ground pin 9 of U2 to simulate a mark and connect J2 to J3. Slowly adjust R21 until D2 lights and continue turning the potentiometer counting the number of turns until the LED extinguishes. Back the potentiometer off one half the number of turns counted so that the VCO is set to the center of the lock range. This will sufficiently approximate the optimum setting of the VCO to 2210 Hz as previously mentioned.

Operating the Terminal Unit

To use the terminal unit, connect your TTY gear through J1, J2 to the microphone circuit of your transmitter and J3 to the receiver loudspeaker. I recommend adding a switch and a potentiometer as indicated in Fig. 2 so that your microphone can also be connected to the transmitter. Adjust R4 and R24 (if used) for a clean signal from your transmitter.

If you have an ssb transmitter, you want a distortion-free signal. If it is an fm transmitter, neither distortion nor over deviation is desirable. Adjust the volume control on the receiver so that the LED, D2, starts to flicker as you tune across the band. To tune in an RTTY signal, slowly tune through the signal until the LED lights brilliantly, indicating that the PLL is locked onto the mark tone. On ssb, the tuning will be narrow; very often the TU will lock onto a signal that is so weak and plagued with interference that your ear will not be able to distinguish it from the noise. Adjust the volume to a level just above that which allows the LED to light. If fading is present, turn the volume up to a point where the LED still lights during a fade. When using the unit on vhf fm, no tuning of the receiver is required but be sure to place S1 in the 850-Hz position so that your transmitted tones will be standardized with other amateur stations. If you find "garbage" being printed, try switching S2 to reverse as the other station may be sending inverted data. On the other hand, you may have inadvertently locked the TU on the space tone instead of the mark. To ensure that you are tuning to the mark tone and not the space tone, wait for the station to be idle, at which time only the mark tone is present. Then tune in the signal properly.

Transmit With S2 in Reverse Position

When you wish to transmit or just type on a local loop, S2 must be in a reverse position. The reason is that with no audio coming into J3, Q1 would normally be turned off, thus breaking the loop. Inverting the signal to Q1 turns it on, thus connecting the loop.

If a cassette tape recorder is connected to J2 and J3 via the microphone and headphone or monitor jacks, a conversation or self-generated message can be recorded for later playback. As a station is being received and the loop is being keyed by Q1, the optoisolator, U1, is also keying U2, thus generating a clean version of the station signal which is available at J2. Cassette tape is a nice alternative to paper tape. It will allow you to discard your old model 14 typing reperferator and transmitting distributor.

The Chips as Black Boxes

My approach to writing this article is to treat the IC chips as "black boxes" and provide a minimal discussion of their inner workings. By doing so, the average person could understand the article without being burdened with a lot of technical theory. Refs. 1 and 2 provide additional technical discussion for those desiring it.

Through many months, my unit has permitted me to enjoy operation on ssb and fm with the same terminal unit. The device works equally well with my model 15 TU and my video TTY. I have presented this article on a high-performance state-of-the-art project as a means of helping you to upgrade your RTTY station. QST

References

[1] "Tri-State FSK Modem Design Using XR-2206 and XR-2211," Exar Applications Note AN-05, January 1979, Exar Integrated Systems, Inc., 750 Palomar Ave., Sunnyvale, CA 94088.

[2] Refioglu, Ilhan et al., "A Frequency-Shift Keyed Modem in LSI," *Electronic Design* no. 8, April 12, 1979.

[Editor's Note: An article entitled "Integrated Circuit Function Generator," by Frank Getz, N3FG, which appeared in August 1980 *Ham Radio*, is suggested as additional reference material.]

Capacitance Measurement with a Dip-Meter

This simple gadget is characterized by moderate accuracy and very low fiddle-factor!

By Frank Noble,* W3MT

Surplus and old capacitors have one common feature — no clue as to capacitance value, either because the label fell off or faded out, or because the color code is no longer readable. Also, even though the labeling is legible, the capacitance value may be far removed, for one reason or another. A measurement sufficiently accurate for most purposes can be obtained in a simple manner.

In the interest of providing a wide range of measurement, we chose the largest semi-circular plate variable capacitor[1] that is commonly available, 400 pF, and resonated it with a coil at about 2 MHz, the lowest usable frequency on most dip meters. The desirability of a low frequency is twofold: First, the L/C ratio is reasonable for the large capacitance desired and, second, hand capacitance effects are minimized.

Low Capacitance Measurement

To measure capacitance from zero to 400 pF, the circuit is dipped with the variable, C_R, at maximum capacitance and with the unknown capacitor out of the circuit. Then the unknown capacitor, C_X, is directly shunted across the coil (D to G in Fig. 2) and the circuit is reresonated with C_R. The capacitance removed by rotating the variable unit is equal to the unknown capacitance; accordingly, C_R is calibrated in capacitance removed so that the device will be direct reading over this range.

High Capacitance Measurement

Where the unknown capacitance is larger than 400 pF, a fixed, 400-pF capacitor is connected in series with the unknown (S to G in Fig. 2). The range is thus extended to infinity, in theory, although accuracy will suffer severely for values greater than about 3000 pF. We are fortunate here in that the required accuracy in measurement of large capacitors is usually low, since these values are generally used for bypass and coupling purposes. The external capacitance the tuned circuit "sees" in this situation is

$$C_S = C_R = \frac{400\ C_X}{400 + C_X} \qquad \text{(Eq. 1)}$$

where C_S is the capacitance of the series combination, and C_R is the capacitance removed by rotating the variable, as before. Rearranging Eq. 1

$$C_R = \frac{1}{\frac{1}{C_X} + 0.0025} \qquad \text{(Eq. 2)}$$

$$C_X = \frac{1}{\frac{1}{C_R} - 0.0025} \qquad \text{(Eq. 3)}$$

All capacitances are in picofarads. The relationship between C_R and C_X is plotted in Fig. 1.

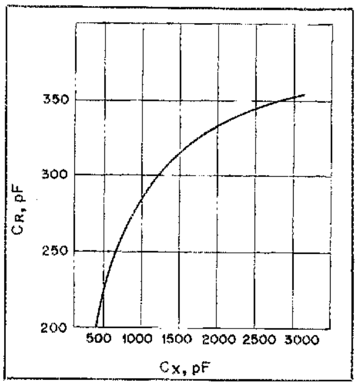


Fig. 1 — This curve shows the values for unknown capacitors in relation to various settings of the main tuning capacitor, C_R, where C_R has a range between 200 and 350 pF. See text concerning capacitance values larger than 3000 pF.

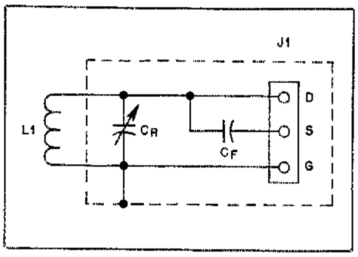


Fig. 2 — This simple resonant circuit permits the measurement, in connection with a GDO, of capacitors of unknown value. Small-value capacitors (400 pF and under) are connected between the direct (D) terminal and ground, while larger-value capacitors are connected between the series (S) terminal and ground.
C_F — 400-pF silver mica.
C_R — 400-pF air variable.
J1 — Three-terminal barrier strip.
L1 — 45 turns of no. 28 enamel wire wound on a National XR-50 form (or equivalent), slug removed. Dia 1/2 inch (13 mm), winding length 11/16 inch (17.5 mm). Outer (hot) end returned via interior through empty threaded hole.

Circuit

The schematic diagram is given in Fig. 2. Coil geometry and the operating frequency are not critical; the values used here are roughly 14 µH and 2 MHz. A good choice for the chassis is a Radio Shack 270-239 measuring 2-1/8 × 1-5/8 × 4 inches (54 × 29 × 102 mm). It is this large to prevent it from walking around.

Entirely adequate calibration can be done with four 100-pF, 5% mica capacitors. In this model, the dial skirt is labeled with the digits 0 through 4, corresponding to hundreds of pF of capacitance removed. A more-careful calibration is probably not justified because the ambiguity of the dip is considerable, even with light coupling.

Since this is a substitution method, inaccurate dip-meter calibration does not affect the measurement. The only requirement is frequency stability. This approach does not require the use of an inductor of known value, as would be the case where the "standard" technique is used.

[1]Although not strictly necessary, a semi-circular plate capacitor will yield a nearly linear calibration, which is much easier to interpolate.

*10004 Belhaven Rd., Bethesda, MD 20034

The Coaxi-Match

Aren't you just itching to build something? This SWR meter is designed for utmost simplicity, low cost and convenience.

By C. Phil Guild,* KAØBEO

The Coaxi-Match is an SWR metering method that is designed to place the meter assembly at any convenient location in the hamshack. It is a useful tool for both the home antenna experimenter and mobile operator. Fig. 1 is a diagram of the system, which is composed of two separate units: the Coaxi-Match pickup unit and the meter assembly. What makes this unit so attractive is its simplicity and low cost. The majority of the parts required for construction can probably be found in your junk box or can be purchased at minimal cost. For example, a surplus 0- to 100-μA meter can be obtained for prices ranging from $2 to $5; the 3/4-inch[1] hard-drawn copper pipe and wire cost approximately 80 cents!

Getting Started

Fig. 2A shows a cutaway view of the Coaxi-Match. The detailed drawing of the three-hole wafers which position L1 and L2 is shown in Fig. 2B. Begin assembly by using a *hacksaw* to cut a 1/2-inch piece from one end of an 8-inch length of 3/4-inch-diameter hard-drawn copper pipe. Discard this short piece. This is done to eliminate any pipe-section indentations that might have been made by the pipe cutter used at the source of purchase. Cut a 4-3/4-inch length of pipe for use as the main section of the pickup unit; save the remaining shorter piece for later use.

Place a sheet of emery cloth or sandpaper on a flat surface and, holding the pipe in a vertical position, sand both ends of the pipe until it will stand perpendicular to a flat

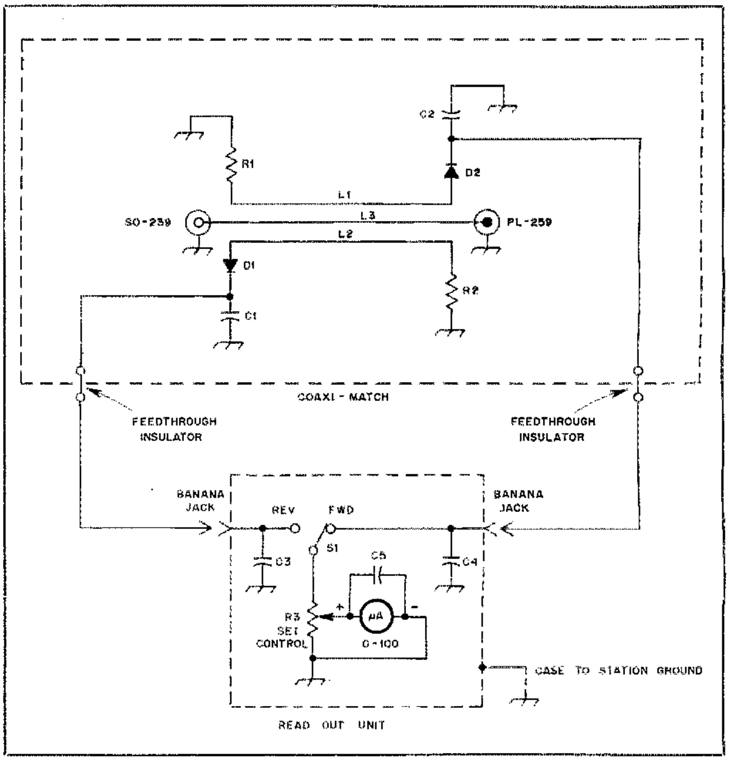
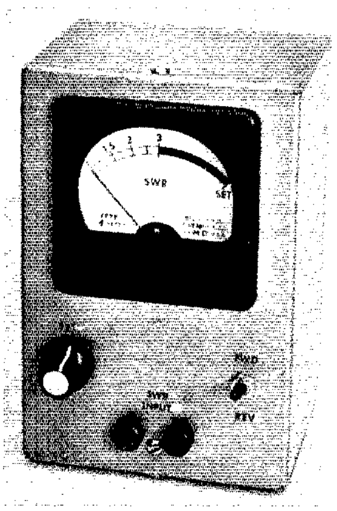


Fig. 1 — Schematic diagram of the Coaxi-Match. Many readers will recognize the circuit as that of the familiar Monimatch.

C1-C4, incl. — 0.005 μF, 1-kV disc ceramic.
C5 — 0.01 μF, 1-kV disc ceramic.
D1, D2 — 1N34A germanium diode.
L1, L2 — 3-3/4 in. no. 14 solid copper wire.
L3 — 6-1/2 in. no. 12 solid copper wire.
M1 — 0 to 100 μA.
PL1 — PL-259 coaxial connector.
R1, R2 — 150 Ω, 1/2-watt carbon resistor.
R3 — 10 kΩ, linear taper potentiometer.
S1 — Spdt toggle switch.
SO1 — SO-239 coaxial connector.
Misc. — Copper pipe, scraps of Plexiglas, Lucite or plastic (see text).

*14470 E. 13th Ave., G14, Aurora, CO 80011
[1]Notes appear on page 26



The Coaxi-Match metering unit. This is all you need at the operating position; the pickup unit can be located remotely.

surface on both ends. Remove the burr from inside the ends — a pocketknife will do the job well. Now sand the inside and outside walls at the ends until they are shiny.

Cut the no. 12 and 14 gauge wire to the lengths shown in Fig. 2. File or sand flat L1 and L2 at both ends and round off the ends of the no. 12 wire used for L3.

The material for the spacing wafers shown in Fig. 2 can be made from Plexiglas, Lucite or even scrap plastic; the thickness should be 1/8 inch or less. Using the same center, scribe two circles — one being the ID of the pipe and the other 5/16 inch in diameter — on 1-inch squares of the material. Scribe a line through the center of the circles; the intersection of this line with the smaller circle will locate the holes for L1 and L2. The center hole of the circles positions the main conductor of the pickup unit, L3.

Use a small drill bit to make a set of guide holes and then enlarge the holes to pass the wires with a snug fit. Shape the plastic squares into roughly defined circles using diagonal cutters. Then, holding the wafers between your thumb and forefinger, move them across a flat file or emery cloth, rotating them until they are rounded out at the outermost scribed circle. Check the wafer for fit in the end of the copper pipe; if necessary, continue the grinding process until the wafer fits snugly into the pipe.

Insert L1 and L2 into the two end wafers as shown in Fig. 2. Mix a small amount of epoxy and, using a toothpick, place a small drop on both sides of each wafer at the wire passage points. Ensure that both wires are parallel and perpendicular to the wafers, and set the subassembly aside to let the epoxy cure.

Take the short section of copper pipe and, with your sheet-metal shears, cut it along a line parallel to the axis. Straighten out the two halves as much as possible with your fingers. Then place the piece on a heavy piece of flat metal (or the flat end of your vise) and tap it gently with a small hammer until it is flattened. This piece will be used to support the coaxial connectors at each end of the pickup unit.

Scribe two 3/4-inch circles on the flattened piece so that you have equal distances between the circles and the ends of the piece. Drill the holes for the PL-259 and SO-239 fittings. The PL-259 shank hole should be made slightly smaller and then enlarged with a rat-tail file until the shank will press fit into the piece. A 5/8-inch hole is made for the SO-239 connector, the connector should fit flush with the plate. Tin both sides of the plate, remove any excess solder from the insides of the holes and cut the plate in two between the holes.

Tin the back of the SO-239 mounting flange. Also tin the shank of the PL-259 about 1/4 inch from the bottom. Now solder the back of the SO-239 to the copper plate so it is flush with the plate. Push the shank of the PL-259 connector through the hole in the other plate, letting it protrude about 1/16 inch; solder it to the plate. The coupling sleeve of the PL-259 may be kept out of the way by screwing it into a mating connector.

Coaxi-Match Assembly

Insert the L1-L2 assembly into the pipe. Mix up another small amount of epoxy. Center the assembly in the pipe and place two small drops of epoxy opposite each other on each wafer, then check to ensure the assembly is properly centered. Let the epoxy cure.

After the epoxy has cured, drill two holes in the copper pipe for the feedthrough insulators (see Fig. 2). The hole size required will depend upon the diameter of the particular feedthroughs used. Remove the burr from the inside of the pipe. Epoxy the feedthroughs in place and allow the epoxy to cure.

While you're waiting, pre-tin the pigtails of the diodes, resistors and capacitors.[7] If the capacitors have insulating material on their leads, scrape it off. Place a diode at the center of a disc capacitor, make two wraps of the diode negative lead around one of the capacitor leads (close to the body) and cut off the excess lead length. Crimp the end of the diode lead close to the capacitor lead and solder the connection. Make two of these assemblies. Bend the remaining capacitor lead back so it is parallel with the diode. Make a small hook shape in the lead to which the diode is soldered — close to the solder junction — and cut off the excess lead length. Insert the combination into the pipe so that the hook will encircle the inside terminal of the feedthrough insulator. Use needle-nosed pliers to crimp the hook around the terminal and solder the connection. Repeat this procedure at the other end of the pipe.

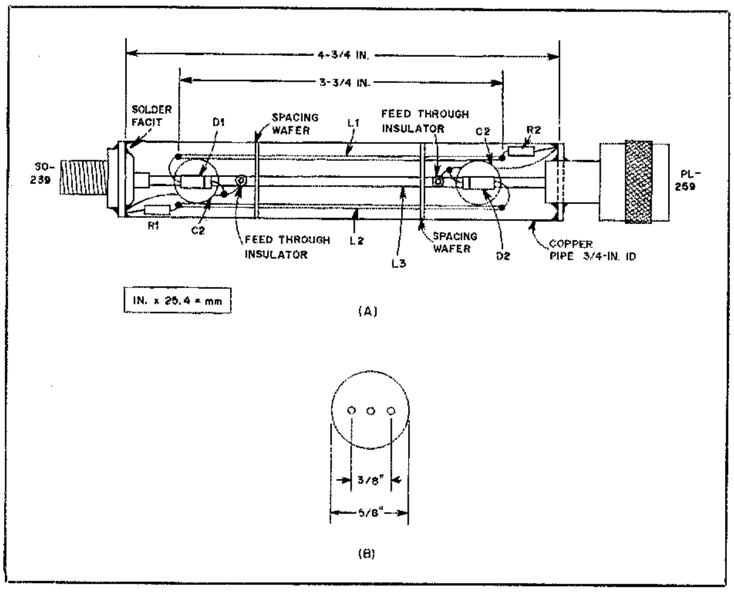


Fig. 2 — At A, a cutaway view of the pickup unit constructed from a piece of copper pipe. The insulating wafers used to support the conductors are cut to the dimensions shown at B.

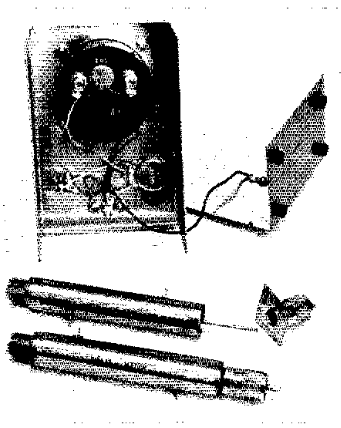
Solder the diodes and resistors R1 and R2 to the ends of L1 and L2; be sure to heat sink the diodes during soldering. File small V-shaped notches at the ends of the pipe to accept the remaining resistor and capacitor leads. Crimp the leads so that they lie against the inner and outer surfaces of the pipe.

The center conductor wire (L3) is now soldered to the SO-239 connector. Form a small bead of solder around the inside edges of the pipe and insert L3 through the center holes of the insulating wafers. Clamp the SO-239 mounting plate in a vise with the plate flush against the edge of the pipe; use wood blocks to insulate the assembly from the vise and prevent heat loss through conduction during soldering. Flow solder around the plate and end of the pipe; a 100-watt soldering iron should be sufficient to melt the bead of solder within the pipe assembly. Mount the PL-259 plate at the opposite end of the pipe in the same manner. Trim the excess lead lengths of the resistors and capacitors from both ends of the assembly.

Using sheet-metal shears, trim the connector mounting plates as close to the pipe as you can, then file the excess material until a flush finish is obtained. Finally, solder the center conductor to the PL-259 connector.

The Metering Unit

The cabinet chosen for the metering unit will depend upon personal preferences and the size of the meter. Insulated banana jacks must be used and C3 and C4 should be mounted as close to the jacks as possible. A ground lug should be provided at the rear of the cabinet to permit connection to station ground.



An inside view of the metering unit with two pickup assemblies in the foreground. The rear pickup assembly is in the final stage of construction.

To add a professional touch, the meter may be disassembled and the meter face relettered. Unwanted lettering may be removed with a sharp knife and the areas touched up with flat-white acrylic paint; small bottles of paint may be obtained at your local hobby shop.

Interconnection between the Coaxi-Match pickup assembly and the metering unit may be made with no. 20 stranded wire. The two wires may be made into a neat twisted pair by securing one end of the wires in a vise and the opposite ends in an electric drill. Run the drill at low speed, twisting the wires until three or four turns per inch is obtained.

Calibration and Operation

I calibrated the Coaxi-Match by placing it in series with a meter of known accuracy, a Transmatch and an antenna. The Transmatch was adjusted to provide deliberate mismatches, the meter readings noted and marked on the Coaxi-Match meter face.[3]

In operation, the FWD/REV switch is placed in the FWD position and the SET control adjusted to produce a full-scale meter indication. Then, switch to REV to read the indicated SWR.

The Coaxi-Match can be used outside and placed at the feed point of the station antenna, where the SWR measurement is most meaningful. Even though the unit is waterproof, the feedthrough connectors should be covered with silicone rubber after the wires to the metering unit have been attached. The end connectors may be protected from the weather by wrapping them with plastic electrical tape and covering that with a couple of coats of marine spar varnish.

I'm sure you'll find many ways to enjoy the convenience and versatility of your Coaxi-Match. And you'll also have the pride of knowing you made it yourself! QST

Notes

[1]Inches × 25.4 = mm; feet = m × 0.3048.

[2][Editor's Note: The diodes should be checked with an ohmmeter and matched as closely as possible in forward and reverse resistance; this will ensure better bridge balance.]

[3][Editor's Note: Ideally, the pickup unit should be checked for symmetry by reversing its position in the line and ensuring equal (or nearly equal) readings for a given set of conditions. Unbalance might require a repositioning of the diode lead on the pickup wire (L1 or L2).]

Strays

CHRISTMAS, FLORIDA EXPEDITIONS

☐ The Indian River ARC, of Cocoa, Florida, will operate from Christmas, Florida from December 20 to December 27, from 1400 to 2000 UTC daily. A certificate will be available to all stations worked. Please include a large s.a.s.e. with your request. Operating frequencies for W4NLX/4 will be 7.280, 14.280, 21.380 and 28.680 MHz on ssb, and 60 kHz from the bottom of the 40-, 20-, 15- and 10-meter bands on cw. The 34/94 repeater will be used for local contacts. QSL to Indian River ARC, W4NLX, P. O. Box 105, Christmas, FL 32709. — *Carl S. Zelich, AA4MI, Merritt Island, Florida*

☐ The Southeast Volusia ARC, of New Smyrna Beach, Florida, will be operating from Christmas, Florida, from 0200 to 2000 UTC on December 20 and 1400 to 2000 UTC on December 21. Frequencies will be 7.125, 21.130 (Novice), 7.250, 14.300 and 21.400 MHz (plus or minus 5 kHz). All contacts will be sent a 4- by 8-1/2-inch QSL — requests should be accompanied by an s.a.s.e. and a size 10 envelope. — *William C. Kennedy, KA4BIW, Edgewater, Florida*

BETHLEHEM, INDIANA DXPEDITIONS

☐ The Clark County ARC, of Jeffersonville, Indiana will go on a DXpedition to Bethlehem, Indiana from 1700 UTC, December 13, until 1700 UTC, December 14, 1980. They will use the call sign W9WWI/9 and operate on 3.900, 7.235, 14.285, 21.360, 28.510 and 147.300 MHz. Special Christmas season cards will be sent to all contacts. QSL with s.a.s.e. to Clark County ARC, P. O. Box 352, Jeffersonville, IN 47130. — *John W. Shean, N9TV, Jeffersonville, Indiana*

☐ The Delaware-Lehigh ARC, W3OK, will operate as part of Bethlehem's Christmas City celebration from 2300 to 0300 UTC daily from December 15 until January 1, 1981. Operation will be 15 kHz from the top of Novice bands and 15 kHz from the bottom of the General phone bands. Special QSL certificates will be sent from the Christmas City Station. QSLs or requests should contain a business-size (4-1/8- by 9-1/2-inch) s.a.s.e. and be sent to W3OK, DLARC, 1719 Callone Ave., Bethlehem, PA 18017. SWL requests welcome. — *William R. Ranzola, N3BIB, Walnutport, Pennsylvania*

A Crystal-Controlled AFSK Generator

RTTY operators — how often do you have to tweak your afsk generator tones? Build this simple digital unit and make tone tweaking a thing of the past!

By Greg McIntire,* AA5C

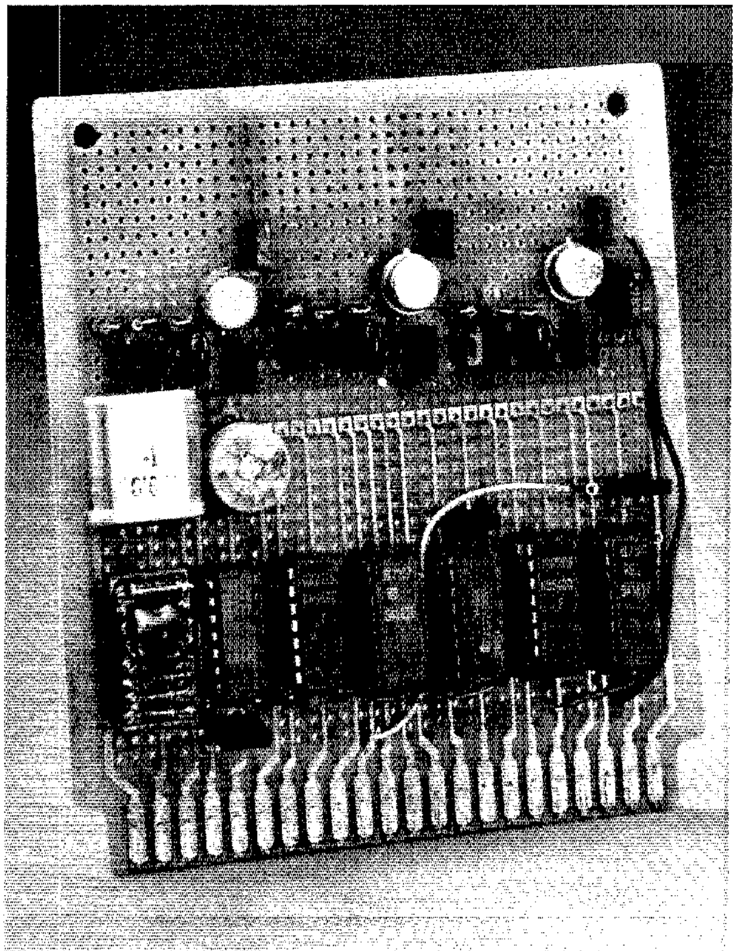
This compact afsk generator can probably be assembled over the course of a weekend. The parts are few in number and easy to find. An inexpensive TV color-burst crystal is used in the reference oscillator. All digital ICs are commonly available TTL devices, and the low-pass filter uses 741 op amps, a few capacitors and some one-percent tolerance resistors.

Circuit Description

There are two basic parts to the circuit: the frequency generator (Fig. 1) and a low-pass filter (Fig. 2). The generator is a programmable frequency divider. Y1, U1 and their associated components form the master oscillator, which operates at a frequency of 3.579545 MHz. U1C buffers the oscillator and provides a TTL level output for U5A. In turn, U5A divides the 3.579545 MHz signal by two and drives the three counters (U2, U3 and U4) with a 1.7897725 MHz clock pulse. The load inputs into the counters are gated by U6A, B, D and U1D to force the counters to divide by 421 for mark, 390 for space and 444 for a cw i-d. U5B takes the output of the counter chain and performs an additional divide-by-two and squares up the output waveform.

The equations in Table 1 show how the divide counts were derived; output frequencies are within 1 Hz of that desired, with the cw i-d tone being 100 Hz below the mark frequency. This is within FCC guidelines and as such it should not glitch the machine at the receiving end. An earlier version of this circuit used a custom-made crystal to come up with the exact RTTY tone frequencies, but what discriminator is going to "know" the difference between 2125.0 Hz and 2125.6 Hz? Table 2 details the gating of the loads

*5232 Aztec Dr., Box 77512, Lewisville, TX 75056



A readily available, multipurpose, edge-card board was used in this version of the afsk generator.

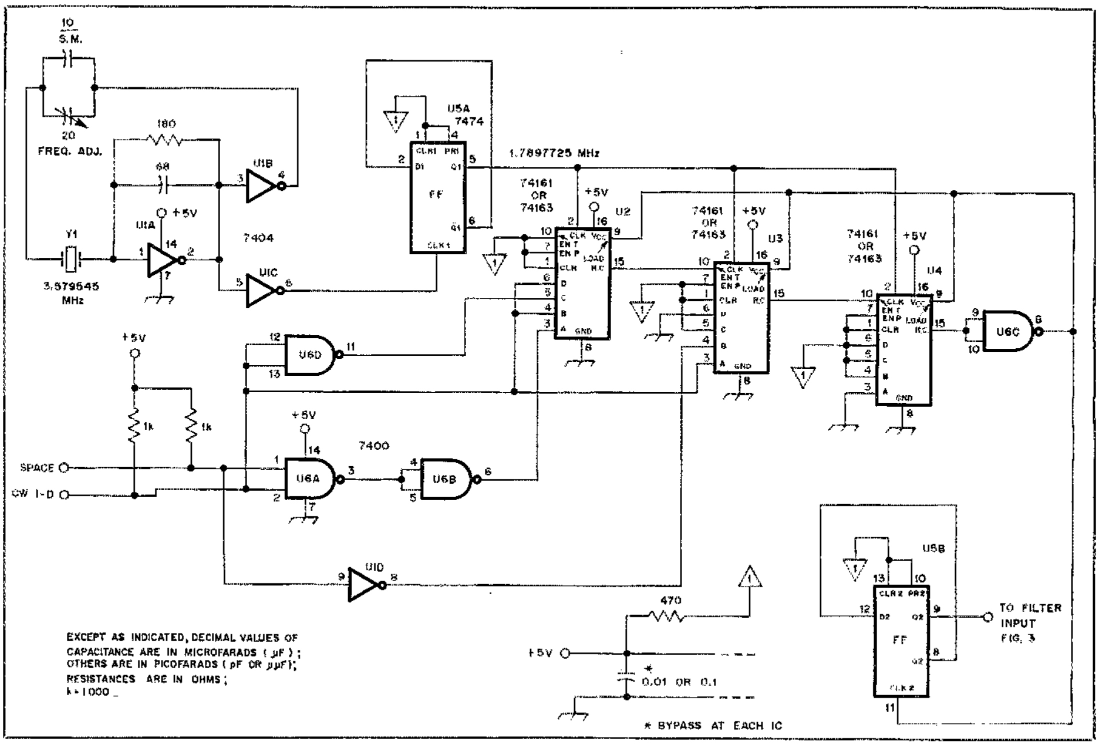


Fig. 1 — Schematic diagram of the simple, crystal-controlled afsk generator.

Table 1

Divider Counting Derivation

$$\text{Mark} = 2125\ \text{Hz} = \frac{3.579545\ \text{MHz}}{2(421)2} = 2125.6\ \text{Hz}$$

$$\text{Space} = 2295\ \text{Hz} = \frac{3.579545\ \text{MHz}}{2(390)2} = 2294.6\ \text{Hz}$$

$$\text{Cw i-d} = 2015\ \text{Hz} = \frac{3.579545\ \text{MHz}}{2(444)2} = 2015.5\ \text{Hz}$$

for the counters for those who may wish to add additional gating for other system considerations, such as automatic i-d, and so on.

Tone Shift and Filtering

The generator tones are shifted by grounding the proper input for either space or cw i-d; the unit outputs a mark tone when the inputs are high. Be sure to isolate any high-voltage loops from these inputs with a suitable optoisolator circuit.

The output of the digital portion of the circuitry is a TTL-level square wave which is very rich in harmonics. Adding the nine-pole active filter shown in Fig. 2 removes the harmonics and provides a good-quality sine wave to the transmitter audio input. The output of U9 is a high-level signal capable of driving almost any audio input stage. A voltage divider with a potentiometer for level adjustment can be tailored to the user's requirements. For those intending to use the generator on vhf only, another not-so-elaborate filter may suffice; the filter described here will

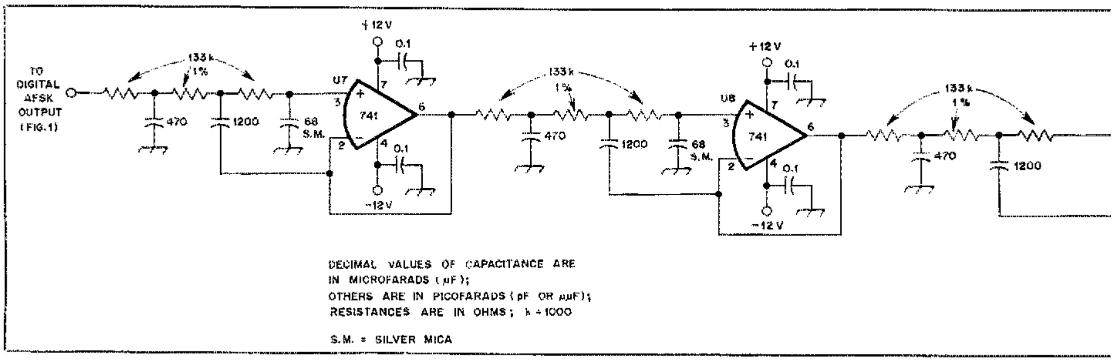


Fig. 2 — This nine-pole audio active filter "scrubs" the afsk generator output producing a good-quality sine wave. The silver-mica capacitors are 5% types (CM04, CM05). All 133-kΩ, 1% resistors are metal film types.

Table 2
Central Divide Load Values

IC and Pin no.	Mark ÷ 421	Space ÷ 390	Cw i-d ÷ 444	Change?
U2-3	1	0	0	Yes
U2-4	1	1	0	Yes
U2-5	0	0	1	Yes
U2-6	1	1	0	Yes
U3-3	1	1	0	Yes
U3-4	0	1	0	Yes
U3-5	1	1	1	No
U3-6	0	0	0	No
U4-3	0	0	0	No
U4-4	1	1	1	No
U4-5	1	1	1	No
U4-6	1	1	1	No

Note: The Change column indicates whether or not one of the load inputs of a counter needs to change between mark, space and cw i-d.

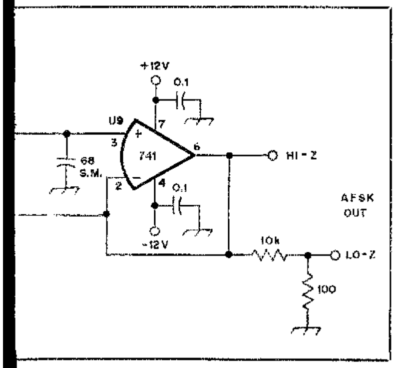
provide a top-quality signal for use on the hf bands.

Construction Techniques

Several units have been built using solder-wrap techniques. Wire-wrap or any other construction method can be used so long as good construction practices are followed. A 4 × 4-inch (102 × 102-mm) board with holes on 0.1-inch (2.54-mm) centers (such as Radio Shack 276-155) is more than adequate to accommodate all the components.

Here are some construction hints: Bypass the dc supply bus at each device with a 0.1- or 0.01-μF ceramic capacitor; use shielded wire for the audio output line and separate 741 op amps for the audio filter stages; lay out the circuit in a fashion that prevents feedback (this is a high-impedance circuit); finally, place the completed unit in a shielded enclosure to prevent rf from getting into the digital circuitry.

I hope you'll enjoy building this generator and know it will provide you with a stable source of RTTY afsk tones for a long time to come. My thanks to Otis Hanby, W5TKK, for his design of the filter, and Allan Kaplan, WA1AEL, for his advice and comments.

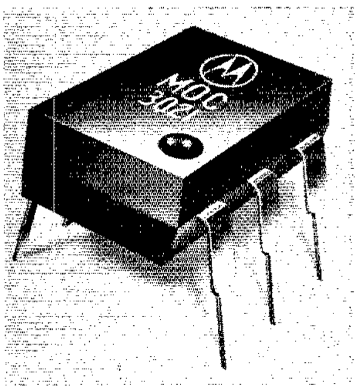


New Products

MOTOROLA OPTICALLY ISOLATED TRIAC DRIVERS

Two state-of-the-art optically isolated, 400-V triac drivers have been introduced by Motorola. According to the manufacturer, these devices exhibit a minimum peak off-state voltage of 400 volts and a minimum isolation voltage between input and output of 7500 volts. The MOC3020 and MOC3021 were designed to drive power triacs from a 220-V ac line, but amateur ingenuity will certainly find other uses for these devices.

The MOC3020/21 consists of a GaAs infrared emitter and a monolithic chip containing the detector and bidirectional triac driver housed in the popular 6-pin plastic DIP. Motorola recommends that it be used with resistive incandescents and heaters, inductive motors, solenoids and relays. The opto couplers are available from OEM sales offices and from authorized Motorola distributors. — *Paul K. Pagel, N1FB*

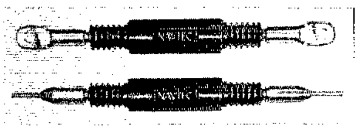


Motorola's MOC3021 requires an emitter current of only 15 mA to latch the output; the MOC3020 requires 30 mA.

NAVTEC BACKSTAY INSULATORS

Here's an item that looks like just the ticket for seagoing amateurs or others looking for a heavy-duty insulator to hold up a sky wire. Navtec, a manufacturer of stainless-steel rod rigging, turnbuckles and other rigging hardware is marketing backstay insulators designed to perform under all weather conditions. According to the manufacturer, these insulators, which have specifically designed fins to increase path length, will not break down electrically when wet with spray or rain. Mechanically, these insulators are designed to be used at high sustained loads even under a tropical sun. Navtec claims a resistance of greater than 10^8 ohms, a capacitance of approximately 60 pF, and a breakdown voltage rating of greater than 8000 volts when wet with salt water, allowing approximately one second for drainage.

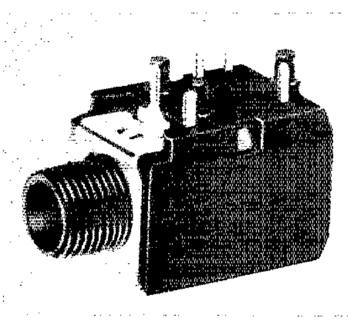
The insulators come in various sizes to fit most all backstays, whether wire or rod. Available end fittings include wire swages, eyes, jaws or Navtec Headed Rod. These units are priced from $120 to $600 each depending on insulator size and end fittings required. They are available from Navtec, 527 Great Rd., Littleton, MA 01460. — *Paul K. Pagel, N1FB*


These Navtec insulators are designed to perform under adverse weather conditions. A number of different sizes and end fittings are obtainable.

SWITCHCRAFT HI-D JAX[R]

Switchcraft is marketing compact, two- or three-conductor jacks with built-in right angle mountings. These new phone jacks are designed to allow the plug axis to be parallel to the printed circuit board on which they are mounted. The jacks are available with or without shunt circuits and are designed to be used with 1/4-inch diameter plugs. The sleeve circuit can be insulated from metal panels by simply using a flat, nonconductive washer.

For information, write: Switchcraft, Inc., 5555 No. Elston Ave., Chicago, IL 60630. — *Paul K. Pagel, N1FB*


The Switchcraft jacks have the added features of stable standoff mountings and a sleeve circuit that can be easily insulated from metal panels.

Another Look at an Old Subject: The Bug Catcher

Why aren't more hams going hf mobile? Some say the lack of effective, inexpensive antennas keeps them away. Here is one solution.

By Charles W. Frazell,* WD5FRN and Terry D. Allison,** WB5AZI

There are many high-frequency (hf) rigs around with 12-volt capabilities, yet hf mobile operation seems to be a novelty to most amateurs. Perhaps part of the reason more amateurs are not on hf mobile is the antenna. Mobile antennas are usually large, expensive, poor performers and a general nuisance with five or six separate coils to keep track of.

The antenna described in this article, while still large, is inexpensive to build (approximately $35) when compared to commercially available models (about $120) and has quite an impressive performance record. The frequency range of the antenna is from 80 to 10 meters. Its overall height can be reduced to slightly above the roof of the car in less than 10 seconds, should a low obstacle be encountered.

Rebirth of the Old Standard

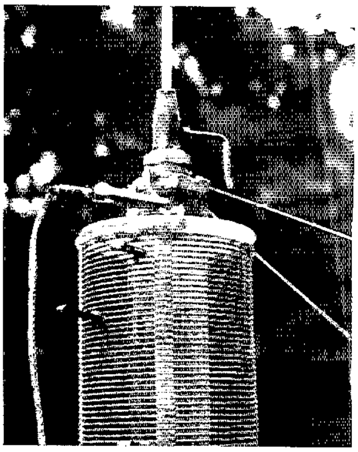
This antenna is quite similar to some of those that were popular in the '50s and the early '60s. These "Bug Catcher" types of antennas (so named because of the open coil, which collects insects) generally performed quite well. This one has some improvements incorporated into it that were not used on its ancestors:

1) It uses locally available parts.

2) It is adjustable to be a full 1/4-wave antenna on either 15 or 10 meters. Most of the parts can be obtained at either a hardware store or the plumbing-supply section of a discount store. The Plexiglas tubing and sheet will have to be purchased at a glass company. It would be a good idea to buy some extra stock and practice on it before attempting to work with the real thing as Plexiglas can be difficult to work with. The coil stock will be the most difficult part to find. It is marketed under the trade name "Miniductor" or "Airdux." We would suggest trying some of the older, more established ham stores which still cater to the do-it-yourself artist.

An electric drill with an assortment of drill bits and grinding devices is an almost essential tool to construct this antenna. A hacksaw is necessary and a saber saw is a big help. Epoxy cement works well to cement the coil assembly together, but seems to become brittle after exposure to the elements. Silicon bathtub caulk has proven to be an excellent substitute for the epoxy.

After procuring the necessary parts and tools, several subassemblies must be completed before the coil is assembled. One of these is the disassembly of the CB whip. The best way we found to accomplish this is to clamp the whip in a vise a short distance above the base fitting (ferrule).[1] Then find a small box-end wrench that will just fit over the threads, contacting the remainder of the base fitting. The base is removed by striking the wrench close to the whip, forcing the base fitting up the whip. Note: slight damage to the threads is not important, as they are going to be forced into a nonstandard fitting later. Continue forcing the base fitting up the whip until it is free and can be completely removed from the whip. The Corona ball



Here is a close-up view of the completed coil assembly. Notice the Allen wrench that has been soldered to the setscrew in the ferrule. Horizontal lines extending from the coil are the noninductive guy lines.

*4312 N. Dixie, Apt. 2B, Odessa, TX 79762
**P. O. Box 544, Marfa, TX 79843

[1]Notes appear on page 32.

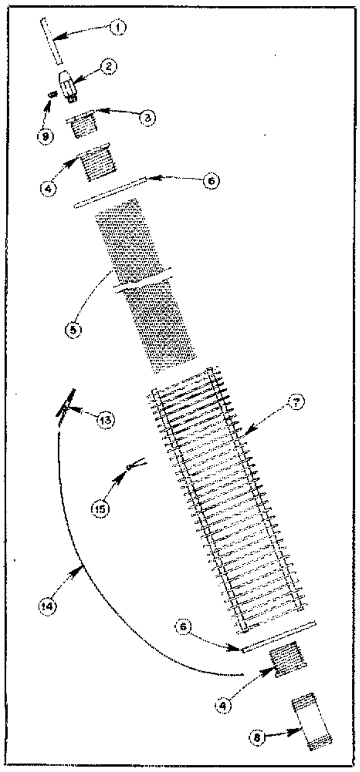


Fig. 1 — This is an exploded view of the coil assembly. Parts numbers refer to the parts list in Table 1.

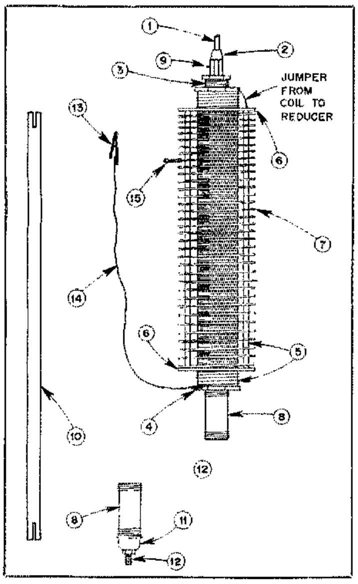


Fig. 2 — The completed coil assembly is shown here along with aluminum tubing mast. The inset shows the reducer which is threaded into the Plexiglas tubing. (Parts list is in Table 1.)

may have to be removed to allow the fitting to slide over the end. Not all whips are manufactured the same way: If, after repeated attempts, the base still won't slide over the top of the whip, then it may have to be taken off at the bottom.

Once this is accomplished, grind down the large end of the whip until the base fitting will slide freely over the whip. Some enlarging of the hole through the base fitting may be necessary. Drill and tap a hole into the side of the base fitting so that a setscrew inserted into the hole will prevent the whip from sliding through the base fitting. If you do not have the facilities to tap the brass base, then any machine shop can do it in a few minutes.

To support the coil, two Plexiglas "doughnuts" must be fabricated from the Plexiglas sheet. Fig. 1 depicts an exploded view of the coil assembly. It is best not to remove the covering from the Plexiglas until final assembly. Begin by drawing two sets of concentric circles on the covering of the Plexiglass. One should be larger in diameter than the outside of the coil, and one slightly smaller than the diameter of the Plexiglas tube. Form two discs by sawing along the larger circles. Next, drill a hole in the exact center of each disc. Enlarge the holes until a snug fit is obtained over the Plexiglas tube. The small circle can be used as a guide.

Another method of making the plastic doughnuts is to find a tin can that is slightly larger in diameter, or the same size, as your coil. Heat the open end of the can over the stove or use a propane torch or other suitable heat source. Be sure to put Plexiglas, to be cut with the can, on top of a piece of wood or other insulator as the can will get hot enough to transfer heat to the bottom side. (Note: Only the open end rim of can need be heated; use a thick glove.) When the can is relatively hot, place it on the plastic sheet and turn with twisting motion until the can starts to cool. Remove it from the plastic and heat it again. Repeat the process about three times on each side; this should render a perfect circle. Then, with a hole saw and some rotary files you can complete your doughnut.

A piece of aluminum tubing of 7/8-inch[2] inside diameter must be modified to go between the bottom of the coil and the mounting assembly. Cut a piece of the aluminum tubing approximately 30 inches long. Then cut two 3-inch-long slots (on perpendicular planes) in each end of the tubing. Slide two hose clamps over the tubing prior to final assembly.

Tackling the Coil

After the above work has been completed, the coil assembly can be tackled. First, screw one of the large reducers into one end of the Plexiglas tube. To do this, heat the reducer over a stove or with a torch until it will melt its way into the

Table 1

Parts List[3]

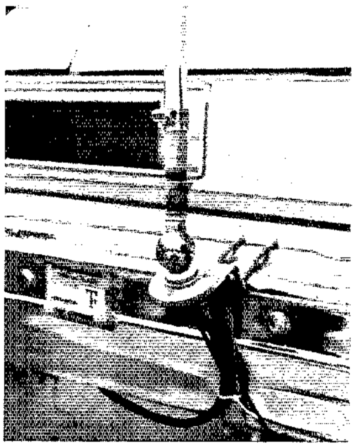
1) Whip (standard 102-inch).
2) Whip base or ferrule (removed from whip).
3) 1/2-inch to 1/4-inch reducer (pipe coupling).
4) 1-inch to 1/2-inch reducer (two required).
5) 1-1/4-inch-OD × 12-inch-long Plexiglas tube.[1]
6) Plexiglas doughnuts (two made from 1/8-inch-thick Plexiglas sheet).
7) Coil (3-inch dia × 10 inch long × 8 turns/inch).
8) 1/2-inch pipe nipple (2 required).
9) Setscrew.
10) Aluminum tubing 30 inches long × 7/8-inch ID.
11) 1/2-inch pipe cap.
12) Mounting bolt 3/8 × 24.
13) Alligator clip.
14) Shorting wire (RG-58 braid, see text).
15) Coil clips (at least five needed).
16) 1-inch dia hose clamps (two required).

Plexiglas as it screws down. It is important that care be taken to ensure that the reducer goes in straight. After the reducer cools, slide one of the Plexiglas doughnuts over the open end of the tube until it will go no farther.

Next, make sure some wire is left sticking out of the top end of the coil stock so that a connection can be soldered to it later. Slide the coil down over the tube followed by the remaining doughnut. Heat and screw the top reducer into the tube. Again take care to ensure that the reducer is in straight. Cement the doughnuts to the tube in such a way that they have the coil tightly sandwiched between them.

The end that has the wire available for soldering will now become the top of the coil. Screw the small reducer into the large reducer at the top of the coil. Screw the whip base into the top of the small reducer (the threads do not match perfectly but the brass base fitting will conform as needed). Solder a wire from the top large reducer to the top of the coil. When cleaning the reducer prior to soldering, don't file through the galvanizing or soldering will become impossible. Solder a piece of large, flexible wire (such as RG-58 shield) to the bottom reducer, leaving it long enough to reach the top of the coil. Solder an alligator clip to the free end of this wire. This completes assembly of the coil.

To assemble the rest of the antenna proceed as follows (Fig. 2): Drill a hole in the exact center of the pipe cap, large enough to just pass the threads of the bolt. Insert the bolt into the hollow portion of the pipe cap and through the hole. Then screw one of the nipples into the pipe cap and down onto the top of the bolt head. An alternative method would be to weld the bolt head to the bottom of the pipe cap. Regardless of which method is used to secure the bolt, screw the exposed bolt threads firmly down into your mount. (Washers may be necessary.) Screw the remaining nipple into the bottom of the coil



"Plumber's Delight" type mast is screwed into a regular CB bumper mount.

assembly. Place the aluminum tubing over the exposed end of the nipple which is attached to your mount. Clamp the tubing in place with one of the hose clamps. Try to get the tubing vertical. Force the pipe nipple at the bottom of the coil into the top of the aluminum stalk. Secure this by the remaining hose clamp. Slide the whip into the top of the coil and make sure that it will slide freely all of the way down through the assembly until it contacts the base mounting assembly. This completes assembly of the antenna.

Tapping the Bands

A tap must be placed on the coil for every band, and for portions of the 80-meter band. Several methods might be used to select the tap locations on each band. Generally it is better to start with the higher-frequency bands and work down. The method we prefer follows, but don't be afraid to try any method you think might work. To locate the tap for the 10-meter band, place the clip as close to the top of the coil as possible. This should be on the top turn next to the solder connection. (The solder connection itself may be used.) Slide the whip all of the way down and the antenna should be resonant on 10 meters. When the whip is extended to the point where the setscrew is close to the bottom of the whip, the antenna should be resonant on 15 meters with the same clip location. Small changes in resonant frequency can be achieved by sliding the whip up or down a small amount. The whip should be fully extended for operation on all lower bands.

To find the tap for 20 meters, it is best to find the point where maximum signal strength is observed in the "receive" mode. To do this, find a signal that is fairly strong and steady. Move the clip down one turn at a time from the top until a peak is observed on the receiver "S" meter. Then with an SWR bridge, move the tap up and down the coil from this point until minimum SWR is observed at the desired frequency. Place the clip here. Taps may be located on any side of the coil, or they all may be kept in a straight line if a slight increase in SWR is tolerable.

The same procedure is followed for 40 meters. The final SWR may not be as good as on 20 meters, however, since the impedance of the antenna is getting lower as more loading is used.

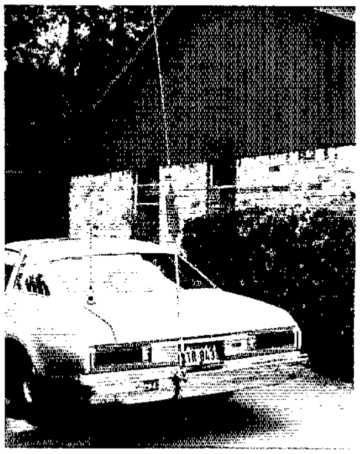
Eighty meters is quite difficult to tune using this method. The impedance of the antenna is down to less than 20 ohms, causing a high SWR on a 50-ohm line even at resonance. This SWR is acceptable with tube-type finals, as long as the rig loads up properly. If operation with solid-state rigs is contemplated, a matching transformer or some other form of impedance matching should be used. Because of the high SWR, the 80-meter taps must be located differently. A field-strength meter is probably the best tool to use. Tune the antenna for maximum observed field strength. If you don't have one and have access to a radio with tube-type finals, however, the following procedure works well. Locate the point on the coil where maximum noise is observed. Then with the clip located at this point, tune the rig up according to the manufacturer's instructions, except do not increase the load control at all, i.e., leave it in the maximum capacitance position. Then move the clip up and down one turn at a time until the observed dip in plate current as the plate-tune control is rotated just dips down to the normal fully tuned level.

Several taps will be necessary to cover very much of the 80-meter band. The resonant frequency of the taps extends upward from each location until the load control can no longer load the rig to normal plate current.

A Bumper Crop

Generally this type of antenna will be located on the back bumper of an automobile. Some people mount it on the fender or the rear deck. The higher it is mounted the better it will work, but the more obstacles it will hit. It is also hard to get a solid mount up high on a vehicle. If the antenna is to be mounted on the bumper, any of the heavy-duty bumper mounts made for CB whips may be used. A nonconductive guy line should be run to the rain gutter or to some other point in front of the antenna on the same side of the vehicle. The guy can be looped around the top of the coil assembly just below the whip. Either RG-8 or RG-58 cable may be used to feed the antenna.

All of the models built by local hams used some kind of "handle" soldered to the setscrew. An Allen wrench works well, as does a washer. This makes it easier to adjust or remove the whip quickly should the need arise.



WD5FRN's antenna farm on wheels.

Most of the rigs now on the market have very good noise blankers and no noise suppression is needed on the vehicle. The subject of noise suppression is covered in *The Radio Amateur's Handbook* (available from ARRL for $10) should a problem arise, however.

The best test of a mobile antenna is to operate it on the lower frequencies. Several models have been constructed and have been in use for over a year. Mobile-to-mobile contacts on 80 meters always have been possible up to distances of 1000 miles. Several late-night contacts have been made over distances exceeding 3000 miles on 80 meters. Checking into local traffic nets rarely has been a problem, with this antenna performing better than a random wire combined with a tuner at the fixed station. Come on in and try "low-band" mobile. The water is fine!

We would like to acknowledge the help of Mark Kelly; Jimmy Vaello, WD5HBV; Texas Traffic Net; Bruce Love, WB5NOQ; members of the MSC Radio Committee at Texas A & M University and Shelly Gilbert. QST

Notes

[1]Most CB-style whip antennas have a completely hollow ferrule that is soldered or brazed to the bottom of the whip. Some antennas used by the commercial services have a different style of construction. On those whips, the ferrule is hollow only a portion of the way down and the whip is held in place by setscrews. It will be necessary to drill the hole all the way through the ferrule to be able to use it in this project — probably a most difficult task. We suggest starting with the CB-style ferrule.

[2]Feet × 0.3048 = meters; inches × 25.4 = mm.

[3]PVC pipe can be used instead of Plexiglas tubing if one does not mind not being able to see the base of the whip when it is inside the tubing.

A Memory for the K2BLA CMOS Keyboard

For contesting, a keyboard with memory can't be beat. If your board lacks this feature, you can add this easy-to-build circuit without modification.

By Al Helfrick,* K2BLA

After numerous requests from readers, I've designed a memory to interface with the CMOS keyboard described in January 1978 *QST* and the 1981 *Radio Amateur's Handbook* (available from ARRL for $10). In the best amateur fashion, the memory, built the night before Field Day, received its shakedown cruise during the contest. That baptism clearly indicated that, for contest work, nothing can beat a keyboard with memory. Additionally, one significant advantage to a battery-operated keyboard with memory is that no messages are lost when the generator quits — a not infrequent occurrence on Field Day! As designed, the memory can contain the usual contest exchange in one half of the memory and a contest CQ in the other half.

The memory is arranged to interface with an existing keyboard and commercially available printed circuit boards without any modifications. A circuit that contains only nine ICs and requires only a few additional connections to the keyboard achieves this goal. In fact, if the external connections are brought out to a plug, the memory can be removed simply by disconnecting the plug without disturbing the normal operation of the keyboard. Not only would this plug allow a return to micropower if necessary, but also the memory can be built and debugged independently.

The Memory Add-On

The heart of the memory add-on is a pair of 2102 random-access memory chips (RAMs). The 2102s are the only non-CMOS ICs in the keyboard/memory circuit. Rather unfortunately, they consume more energy than the rest of the keyboard. To interface with the memory ICs, the supply must provide +5 volts for the entire keyboard. All keyboards built to the *QST* design will operate correctly at that voltage.

The memory ICs are arranged as a 1024-byte (word) memory with two-bit words. The two-bit word implies that four different pieces of data can be stored for each word. In the memory addition, the data words are: 10 = space, 01 = dit, 11 = dah and 00 = stop. The stop command causes the memory to stop sending and returns the keyboard operation to normal. One memory location is required for every dit, dah and space, plus one more per message for the stop command. The memory could be arranged as a single 1024-byte size or divided into halves of 512 bytes each. A little experimenting will convince you that 512 words is long enough for any normal message. The total memory space can be calculated by the following formula: Add the number of words plus the number of dits and dahs plus the number of letters plus one. A three-by-three CQ with a long call will not even begin to fill the memory.

Because the capacity of the memory, no warning device is included to warn that the memory is nearly filled. If you suspect that a message will not fit, try it anyway. Doing so takes only a few minutes and you may be pleasantly surprised. If the memory is overrun, the beginning of the message will be erased.

Both halves of a CD4520 dual four-bit counter in cascade plus one half of the dual flip-flop serve as the address counter for the memory ICs. The tenth bit of the memory address is selected by a panel switch labeled MEM A/MEM B. Dit and dah data plus the internal clock are provided by the keyboard. The dit/dah generating circuits are copied from the original keyboard. Use of the three flip-flops within the keyboard would save a few pennies. Repeating these circuits greatly eases the interface, however. That alone seems worth the investment.

The memory is constructed on a universal-type DIP board, very much like the one used in the original keyboard.[1] Not shown in the schematic diagram are three 0.01-μF bypass capacitors, which should be placed at three convenient

*RD 1, Box 87, Boonton, NJ 07005

[1]Universal circuit boards and construction kits for the K2BLA Memory are available from Circuit Board Specialists, Box 969, Pueblo, CO 81002.

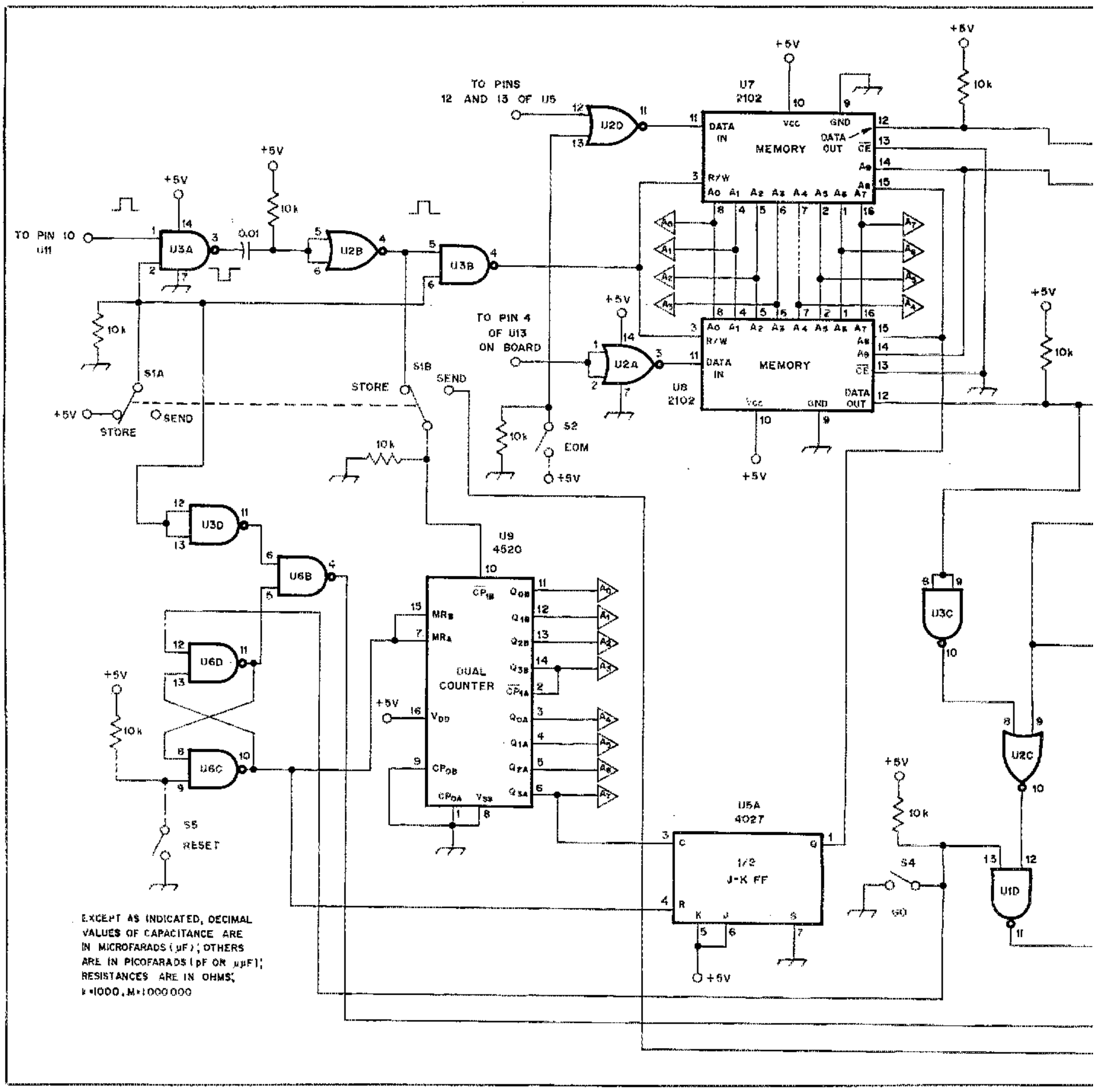


Fig. 1 — Two 2102 RAMs form the heart of this memory unit designed especially for the K2BLA CMOS Keyboard. For battery operation, four nickel-cadmium cells provide adequate power. The dit/dah generating circuit is copied from the original board. Resistances are 1/4 watt.

S1 — Dpdt, pushbutton.
S2, S4, S5 — Spst, pushbutton.
S3 — Spdt, pushbutton.
U1, U3, U6 — 4011 quad dual-input NAND gate (Radio Shack or equiv.).
U2 — 4001 quad dual-input NOR gate (Radio Shack or equiv.).
U4, U5 — 4027 dual J-K flip-flop (Radio Shack or equiv.).

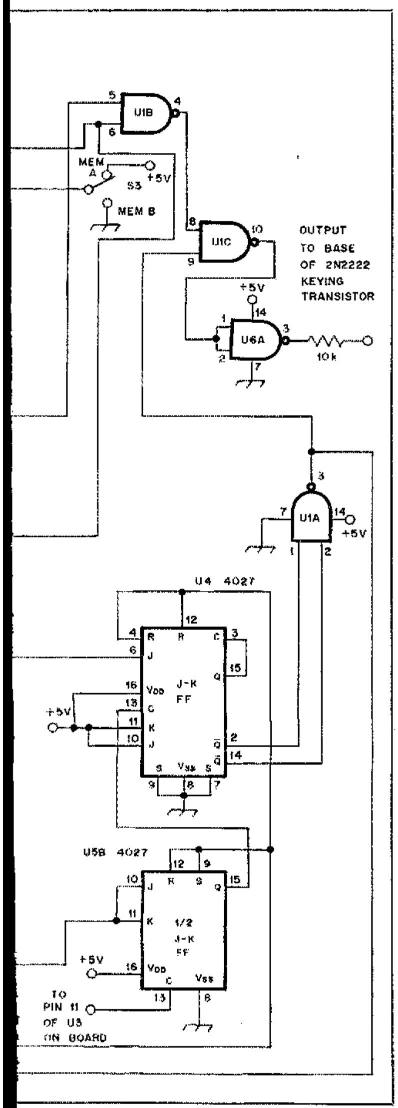
locations between the +5-V circuit and ground.

Do not make the leads longer than necessary. If the memory is to be added outside the keyboard enclosure, keep the external leads shorter than 12 inches to minimize RFI.

No Major Keyboard Modifications

Although no extensive modifications to the keyboard are required, some small items must be added. First, the power supply must be changed to provide 5 V if it is not already operating at that value. If battery operation is required, four nickel-cadmium batteries will be quite satisfactory, supplying exactly 5 V. If ordinary flashlight batteries are to be used, four cells will supply 6 V, a safe operating value.

The space bar must be connected since it is now required for storing messages. In the author's original keyboard, the space bar was removed since it was not essential for normal operation. A spare key now serves that function. Although the keyboard does not conform to a standard typewriter keyboard, with the odd space key, the occasional use of the space only for storing was judged a minor annoyance. The space key or bar is wired



U7, U8 — 2102 static random access memory (Fairchild, Intel or equiv.).
U9 — CD4520 dual counter (RCA or equiv.).

from A7 to B6. Required connections are made by tack-soldering wires to the appropriate points within the keyboard. If a plug is to be installed it may be a wise idea to check the operation of the keyboard after the connections are made to determine if there are any shorts.

Testing the Memory

The memory addition is easy to use and easy to test. To test the memory, the sequence of operation must be followed. Place the STORE/SEND switch to send, the MEM A/MEM B switch to MEM A, and press the reset button. If all is performing correctly, the keyboard should operate in a normal fashion, that is, as if no memory were attached.

To store a message, place the STORE/SEND switch in STORE, press the reset button and press GO. Anything typed from the keyboard will be stored in memory A at this time. After the desired message has been stored, press EOM (end of message) and place the SEND/STORE switch in the SEND position. To transmit the message, press RESET, then GO, and the entire message will be sent exactly as it was typed from the keyboard. A completely independent message may be stored in the B half of the memory by repeating the sequence with the MEM A/MEM B switch in the MEM B position.

Messages may be separated by the use of the EOM button. A stop command can be placed anywhere within the message and the memory will stop. The message may be restarted without resetting by pressing the GO button, whereupon the message will continue until it encounters another stop command. This may be used in the following example: The message "BK TNX FOR CALL UR RST (stop) HR IN NNJ BK (stop) QSL 73 DE K2BLA K (stop)" is stored in the memory by using the EOM key for inserting the stops without pressing the reset button. This message would be used for contest work in the following fashion. After a contact is made and the calls are sent from the keyboard, the contest message is initiated by pressing the GO button. The memory will send TNX FOR CALL UR RST and stop. The RST is entered from the keyboard and the GO button is depressed again. The memory continues, HR IN NNJ BK and stops. At this time the other station operator sends his message. Once that station signals for you to transmit again, the GO button is pressed and the memory continues, BK QSL DE K2BLA K and again stops. The memory must be reset for the next interchange. The obvious message for the second half of the memory would be a contest CQ, which could be started at this time while the chore of logging is finished.

About the Buffer Memory

A final word about the buffer memory is needed. The buffer memory differs from the memory described, since it buffers the input to the keyboard rather than to a permanent storage. Some time ago, I tried to design a buffer that would interface easily with the CMOS keyboard, but that effort was without success. It seemed that to make such an interface would be so difficult that starting from the beginning with an all-new buffered design would be simpler. See the 1981 *Handbook*.

Strays

TA PROFILES

☐ We are indeed fortunate to have Edward E. Wetherhold, W3NQN, of Annapolis, Maryland, as one of our ARRL Technical Advisors. His professional field of expertise is the design and application of passive LC filters. He has written numerous technical articles on the subject, which have appeared in *QST*, *Ham Radio* and many professional electronics publications. He has also contributed material for the ARRL *Radio Amateur's Handbook*. First licensed in 1947, Ed now holds an Advanced class license.

Ed received his B.S. in Radio Engineering from Tri-State University. He is a member of IEEE, with memberships in the following IEEE groups: Professional Communication, Electromagnetic Compatibility, and Communications. Employed by Honeywell, Inc., Ed does the testing of communications systems. Ed is active in tournament tennis and is ranked number 15 in Men's-45 singles by the Middle Atlantic Tennis Association. — *Marian Anderson, WB1FSB*

Meet TA Ed Wetherhold, W3NQN.

ATTENTION CERTIFICATE HUNTERS

☐ Did you know that when you upgrade to Amateur Extra Class, the FCC will issue a diploma-style certificate? If you want one, send a copy of your license to the FCC engineer in charge of the district in which you took your Amateur Extra Class examination. The certificate fits into an 8- x 10-inch frame and looks nice on the wall of your shack. — *Richard Bert, KF8I, Pontiac, Michigan*

Broad-Band 80-Meter Antenna

The cage is back! Almost forgotten since the 1920s, this multiwire antenna, arranged as a center-fed dipole, provides edge-to-edge band coverage without the help of a tuner. The low SWR will make you and your rig happy!

By Allen B. Harbach,* WA4DRU, VP5AH, VP1AH

I dislike antenna tuners! I suppose there is a place for them when one can put up only one piece of wire to cover all bands, but they definitely slow down the ability to QSY quickly from one end of the band to the other to catch the rare one.

When I began chasing DX in the early '70s, I rapidly became aware that something had to be done to broaden the response of my antenna system — particularly on the 80-meter band. The reason 80 meters is so tough is that it has the greatest percentage bandwidth of any of the popular amateur bands (see Table 1). Percentage bandwidth is a concept that gives a clue to the required Q of an antenna in order to have low SWR from top to bottom. It is calculated by dividing the bandwidth (in kHz) by the band-center frequency (in kHz) and multiplying by 100 to get percent. The 80-meter band is 13.3% wide

$$\left(\frac{500}{3750} \times 100\right)$$

which means that it requires an antenna Q of 7 or below to be able to cover the whole band at low SWR. To further illustrate the concept, the 15-meter band is nearly as wide as the 80-meter band, in kHz, but is much narrower in percentage bandwidth

$$\left(\frac{450}{21{,}225} \times 100\right)$$

An antenna Q of 45 or less will cover the entire 15-meter band with reasonable SWR (a dipole of no. 12 wire). On 80 meters the typical dipole of no. 12 wire has a bandwidth of 75 kHz at the 1.5:1 SWR points, or in excess of 5:1 at the band edges when resonated at 3750 kHz (band center).

To get around this problem, I did some reading in the library at the local engineering college. I arrived at the well-known fact that the fatter one makes an antenna, the lower the Q; hence the greater the bandwidth. But how thick? Doing some more reading and a lot of paper scratching, I arrived at some relationships that could be solved with the average scientific calculator. Later, I programmed these into our company computer to speed calculations and print tables and graphs.

Table 1

Percentage Bandwidths for the Popular Amateur Bands

Band (meters)	*160*	*80*	*40*	*20*	*15*	*10*	*6*	*2*
Percent Bandwidth	10.5%	13.3%	4.2%	2.5%	2.1%	6.3%	7.7%	2.7%

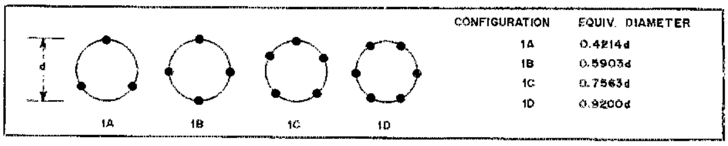


Fig. 1 — Solid-tube equivalents of wire cages.

The equations and math I'll tackle later for those who are interested. For the others who want to know what to build, I'll cover that now. Calculating several antennas from the equations, I found that the antenna had to be at least 3 feet in diameter to cover the whole 80-meter band with a low SWR. Now, how to put up a 3-foot-diameter pipe 120 feet long! That's the question., So back to the books!

More reading showed that one can approximate a cylindrical conductor with parallel wires of various configurations. The equivalent diameter of a conductor, made up of parallel wires, is shown in Fig. 1.

The easiest type to construct is a four-wire cage. For my antenna, I used cross sticks of 1 × 1 material, 4 feet (1.2 m) long, which were held together at the center by a couple of brads. Holes were drilled in the ends of the sticks to take the antenna wire. Wire ties served to keep the spreaders from slipping (Fig. 2). I used a no. 16 wire for each element. This is equivalent in antenna resistance to a dipole made of no. 10 wire, and it keeps ohmic losses low.

Mechanical Considerations

Some mechanical considerations must be kept in mind. This antenna will swing in the wind. The first antenna I installed failed through fatigue both at the center and the end points. Therefore, the end sections of each half must be made of heavier material. I have used both no. 16 Copperweld and no. 12 soft-drawn copper wire for the end sections with no failures in over six years.

The ends of each half section are tapered over a distance equal to the spreader length to provide a transition between the large-diameter conductor of the antenna and the balun or coaxial connection. To keep construction simple, I did not attempt to optimize the end terminations.

Use fairly heavy insulators at the center support, as this is a heavy antenna; wind loading is five times that of the usual

*2318 S. Country Club Rd., Melbourne, FL 32901

Table 2

Characteristics for the 80-Meter Band

Freq.	*Ohms*	*Reactance*	*SWR*
3.500	53.4	−45.0	2.18
3.520	54.2	−41.3	2.03
3.540	55.0	−37.5	1.90
3.560	55.8	−33.8	1.78
3.580	56.6	−30.1	1.67
3.600	57.4	−26.4	1.56
3.620	58.2	−22.7	1.46
3.640	59.0	−19.0	1.37
3.660	59.8	−15.4	1.29
3.680	60.6	−11.7	1.21
3.700	61.4	−8.0	1.14
3.720	62.2	−4.4	1.07
3.740	63.0	−0.7	1.02
3.760	63.8	2.9	1.06
3.780	64.7	6.6	1.12
3.800	65.5	10.2	1.18
3.820	66.3	13.9	1.25
3.840	67.1	17.5	1.33
3.860	67.9	21.1	1.40
3.880	68.7	24.8	1.48
3.900	69.5	28.4	1.56
3.920	70.3	32.0	1.64
3.940	71.1	35.7	1.73
3.960	71.9	39.3	1.82
3.980	72.7	42.9	1.91
4.000	73.5	46.5	2.01

Note: Calculations for an antenna 124 feet (37.8 m) long and 3 feet (0.9 m) in dia covering 3.5 to 4.0 MHz. Zo = 62.

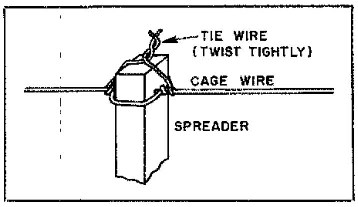


Fig. 2 — Detail of spreader ties.

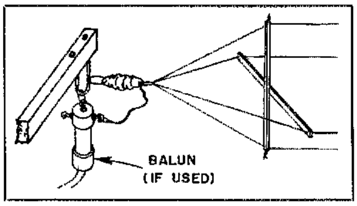


Fig. 3 — Center-support and end-taper detail of the cage.

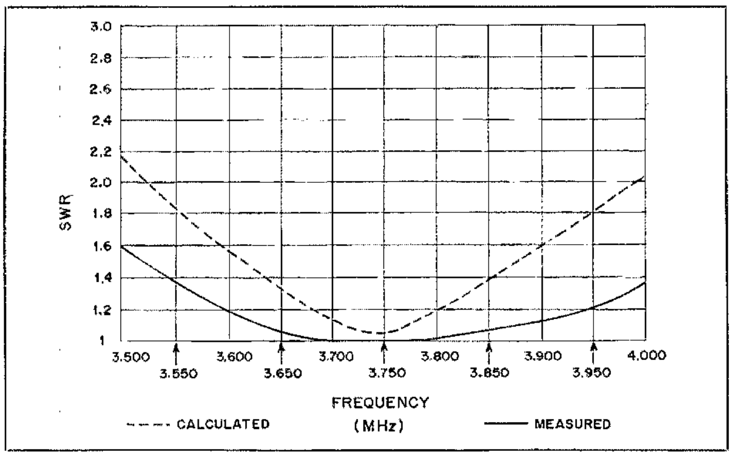


Fig. 4 — This graph shows the calculated vs. measured SWR values for the broad-band cage antenna over the entire 80-meter band. The gradual slope of the measured curve and the low SWR range indicate good bandwidth and matching.

dipole. (Do not despair! Mine has survived a twister and a hurricane!) I used a separate insulator for each half with each fastened to a U bolt in a wooden arm protruding from my tower (Fig. 3). Separate insulators at the center allow each half to be made and raised separately. A no. 12 flexible wire connects the center of each half to the balun or coaxial line.

Naturally, the higher the antenna, the better it is for DX. Mine is 68 feet (20.7 m) at the center, with one end held at 55 feet (16.8 m) and the other at 40 feet (12 m) above ground.

Testing

Once in place, the antenna is ready for testing. Each installation seems to have its own peculiarities, the result of nearby objects such as trees, houses and metallic structures. These affect the resonant length of the antenna to a greater extent than they would affect a single-wire dipole because of the larger capacitance between the antenna and nearby objects. While the length was calculated to be near 124 feet (37.8 m), I had to shorten mine to 115 feet (35 m) to have it be resonant at the center of the band. I performed the shortening in the last outboard section rather than redo the end termination. That, however, was a personal choice.

All the theory in the world is useless if the thing doesn't work! I'm delighted to say, though, that the antenna does perform well. Observe, for instance, the calculated SWR plot and the measured SWR curve in Fig. 4. The return on invested time is very high. It took me only one afternoon to put the thing up. My rewards for the 80-meter portion of both 5BDXCC and 5BWAS were gained with the use of this cage dipole. The significant advantage of this antenna, however, is that you can throw away that 80-meter antenna tuner and QSY all over the band with ease without concern about the SWR!

Math 'n Stuff

The characteristic impedance of an antenna with a length-to-diameter ratio greater than 15 is given by the expression

$$Z_{in} = R(k\ell) - j[120\,(\mathrm{Ln}\,2\ell/a - 1)\cot(k\ell) - X(k\ell)]$$

where

2ℓ = total length

a = conductor radius

$k\ell = 2\pi(\ell/\lambda)$, or the length of one half the antenna measured in radians.

Ln = natural logarithm

Since $\lambda = 984.25/f_{MHz}$, then $k\ell = 6.384 \times 10^{-3} f_{MHz}\ell$, where ℓ and λ are in feet.

$R(k\ell)$ and $X(k\ell)$ are quite complex functions, but are calculated as a table in Ref. 1. Fortunately, we are interested in antennas near 1/2 wavelength long. In this region, these functions can be approximated by the following linear equations:

$$R(k\ell) = 102\,(k\ell) - 87.86$$
$$X(k\ell) = 48.54(k\ell) - 34.86$$

Some error is introduced by this approximation, but it is less than 5%. Antenna location, height and trees will introduce larger errors than that! Now, the equation for the center impedance is simplified to the point where one can calculate values with the average scientific hand-held calculator.

For angles calculated in radians:

$$Z_{in} = (0.6512 f_{MHz}\ell - 87.86) - j[120\,(\mathrm{Ln}2\ell/a - 1)\cot(6.384 \times 10^{-3} f_{MHz}\ell) - 0.3099 f_{MHz}\ell + 34.96]$$

For angles calculated in degrees:

$$Z_{in} = (0.6512 f_{MHz}\ell - 87.86) - j[120\,(\mathrm{Ln}2\ell/a - 1)\cot(0.3658 f_{MHz}\ell - 0.3099 f_{MHz} + 34.96]$$

SWR calculated by the *Antenna Book* formula:

$$SWR = \frac{1 + k}{1 - k};\ k = \frac{(R - Z_0)^2 + X^2}{(R + Z_0)^2 + X^2}$$

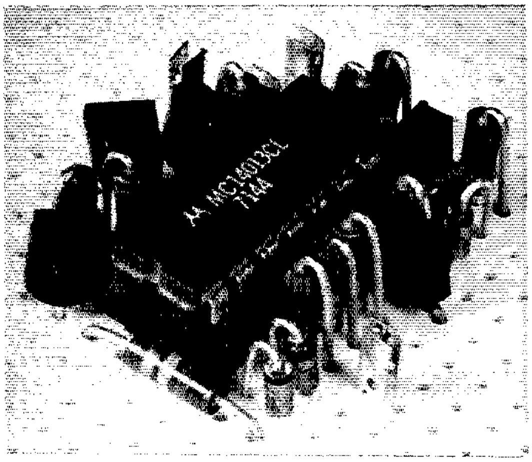
where R and X are the resistive and reactive parts of the load, and Z_0 is the transmission-line impedance.

References

[1]Jasik, *Antenna Engineering Handbook*, first edition, McGraw Hill, 1961, pp. 3-2 through 3-7.

The Radio Amateur's Handbook, fifty-eighth edition, ARRL, 1981, p. 19-2.

A Smart Push-to-Talk Circuit



Tired of juggling the steering wheel, the gear shift, the cup of coffee and the microphone when you make a sharp left? This circuit won't clean the coffee off your suit, but it will help with the microphone.

By Ken Stuart,* W3VVN

For a number of years I've operated 2-meter mobile with an imported car having a 4-speed manual transmission. Trying to maintain a QSO while steering, shifting gears, and holding down a microphone push-to-talk switch can be frustrating, to say the least. Often, a momentary break in the carrier while transferring the microphone from one hand to another is interpreted by the listener as an invitation to transmit, with "doubling" as the result. Also, for long transmissions on simplex or hf, holding down the microphone button can be downright tiring. I felt that there must be a better way without resorting to a toggle switch. Finally I came up with what I call a "smart" push-to-talk (PTT) circuit.

Basically, the circuit operates in two modes, dependent upon the time that has elapsed between the pressing of the microphone PTT switch and its release. If the switch is depressed for a half second or longer, when the switch is released the transceiver will return to the listen mode. But if the switch is released immediately after it is pressed (within one-half second), the circuit will latch in the on state until the PTT switch is again pushed and released.

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How It Works

The heart of the circuit is the CD4013 dual-D flip-flop (only one of the two sections is used in this application). The operation of a type D flip-flop, or latch, is quite simple. As long as no clock pulse is applied to the clock input, its output will not change state. When a clock pulse is received the digital state of the data input will be transferred to the flip-flop Q output during the positive-going transition of the clock pulse. The output will remain in this state until the next clock pulse is received, at which time the output will assume the state of the data input at that instant.

Referring to the schematic diagram in Fig. 1, let's assume that the microphone push-to-talk switch is open, and that the circuit is calling for the transceiver to be in the RECEIVE mode. Under these conditions, the voltages at the U1 clock input (pin 3) and output (pin 1) will be at +10 volts, and transistors Q1, Q2 and Q3 will be in the nonconducting state. Also C3 will be discharged and the data input on U1 (pin 5) will be near ground potential. (The data input considers any voltage from zero to about 5 volts as a logic 0.)

A transmission is initiated by closing the PTT switch. Q1 is turned on immediately by base current flowing through D1 and R3. Q1, in turn, provides base current to the Darlington-connected pair Q2 and Q3, which turn on and thereby place the transceiver in the TRANSMIT mode. Since the collector of Q1 has been pulled up to +10 volts, C3 begins to charge through R8, and reaches a voltage level of +5 volts in about a half second. Beyond a half second, as C3's voltage continues to increase with time, the data input of U1 sees this voltage level as a logic 1. (Nothing happens to the U1 output since no clock pulse has been generated by releasing the PTT switch.) So far, nothing unusual has happened to the transceiver; depressing the PTT switch has activated the transmitter, just as though the circuit were not inserted between the microphone and the rig.

Now let's examine circuit operation when the PTT switch is released. To do so, we must consider whether the switch is released at some time after the half second has elapsed (condition 1), or before the half second has elapsed (condition 2).

When the PTT switch is held down for the duration of the transmission and then released (condition 1), the opening switch causes pin 3 of U1 to see a positive transition. This clocks the flip-flop and transfers the logic state at the data input to the output. Since the data input would be at a 1 or "high" level with C3 charged to greater than 5 volts, the flip-flop output would simply remain high. Q1's base-current path through R3 and D1 would be opened, and the transceiver would return to the receive mode since Q2 and Q3 would also turn off.

However, if the PTT switch is released before C3 has had sufficient time to charge (condition 2), the resulting clock pulse at pin 3 allows the logic 0 at the data input to propagate to the output of U1. This maintains the base current in Q1 by allowing it to flow through R3 and D2. The circuit will now remain locked in this mode until the PTT switch is again pushed and released, at which time another clock pulse will propagate the logic 1 at the data input (C3 will have charged by this time) to the U1 output, thereby terminating the transmit mode.

To ensure that the circuit is in the receive mode when power is first applied, the initial start-up network consisting of C2 and R6 has been included. These components force the output of U1 to a high level at initial turn-on by supplying a short pulse to the SET input.

Construction

Layout of the circuit is entirely noncritical, although dense packing of components is suggested to facilitate mounting the unit inside already-cramped 2-meter rigs. The photograph shows what can be expected size-wise with Vectorbord construction and vertically mounted components. If further reduction in size and component count is desired, Q2 and Q3 can be replaced with a Darlington device, such as the Motorola MPS-A13 or MPS-A14 (R12 is then eliminated). Also, if the circuit is to be powered by a well-regulated potential of 8 to 12 volts from the transceiver, Zener diode D3 and R9 can be eliminated. It is recommended, however, that protective resistors R2, R5 and R7 be retained. Otherwise, stored voltages in C2 and C3 can cause heavy charge/discharge currents in internal gate protective networks of U1 when power is applied or removed. Further, transients and rf can be picked up on the microphone cable, contributing to false operation.

And there you have it. Throw away that bottle of liniment! Enjoy a life of fewer cramped fingers and less accidental doubling on your favorite repeater. Install another unit on your hf rig and live up to that Rag Chewer's Club certificate without sacrificing quick break-in capabilities. QST

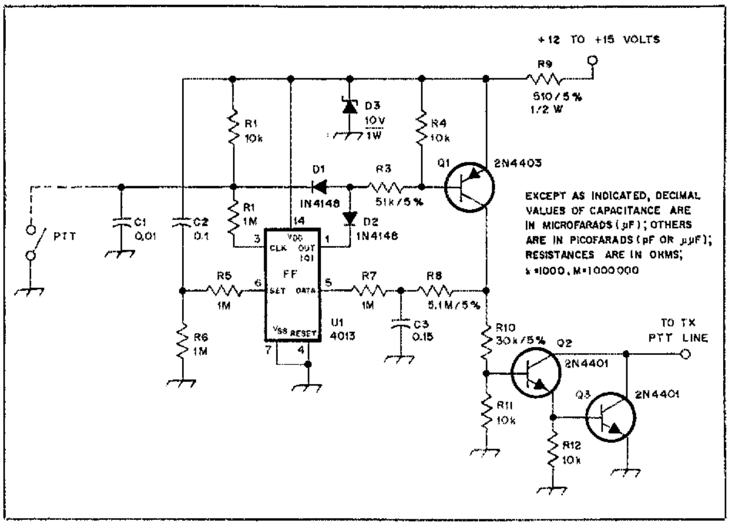


Fig. 1 — Schematic diagram of the "smart" PTT switch. Capacitors are disc ceramic. Resistors are carbon composition, 1/4 watt except where marked. Parts placement is not critical, although the more compact the construction, the easier it will be to fit it inside the case of your radio.

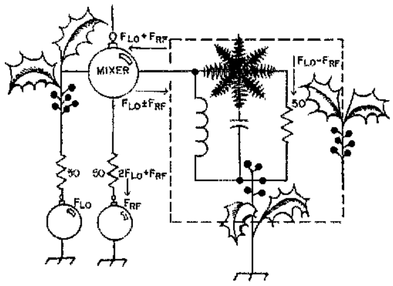
D1, D2 — Silicon signal diode (1N914, 1N4148, or equiv.).

D3 — 10-volt Zener diode (8 to 12 V suitable substitute).

Q1 — Silicon, pnp, general-purpose transistor (2N4403, 2N2907 or equiv.).

Q2, Q3 — Silicon, npn, general purpose transistor (2N4401, 2N2222 or equiv.).

U1 — Dual D flip-flop, CMOS type 4013 (CD4013, MC14013 or equiv.).



SEASON'S GREETINGS FROM THE HAMS AT ARRL/IARU HQ.
(Listed in alphabetical order of call sign)

Richard Palm	K1CE
Jeanne DeMaw	W1CKK
Laird Campbell	W1CUT
George Grammer	W1DF
Elizabeth H. Karpiej	KA1DTU
Joan Merritt	KA1DTV
Byron Goodman	W1DX
Maureen Thompson	KA1DYZ
Chris Schenck	W1EH
Shelly Fuini	WB1ENT
Stephen C. Place	WB1EYI
Paul K. Pagel	N1FB
Doug DeMaw	W1FB/VP2MFW
Hal Steinman	K1FHN
Marian Anderson	WB1FSB/VP2MFR
Marge Tenney	WB1FSN
John Nelson	W1GNC
Bob Atkins	KA1GT
Ed Tilton	W1HDQ
Lew McCoy	W1ICP
Jean Peacor	K1IJV
Stuart B. Leland	W1JEC
Joe Moskey	W1JMY
Clarke Greene	K1JX
Tom Frenaye	K1KI
Brian Downey	WA1KSF
James E. McCobb, Jr.	K1LLU
Stan Horzepa	WA1LOU
Mike Kaczynski	W1OD
Bruce Kampe	WA1POI
George Woodward	W1RN
Richard L. Baldwin	W1RU
Lee Aurick	W1SE
Jerry Hall	K1TD
Perry F. Williams	W1UED
Arline Bender	WA1VMC
Bill Jennings	K1WJ
Chuck Bender	W1WPR
Bob Halprin	K1XA
John Lindholm	W1XX
Sandy Gerli	AC1Y
Joel Kleinman	WA1ZUY
David Sumner	K1ZZ
Dave Bristol	KA2BNV
Mark J. Wilson	AA2Z
Don Search	W3AZD
Dale Clift	WA3NLO
William A. Tynan	W3XO
Gerry Hull	AK4L/VE1BXC
John Troster	W6ISQ
Chuck Chadwick	K8AXL/WA4JXE
Sally H. O'Dell	AE8P
Peter O'Dell	AE8Q
Bernard D. Glassmeyer	W9KDR
George Collins	AD0W
Harry MacLean	VE3GRO
Maxim Memorial Station	W1AW
ARRL hq. Station	W1INF

• *Basic Amateur Radio*

Antennas and Grounds for Apartments

What do you do when the landlord says "no antenna"? Where's rf ground when you are 70 feet up? You won't find any simple answers, but these suggestions are sure worth trying.

By Peter O'Dell,* AE8Q

When my wife and I decided to return to Connecticut, we spent a couple of days going over the apartment ads in the local paper. In one particular Sunday edition, there were about four pages of ads for apartments. Of all those advertising, one apartment complex stated that they "accepted pets and children." Since our family consists of two adults, one three-year-old child and a 10-year-old beagle, we didn't feel that we had much of a choice in the matter. The rental agent (a close relative of Attila the Hun) offhandedly indicated that we could take it or leave it, but that the rules of the lease, including the prohibition of *any* external antenna, would stand without *any* modification. I haven't lived in a place yet where I couldn't put up some kind of antenna and get away with it, so we took the apartment.

How many other hams are in similar circumstances? It is hard to say, but it is probably a sizeable number. If you are one of the multitude, where do you start? The first thing to decide is if there is a chance of getting permission to install an outside antenna. If there is any chance at all, pursue it with vigor. Your best bet is to document your case with drawings of the proposed installation (landlords want to protect their property from damage caused by a poor installation). Material that might make them want you to put up the antenna should be included also. (Photocopy a few articles from back issues of *QST* that tell about the activities of amateurs during natural disasters.)

What Has Been Done Before?

For some amateurs there is little or no possibility of getting permission to erect an outside antenna. There are basically two different approaches to the problem: String wire inside the apartment or use something outside that will not be recognized as an antenna. Let's take a look at the last course of action first.

Antennas made of very small wire work quite well when properly fed. If the wire is size number 26 or smaller and is dull colored, it is almost impossible to see once it is a few feet above ground. Over the years this popular approach has come to be known as an "invisible antenna." Dipoles, loops and random-length end feeds are all possible configurations, depending on the physical layout and oddities of architecture that you have available.

Another approach to the problem is to use some object as an antenna that would not normally be thought of as an antenna. Richard Bell, WA4BNO, once lived in an apartment that prohibited antennas. After a couple of months off the air he tried connecting a short wire from his matching network to a down spout located near one of the windows. Having scraped away the paint from a small area, he used an alligator clip to attach the wire to the gutter whenever he wanted to operate. This system may work in other locations. If the gutters are relatively new and are made of aluminum, chances of success are better than if they appear "aged and rusty." In the case of the latter, you would run a very high risk of non-linear rectification of rf, which would generate harmonics at a rate unequaled except by rabbits and mink.

Although condominiums and "planned communities" often prohibit outside antennas, many have no rules regarding the erection of flagpoles. The owner's association of one planned community in the Kansas City area will not permit a prominent DXer to put up an external antenna (no one has spotted the invisible dipole that is mounted under the overhang

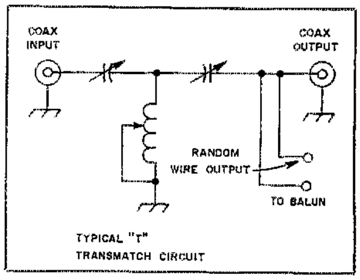


Fig. 1 — This is a typical T-match circuit that has been very popular recently; the "Ultimate Transmatch" is a variation of this circuit. Most commercial versions have a toroidal balun built in to give the user the option of a balanced output.

*Basic Radio Editor

of his 2-story townhouse). His initial plan was to buy and erect a 60-foot flagpole. But, he was quoted prices in excess of $6000 for a new pole. He is busy searching for a used 60-foot flagpole and expects to have it up by early summer. In the meantime, he is "planting radials." He estimates that it would be relatively simple and inexpensive to put up a 32-foot flagpole (less than $300), but he is interested in 80-meter DX and is determined to have a full-size, 1/4-wavelength vertical for 80 meters.

Another approach, less costly and less involved, uses a flagpole disguise. This was described by Fred J. Schnell, W6OZF, in "The Flagpole Deluxe," which appeared in March 1978 *QST*. Fred built a very thin 40- through 10-meter trap vertical, which he placed inside a 17-foot section of PVC pipe that was fashioned into a flagpole. Anyone for a pair of flagpoles in phase?

The other major option is to string wire inside the building. Normally, with the exception of 10 meters and, in some cases, 15 meters, it will be necessary to "shorten" or "bend" any resonant antenna. Also, the proximity to house wiring, metal gutters and metal framework will affect the performance of the antenna. The antenna may be any configuration that works, e.g. dipole, loop, end-fed random length or the like. It may be horizontally or vertically polarized, or both. You can attach it to the ceiling, string it in the attic or even run it under the rug. The secret is to keep trying until you find something that works. Whatever your final choice is, it will probably be something of a compromise.

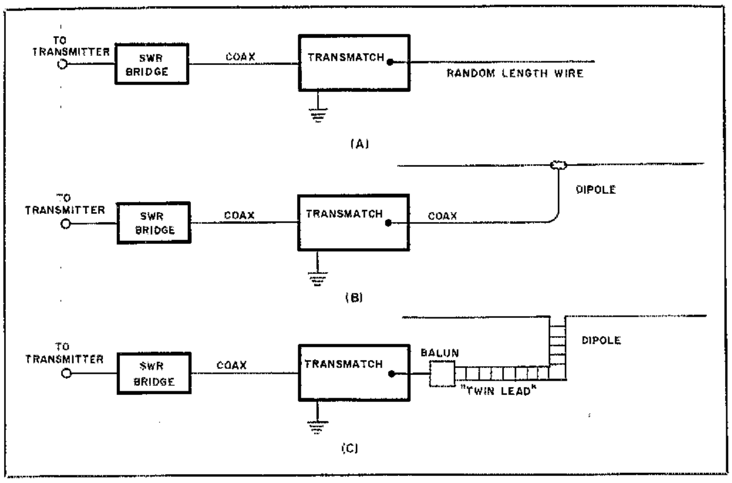


Fig. 2 — Three typical antenna systems used by apartment dwellers. Most suffer from trying to "force" an earth ground when it is physically impossible to have one. Probably the worst course of action for an apartment dweller is to "ground" his station to the cold water pipes.

Got A Match?

As a general rule, any antenna that can be put up inside or disguised on the outside will probably not present a 50-Ω load to the transmitter. Most modern transmitters do not have a wide matching range built in, so more than likely you will need some kind of matching device to trick the transmitter into seeing a 50-Ω load. In recent years the most popular circuit has been the T match (Fig. 1). Variations of this circuit are available from a number of manufacturers; for those interested in "rolling their own," complete construction plans can be found in *The ARRL Antenna Anthology*. (Incidentally, this excellent source of ideas for practical antennas is available from ARRL for $4. Even though most of the content is oriented toward outside, nondisguised antennas, the apartment dweller should derive a great deal of "inspiration" from the contents.) The chief advantage of the T match is that it will match an extremely wide variety of impedances to the transmitter — and it is not particularly critical to tune. The major drawback is that it does not do much to reduce harmonic energy; therefore, if you have one of these matching networks, it is a good idea to put a low-pass filter ahead of it.

Fig. 2 shows the three most typical setups used by apartment dwellers and others restricted to compromise antennas. Much can be done to improve on these installations. The antenna depicted in part A of Fig. 2 is similar to the system that I set up for our apartment, which was of the two-story town-house variety. A metal box had been built into the side of the apartment for installation of an air conditioner. The box provided a convenient means of getting the wire outside of the apartment. Unfortunately, this box was located on the side of the building that faced the other buildings of the complex instead of the swamp in the rear. After I acquired about 300 feet of wire and secured the help of a couple of friends, we spent one Sunday afternoon putting the darned thing up.

I purchased a powerful slingshot (about $5) and an inexpensive fishing rod and reel (about $8) from the sporting goods section of a discount store. We attached a lead weight to the fishing line and used the slingshot to shoot the weight and line over the building. We then removed the lead weight, attached the line to the end of the antenna and "reeled it in." The same procedure was used to get the wire into the tops of several trees.

Because it was Sunday afternoon, the maintenance crew was not around. Few, if any, of the other residents noticed us. The only "incident" came when we attracted the interest of a half-dozen boys playing in the vicinity. They came closer to watch us with fishing tackle and the slingshot. After a few minutes of speculating among themselves as to what we were doing, one fellow bluntly asked us what we were up to. At first I ignored him, but he was persistent and kept asking the same question. A glance from my friend indicated that he felt I would have to give him some sort of an answer. A scenario rapidly went through my mind in which the boy told his father that a radio antenna was up, followed by rumors and complaints to the management for every perceived incidence of interference. I decided that discretion was the better part of valor; I told him such a preposterous lie that he wouldn't dare to repeat it. "I'm putting this up to keep the UFOs away," I said. "Every place I go the UFOs drive me *crazy* unless I put one of these up. As soon as I put one of these up, they go away and leave me alone." The boys rapidly lost interest in what we were doing and left.

Fig. 2B shows the output of the T match feeding coax transmission line, which in turn feeds the dipole. Because the antenna impedance may be influenced by nearby objects or because the antenna may not be resonant, the Transmatch probably sees something other than a 50-Ω load looking into the antenna. A similar system exists at C, except that the coax has been replaced with twin-lead and a balun. One form of balun is a network that transforms a *bal*anced impedance to an *un*balanced impedance. Although it is shown as a separate and distinct item from the Transmatch, the balun is frequently built into the Transmatch housing. Balun transformers are wound for some specific transformation ratio. The norm seems to be to wind them on toroid cores, but they can be wound on air cores also. At very high impedances, the baluns (particularly the toroidal ones) may not perform well.

Each installation depicted in Fig. 2 shows the Transmatch connected to an earth ground. This is what most of the books and articles have called for over the years. There is just one catch. Suppose your station is located on the second floor and that it is 16 feet (5 meters) from the end of the ground wire attached to your equipment to the end attached to a ground rod. Keep in mind that the whole idea of grounding the station for rf is to have the equipment at a low-impedance (and, therefore, low-voltage) position. How effective is the ground when the station is transmitting on the 20-meter band? At 20 meters, 16 feet (5 meters) is approximately 1/4 wavelength long. A quarter-wavelength of wire will act as an impedance inverter from one end to the other. Since the grounded end is at a very low impedance, the equipment end will be at a very high impedance!

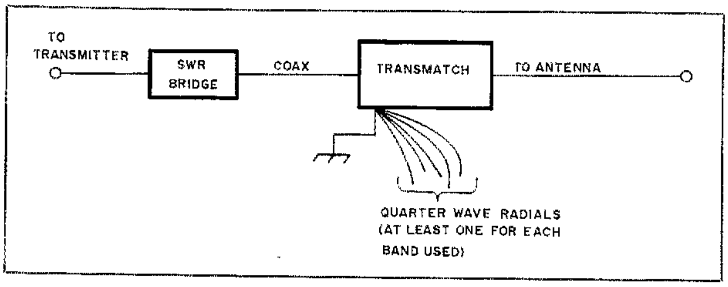


Fig. 3 — Here is an alternative to earth ground for the apartment dweller. At least one quarter-wave-length radial is cut for each band used and attached to chassis ground for the station. This is similar to what the old timers referred to as the counterpoise.

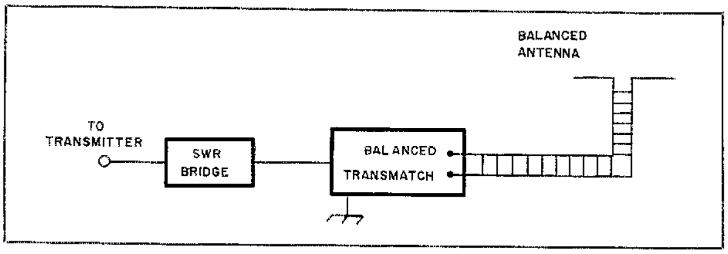


Fig. 4 — A balanced Transmatch is an alternative to the T match. Coax losses and balun losses are avoided by using this system.

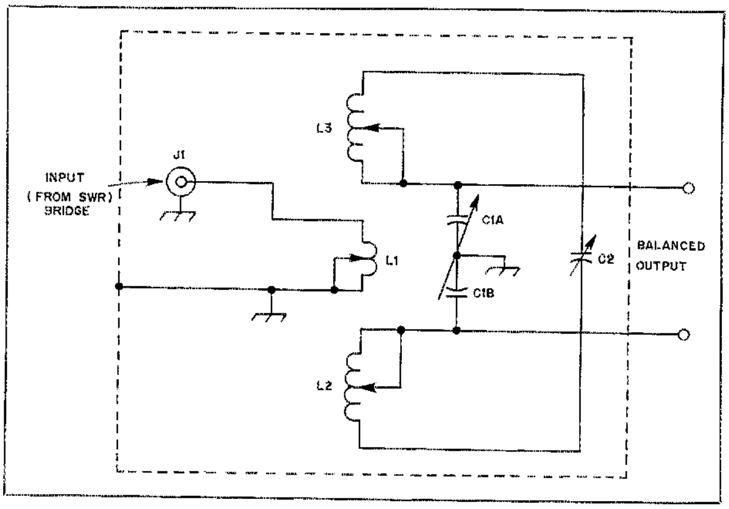


Fig. 5 — Schematic diagram of balanced Transmatch. See text for parts description. Copper-plated alligator clips should be used instead of the ordinary steel clips (Radio Shack #270-373 are suitable). A multipositioned, two-pole ceramic rotary switch may be used instead of the alligator clips on L2/L3. Similarly, a single-pole, ceramic rotary switch may be used at L1. B&W coil stock, shaft couplings, stand-off insulators and miscellaneous parts may be purchased from Radiokit, Box 411, Greenville, NH 03048, Tel. 603-878-1033.

The likely result will be rf hot spots all around the station. Suppose that instead of a wire to ground, you connect a wire to the cold water pipe in your apartment, which will ultimately go to ground. Is it a high or low impedance? But what if this pipe is connected to other pipes in other apartments? What if the telephone company has grounded its equipment to the same pipe? Cable TV? In all probability, you have created more problems for yourself than if you had left the station totally "ungrounded." Actually, in the "ungrounded" situation there may be some capacitive coupling to the ac power line, which may act like a phantom ground. This is why a brute force filter is sometimes needed to clear up TVI.

A workable compromise is depicted in Fig. 3. No attempt is made to ground the station to an earth ground. Rather, the equipment is tied to a central point in the station through short pieces of braid. Quarter-wavelength radials are cut for each band to be used and attached to the central point in the station. This is similar to what the old timers referred to as a counterpoise, and it does work. If you have an outdoor antenna, you may want to provide a dc path to ground to allow safe bleed-off of static buildup. If this dc ground is more than a few feet long, I would suggest disconnecting it during operation (you don't operate during a storm, do you?), or at least put an rf-choke in series with the dc ground.

A Critical Balance

When you start with a compromise antenna, it is a good idea to avoid compromises elsewhere in the system since the compromises tend to compound. As mentioned above, in recent years the T match has been the most-often-used Transmatch. The T match has an unbalanced input and feeds an unbalanced output. If a coax-fed dipole is attached to the T match, it should work fine if the antenna is reasonably close to a 50-Ω load to start with. If not, the high SWR on the coax can increase losses. Twin-lead or ladder line is not nearly so lossy. So another approach is to feed the dipole with twin-lead and use a balun at the T match to convert the unbalanced output of the Transmatch to the balanced input of the twin lead. Unfortunately, at extremely high mismatches transformer baluns can also be quite lossy. Under certain conditions transformer baluns can actually generate harmonics!

Fig. 4 shows an alternative to these two systems. If we use a balanced-output Transmatch we can avoid the potential losses of coax and baluns. It can be positioned in the system just as the T match. An SWR bridge ahead of the balanced

Transmatch is used to indicate a matched condition, just as it is with the T match. Several different circuits have been developed over the years, but we recently came across one that is easy to construct and works very well (Fig. 5).[1] Additionally, it can be duplicated in short order at a very modest cost.

Component values are not critical; substitute with whatever you happen to have available. C1A and B are two sections of a three-section, ganged, variable capacitor removed from the carcass of a defunct tube-type a-m broadcast receiver. At the 100-watt output level I have not experienced any arc-over; if that does happen you may have to find a dual-section variable capacitor with wider spacing. Surplus dealers and hamfest flea markets are the suggested sources for the capacitors. C2 is a single-section, 150-pF variable capacitor (it can be one section of another ganged capacitor). Again the exact range is not critical; use whatever you can find. One thing that is somewhat critical is using insulated shaft couplings on both capacitors. Without the couplings, your body capacitance will affect the tuning. C1 can be mounted directly to the chassis, which will ground the rotor; connections to the A-section stator and the B-section stator can then be made to the solder lugs. Both the stator and the rotor of C2 should be insulated from ground; it will probably be necessary to mount C2 on ceramic standoff insulators.

L2 and L3 are made from one piece of coil stock. The coil stock that I happened to use is B&W Air-Dux 1008T (1-1/4-inch diameter, 8 turns per inch, no. 16 wire). Again, reasonable substitutions may be made. Count the number of turns on the total length of coil stock and determine the middle turn. Cut the wire portion of the coil stock at the mid-point, but do not sever the plastic spacers. Solder two insulated wires to each of the ends created by cutting the coil in two. One wire should be 6 inches long and the other should be long enough to reach C1. Attach copper-plated alligator clips to each of the 6-inch wires. The alligator clips will be used to vary the inductance of L2 and L3.

L1 is fashioned from another piece of coil stock of larger diameter, such as B&W 3051 (1-1/2-inch diameter, 4 turns per inch, no. 14 wire). Six to eight turns should be adequate; again attach a short wire with a copper-plated alligator clip on the end to one side of the coil to enable you to tap L1 for the proper amount of coupling. L1 is then slid over L2 and L3 and positioned directly above the center of the coil stock. Mount the coil assembly to the chassis with ceramic standoff insulators at each end of the coil stock (L2/L3). Solder the L1 leads to ground and to the input jack J1. If L1 is not held rigidly in place, it may be necessary to wedge strips of plastic or other insulating material between L1 and L2/L3. Complete the wiring according to the diagram in Fig. 5.

[1]Hawker, "Technical Topics," *Radio Communications*, RSGB, September 1980, p. 905.

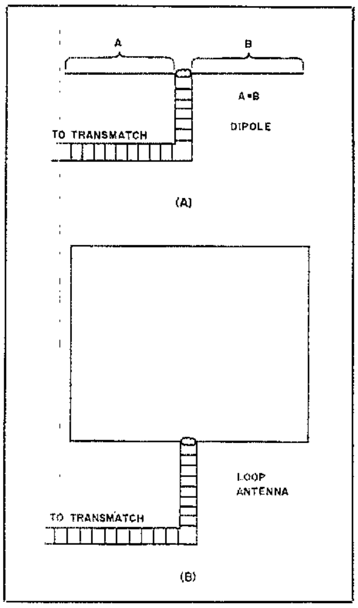


Fig. 6 — Two balanced antennas that should work well for the apartment dweller. The legs of the dipole shown in A should be as long as practical — 65 feet would be considered ideal for each for an 80-meter installation. The balanced Transmatch in Fig. 5 should match any size dipole to the other amateur bands. The loop in B is of any convenient size. It does not have to be laid out in a single plane (flat).

Match It

Adjustment is relatively simple and straightforward. Attach a 50-Ω dummy load to the output of the SWR bridge. Adjust the transmitter for a relatively small amount of power out (e.g. 15 watts from a transmitter capable of delivering 100 watts). Set the controls of the SWR bridge to read full scale in the reference (forward) position. Adjust the SWR bridge to read reflected (SWR); if there are no problems with your equipment, it should read something near 1.1 to 1. Replace the dummy load with the Transmatch and connect a balanced antenna to the Transmatch. Don't touch the transmitter controls during Transmatch adjustment.

Make sure that the taps for L2 and L3 are equidistant from the center of the coil stock; L1 can be tapped at any convenient position. Key the transmitter and adjust C1 and C2 for a dip in the SWR reading. If none is found unkey the transmitter and move the taps on L2/L3 (keeping them the same distance from the center). Repeat the above steps until a match is found. It may be necessary to vary the tap on L1 to obtain the lowest possible SWR reading. Now you can adjust the transmitter for more power and fine tune the Transmatch. Keep a record of the taps for each portion of the band used. This will speed adjustment for future operation. You may also want to use various colored marking pens to mark L2/L3 and L1 at the appropriate spots to speed adjustment.

Two useful balanced antennas are depicted in Fig. 6. The twin-lead can be any convenient length. The legs of the dipole in Fig. 6A can be any convenient length also. If the loop happens to be approximately one wavelength long, maximum radiation will be perpendicular to the plane of the loop; i.e., if it is mounted in a horizontal plane, maximum signal will be straight up. At frequencies other than a full wavelength, maximum radiation will occur in different directions. It is best to experimentally determine the ideal installation for each situation. Either of these in conjunction with the balanced Transmatch should perform adequately inside an apartment, but like other antennas, they will work better if you can get them outside.

There are a few little gimmicks that you learn as you "play around" with indoor antennas. Alan Pike, W8MGF, pointed out to me that plastic mirror clips (found in most hardware stores) are quite useful for holding coax and antenna wires in place. The clips can be mounted to a plasterboard wall with plastic anchors and matching screws. When moving time rolls around, the screw can be removed, the clip taken down and the anchor extracted from the wall. A small amount of spackling compound and a putty knife restores the wall in a few seconds. Holes to attics can be drilled or punched for routing cables and repaired the same way when moving time comes.

Where Do You Start?

The first thing to do is to survey your situation. Is it possible to get something outside? Can you get something in the attic? Is there something that you can use as an antenna that will not be recognized? Start trying things until you find something that works. Keep your eyes open for new ideas or new twists on old ideas that may be applicable to your situation. "Grounding" will probably be the trickiest part of putting in an indoor antenna system. Avoid attaching "ground" wires to the cold water pipes! Strive to optimize everything else since the antenna will probably be a compromise. If at first you don't succeed . . . oh, yeah, I thought I had found the ultimate solution to apartment antennas — a house. But now I am fighting with the city building inspector for the privilege of putting up an antenna on my own property! QST

Silk Screen QSLs for the "Gypsy" Radio Amateur

Homemade QSL cards can be attractive without being expensive. But best of all, they can be original, as well as fun to make.

By Alexander B. Murphy,* WB3IRV, HL9VI

Over the past couple of years, because of my military service, I have operated from several semi-permanent locations including Maryland, the Republic of South Korea and North Carolina. Many of you are probably familiar with the problem of providing QSLs to the many hams you've worked while operating away from the "home QTH." There is a solution to the problem, in the form of commercial QSLs that allow you to write in the QTH and even the call sign. But these generally produce a card that is not very attractive or original. So with the two basic laws of hamming firmly in hand (necessity the mother of invention and good old Murphy's Law), I decided to tackle the problem.

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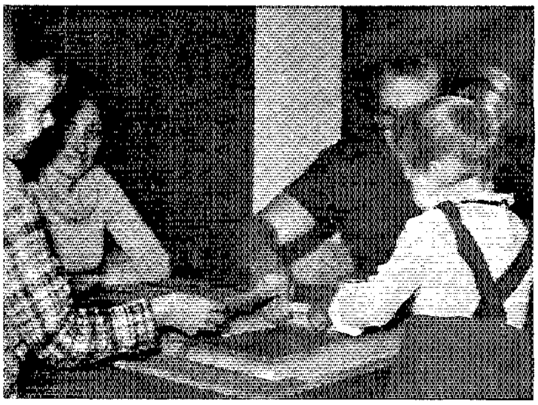
As I had no previous experience in printing and even less in developing artistic ability, I was at a loss for a starting place until I visited a nearby hobby shop. I noticed a process called silk screening which promised to produce, cheaply and easily, a quality QSL tailored to my needs of varying QTH and call sign.

There are several kits on the market for silk screening. They are simple and fun to use. In fact, it is harder to describe the entire process than to actually do it. Table 1 tells you what you'll need, and Table 2 outlines the procedures. Basically, the process involves exposing a positive copy of the desired QSL onto a silk cloth or screen. An ordinary 150-watt electric light bulb with a tin pie plate or aluminum foil as a reflector is used to make the exposure. Time for exposure is not critical.

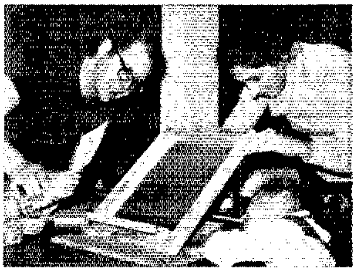
Table 1
Bill of Materials

- Silk screen on a wood frame
- Photo emulsion
- Photo sensitizer
- Squeegee
- Paint
- Masking tape
- Spoon, scissors, damp cloth
- Acetate sheets
- Felt-tip pens
- Rub-on letters
- Straight edge
- 150-watt lamp with tin pie plate or aluminum foil reflector
- 3 × 5 or 4 × 6-inch (75 × 125 or 100 × 150 mm) cards

Note: The first five items are available in most silk-screening kits.



Shown at the left, the screen is exposed for about 1 hour using a 150-watt electric lamp (note the reflector made from aluminum foil and a paper plate, top of photo). The QSL positive is held on top of the screen with a piece of ordinary window glass during exposure. After the screen is washed with water, the pattern of the QSL will wash out of the screen while the exposed areas will retain the emulsion. Shown at the right is the "press" in action — ink is being squeegeed through the screen onto the card beneath. Don't worry; that ink is washable and won't stain clothing.



The blank cards to be printed are positioned under the screen. Any flat surface can be used as a base under the screen and wood frame. Here we're using a scrap piece of plywood. (It may help speed production to hinge the frame to the base and use guide marks for positioning cards on the base.) A QSL card "hot off the press" may be seen to the left of the frame. Cards can be made at 120 to 200 per hour.

After exposure, the screen is washed in ordinary water to wash out the photo emulsion where it was covered with the QSL pattern. A paste-type, water-soluble ink is then forced through the screen with a large squeegee.

The actual printing process can become a family affair. We formed an assembly line that included my XYL, our six-year old and our three-year old. In less than an hour, we had 120 cards run off the press with no fuss and a lot of fun and satisfaction.

Preparing the Positive

As for Murphy's Law, it was definitely in evidence — not in the printing, but in the preparation of the positive of the QSL. In theory, a piece of tracing paper can be used to draw your positive. However, it was my repeated experience that tracing paper produces a poor-quality screen. To get good line definition and professional quality on the first try, it is much preferable to use a clear plastic or acetate sheet. Draw your QSL on the acetate using the felt-tip pens that are made for that purpose. Dry-transfer letters or rub-ons make lettering simple and produce professional lettering. It is especially good for smaller lettering as in an address. Rub-ons are available in most stationery or office supply stores for $2 per sheet. One sheet has enough letters for several QSL designs. Several letter sizes are available, and you might want to consider the larger ones for your call sign.

Another hint to lessen your work in producing the positive is to segment the art work into two or more separate sheets of acetate. One sheet has your basic design, which seldom changes, the second may have your QTH, and a third has your call sign. By stacking the three segments you get a composite positive QSL with the current information. This is a real time-saver when all that has changed, for example, is the QTH from which you operated. You only need to remake the one acetate that has that information on it and make a new "stack." It's sort of like making a sandwich!

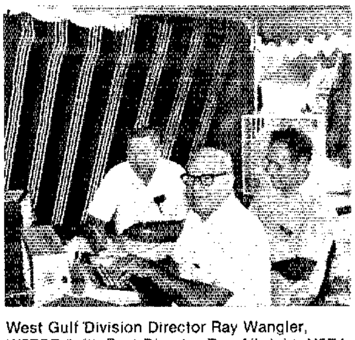
You can print the QSL onto a number of different things. I recommend using either 3 × 5-inch or 4 × 6-inch standard cards. They are cheap and look great. Try to get them without lines on either side. They are available in colors other than white. The big advantage of these is, of course, that you don't have to cut them. Once printed and dried they are ready to use.

This technique for making QSLs is great for those of us who move frequently or for any of us who operate from several locations. It can also be used to make a special card for a contest, operating event or Field Day. This is also a fun way to draw your family into the hobby while at the same time creating a personalized QSL that will be really appreciated by that DX station.

Table 2
Steps to Make a QSL

Step	*Time*
Prepare positive on piece of acetate.	1 hour
Coat the screen with photo emulsion and photo sensitizer.	5 minutes
Dry the screen in a dark place.	1 hour
Expose the screen with the positive taped to it or held down with a piece of glass.	1 hour
Wash the screen with water to "develop" the image of the QSL.	5 minutes
Print the cards.	120 to 200 cards per hour
Dry the cards.	1 hour
Wash the screen with water and store for reuse.	5 minutes
Wash the screen with bleach and water to remove the QSL image. The screen can be reused for a different QSL.	15 minutes

Strays



West Gulf Division Director Ray Wangler, W5EDZ (left), Past Director Roy Albright, N5RA (center) and Vice Director Tom Comstock, N5TC, manned the 20-meter cw position at the San Antonio Radio Club 1980 Field Day site.

ATTENTION HANDICAPPED AMATEURS

☐ Al Kaiser, N1API, has generously offered to build kits for handicapped amateurs who are unable to complete kits because of their disabilities. You pay for the kit and shipping charges and Al builds your kit for you. Interested? Contact Al at 194 Glen Hills Rd., Meriden, CT 06450.

THE CORRECT TIME IS . . .

☐ The ninth edition of the *List of Time Signal Stations*, by Gerd Klawitter, is now available from Gilfer Associates Inc., P. O. Box 239, Park Ridge, NJ 07656, for $3.95 postpaid. This 52-page booklet contains station details for time-signal transmissions from 30 countries.

ARRL Southwestern Division Director Jay A. Holladay, W6EJJ (right), gives a special award to Rep. James C. Corman (D-California) for his support of Amateur Radio in Congress. The award was presented at the ARRL Southwestern Division Convention, held in Los Angeles in September. *(K6PGX photo)*

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood R-1000 General Coverage Receiver

Technology has progressed to the point where a moderately priced, general-coverage receiver can offer the same performance characteristics that we've come to expect from our ham-band-only receivers. The Kenwood R-1000 is one example.

The receiver is designed to cover the frequency range of 200 kHz to 30 MHz. A VFO tunes any 1-MHz portion of spectrum in this range as selected by the BAND switch located at the bottom, right-hand corner of the panel. This switch is a 30-position rotary type with light, yet positive, detent — similar in feel to the uhf tuners on the newer TV sets. Four lighted push-button switches are used to select either the a-m or product detector and also automatically select either the a-m or product detector and also automatically select the i-f filter bandwidth. In the A-M WIDE position, a 12-kHz (at −6 dB)/25 kHz (at −50 dB) filter is switched in, and for A-M NARROW a 6-kHz (at −6 dB)/18 kHz (at −50 dB) filter is selected automatically. The USB and LSB/CW switches choose the 2.7-kHz (at −6 dB)/5 kHz (at −60 dB) filter. A cw-bandwidth filter is not provided with the unit.

The tone and volume controls are concentric, and no rf gain control is provided; rather, a four-position step attenuator (0 dB, 20 dB, 40 dB and 60 dB) is located to the right of the volume control. An i-f, diode-clipper type of noise blanker is controlled by a push-button switch located under the S meter. The blanker proved to be quite effective on several types of interference including automobile ignition noise, Loran and noise from light dimmers (a common source of interference when listening below the broadcast band).

The receiver is equipped with a digital readout that doubles as a clock. Either the frequency readout or time can be displayed as selected by the FUNCTION switch. The clock is a 12-hour type with indicator lights for A.M. and P.M. Two front-panel buttons, one for hours and one for minutes, allow setting the clock while listening to WWV or other time- and frequency-standard station; contrary to rumor, the clock module is *not* convertible to a 24-hour format. Additional circuitry is provided so that the clock can be programmed to turn the receiver on and off. High-impedance audio output and normally open and normally closed relay contacts are available for connection to automatic tape recorders. It is possible to record a program of interest without being present to do so.

On the rear panel are three antenna connectors, one for mw (200 kHz to 2 MHz) and two for hf (2 to 30 MHz); they are selectable with a small slide switch. A fuse, external speaker jack, line-voltage selector, remote jack and the ac receptacle are also located on the rear panel. The back of the receiver was designed so that it can fit flush against a wall or operating console. The receiver can be operated in a vertical position by resting it on the feet provided at the rear of the cabinet for that purpose. The rugged carrying handle serves as a bail to prop up the front of the receiver when mounted on a horizontal surface. The speaker (located on the top cover) provides adeqate sound to fill most any room.

Fig. 1 — Kenwood's R-1000 is a compact performer. The carrying handle also serves as a support if additional table clearance is desired.

The Circuit

The incoming signal is routed through one of six diode-switched filters. Each filter is comprised of a low-pass and high-pass filter section combined to provide a band-pass response. Good skirt selectivity and low passband ripple result from this arrangement. Output from the filter section is fed to a 3SK74 (agc'd) rf amplifier. The signal is then buffered and applied to a singly balanced 3SK74 mixer to produce an i-f of 48.055 MHz. The high-frequency PLL signal provides the necessary LO injection. Output from the first mixer is passed through a 48.055-MHz crystal filter and directly to the second mixer, also a singly balanced type. Injection for the second mixer is fixed at 47.6 MHz. The signal then encounters the noise-blanker gate and from there the diode-switched 455-kHz mechanical filters. Output from the mechanical filters is fed to two 3SK74 i-f amplifier stages and a shunt attenuator that is linked to the front-panel rf attenuator. From there, the signal is detected and applied to the audio preamplifier and output stage. BFO energy is supplied by one of two diode-switched crystal oscillators.

Operation of the PLL synthesizer is straightforward. The VFO output (in the range of 5.545 to 4.545 MHz) is mixed with the output from the 47.6-MHz crystal oscillator. The difference frequency is selected, buffered and applied to a second mixer, along with the output from the VCO, to produce an output signal in the 6- to 35-MHz range. This signal is divided by the programmable divider (programmed by the front-panel BAND switch) and compared in the MC4044 phase detector. The output from the phase detector is filtered and fed to the four VCOs that cover the 48- to 78-MHz range. As each VCO is expected to handle only a little more than 7 MHz, clean output should be ensured. An additional mixer combines the output of the VCO with the 47.6-MHz oscillator to produce a signal at the received frequency plus the second i-f. This signal is fed to the counter/clock LSI which presumably contains a preset countdown function. The BFO frequency is not counted directly. Outputs from the counter/clock LSI control a relay for connection to a tape recorder.

Operational Observations

If a knowledgeable user were blindfolded and asked to operate an R-1000 he might think he was listening to a quality, ham-band-only receiver! It has the feel of an expensive piece of equipment. The receiver was used on a continuous basis for a period of three months and within a few feet of high-power hf transmitting equipment. Unless the received frequency was quite close to the transmitter frequency, it was as though the transmitter wasn't even on the air.

*Assistant Technical Editor

Kenwood R-1000 General Coverage Receiver

Manufacturer's Claimed Specifications

Sensitivity (S + N/N of 10 dB or more):

	SSB	A-M
200 kHz to 2 MHz	3 μV	50 μV
2 MHz to 30 MHz	0.5 μV	5 μV

Image rejection: greater than 60 dB.
I-F rejection: greater than 70 dB.
Selectivity: *a-m wide* — 12 kHz at −6 dB, 25 kHz at −50 dB
a-m narrow — 6 kHz at −6 dB, 19 kHz at −50 dB
ssb/cw — 2.7 kHz at −6 dB, 5 kHz at −60 dB.
Frequency stability: ± 2 kHz maximum from 1 to 60 minutes after power on. ± 300 Hz maximum in every subsequent 30-minute period.
Power consumption: 20 watts.
Power requirements: 100, 120, 220 or 240 V ac, 50/60 Hz.
Dimensions (HWD): 4-1/2 × 12-3/4 × 8-1/2 in. (115 × 300 × 218 mm).
Weight: 12.1 lbs (5.5 kg).
Clock accuracy: ± 15 seconds maximum per month.
Price class: $500; BWK-1, $3; DCK-1, $6.

Although the receiver noise floor and IMD dynamic range were measured, these numbers cannot be compared directly with other receiver or transceiver measurements published previously. This is because the R-1000 does not contain a cw-bandwidth filter, and all other units checked had this option. Tests on the R-1000 produced the following numbers on 80 meters: noise floor, −133 dBm; blocking dynamic range could not be measured because of reciprocal mixing; IMD dynamic range measured 76 dB. On 20 meters, the following measurements were taken: noise floor, −132 dBm; blocking dynamic range again could not be measured because of reciprocal mixing, and the IMD dynamic range measured 82 dB. These numbers indicate reasonable receiver performance.

Each revolution of the VFO knob produces approximately a 50-kHz change in frequency. While this would be considered somewhat fast for a ham-band-only receiver, it is in line with what is needed for short-wave listening. This rate was not found to be uncomfortable for amateur band use.

The rf step attenuator positions are 0, 20 dB, 40 dB and 60 dB. In operation, the first 20-dB step was often too great and the 60-dB position was never found useful — even with large antenna arrays connected to the receiver. A modification, available from Kenwood, converts the 20-dB steps of the attenuator to 10-dB steps.

There were only two areas where I would register strong complaints. The first concerns the lack of a cw filter or the option for adding one. For the most part the receiver performs as well as many ham-band-only receivers; if it is to be used for ham-band reception, a cw filter is a must. Although an external cw audio filter could be added to the receiver, it would be a poor substitute for a good mechanical or crystal i-f filter.

The other complaint is with the digital-frequency readout. Although the correct frequency is indicated for a-m reception, an incorrect frequency is displayed on either upper or lower sideband. For example, on upper sideband, if a signal on 14.105 MHz is injected into the receiver, the frequency displayed on the readout is 14.106 MHz (when the receiver is adjusted for zero beat) — 1 kHz high. On lower sideband, the display will indicate a frequency of 14.103 MHz (when the receiver is adjusted for zero beat) — 2 kHz low. This error occurs because the BFO is not counted in this frequency-readout scheme. Although this may not be a great concern to some, when used with an amateur transmitter it could result in a station operating outside a particular band if the operator relies solely on the R-1000 frequency readout.

The manual supplied with the R-1000, written in English, German, French and Spanish, is heavy on the operational aspects and light on technical topics. For the intended purpose of the receiver, the manual is more than adequate.

Addenda

An option (DCK-1) is available that provides for 12-volt dc operation of the R-1000. Early production units may benefit from an agc and a-m filter bandwidth modification (BWK-1) available from Kenwood. These changes are incorporated in later production units. The a-m agc time constant is thereby shortened and the 2.7 kHz filter is switched in with the MODE switch in the AM NAR position; the 12-kHz filter is then out of the circuit and the 6-kHz filter is used in the AM WIDE position.

The R-1000 has a mute circuit for use in combination with a transmitter or transceiver. By grounding pin 7 on the REMOTE terminal (Fig. 3-9 of the owner's manual), the rf stage will be muted. This information was inadvertently omitted from early manuals, but is included for units with serial numbers 0030502 and above.

This reviewer would give the R-1000 an A-, should such ratings apply to receivers. At the price some of the larger distributors are charging for this receiver (under $400), it is well worth the money in terms of short-wave listening enjoyment and its use as an all-around test instrument. Additional information on this product can be obtained from Trio-Kenwood Communications, Inc., 1111 West Walnut St., Compton, CA 90220. — *Jay Rusgrove, W1VD*

HEATH IB-5281 RLC BRIDGE

□ If you're an average ham, you've got some sort of junk box, that wonderland into which you may delve to produce the much-needed part for that long-awaited project. Ah! But are you certain of the value of that capacitor, inductor or desired matching resistor? If not,

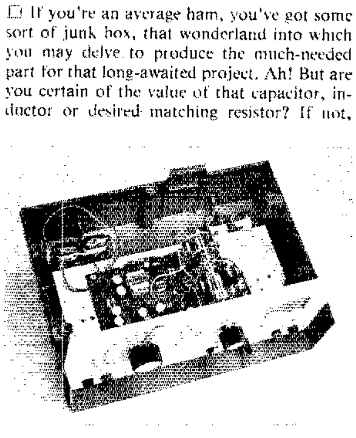


Fig. 2 — The IB-5281 RLC Bridge has compartments for two spare batteries located at the right rear of the chassis. The small vertical panel at the cabinet rear is replaced with an adapter plate when used with the external Heath power supply.

Heath IB-5281 RLC Bridge (S/N02951)

Manufacturer's Claimed Specifications

Resistance ranges: 10 Ω to 10 MΩ in three ranges.
Inductance ranges: 10 μH to 10 H in three ranges.
Capacitance ranges: 10 pF to 10 μF in three ranges.
External standard range: 1:1 to 10:1.
Cabinet dimensions (HWD): 5-3/4 × 11 × 7-3/4 in. (146 × 279 × 197 mm).
Price class: $45.

then perhaps the '5281 is just the item you need.

Heath introduced the IB-5281 RLC Bridge along with five other members of the same family in their 5280 series of test instruments. Aimed primarily at the beginning hobbyist, student or service technician, they were designated to permit the assembly of a low-cost test bench.

Operational Description

The '5281 is a solid-state unit that permits you to determine unknown values of capacitance, inductance or resistance within certain limits. It operates according to the principles of the Wheatstone bridge. To permit measurement of inductance and capacitance, the bridge must use an ac voltage source. In the '5281, this is provided by a Wien bridge oscillator. The oscillator has three output frequencies — 1000 Hz, 10 kHz and 100 kHz — which allow measurement of R, L and C in three separate ranges. In addition to using internal standards for matching purposes, the bridge furnishes a means of using an external standard comparison method. This becomes useful when attempting to match accurately one or more R, L or C components to each other.

The IB-5281 may be powered either by internal 9-V batteries (two required, not furnished) or a power supply capable of providing both ± 9 volts (such as the Heath IPA 5280-1) at less than 10 mA each. Unfortunately, Heath does not supply the external/internal power-supply selector switch, connectors or mounting plate for use with an outboard supply with the '5281 kit. As another alternative, the constructor of the bridge could build a power supply in the cabinet without too much difficulty; there's plenty of room.

Assembly and Calibration

There is no errata sheet to contend with and no problems were encountered during construction. The component quality is excellent. All resistors used are 5% tolerance, carbon-film types. As may be seen in the photograph, the majority of components are mounted on the single pc board or the multi-wafer RANGE switch. Assembly and testing of the IB-5281 took about four hours, not counting the time spent in tracing an incorrectly placed wire on the range switch (attributed to bleary 4:30 A.M. eyes!). Calibration of the bridge takes less than five minutes using a 100-ohm, 5% tolerance resistor supplied for the purpose.

An attractive blue and white plastic case is used to house the instrument. At the rear of the upper half of the unit is a small compartment which is used to store the clips, standard(s), or whatever else you feel you might need during use of the instrument. Front-panel-mounted banana jacks are used to mate with banana plug/alligator clip connectors to introduce the unknown component into the bridge circuitry.

Results and Use

While the '5281 is not a precision lab instrument, the accuracy of the unit will certainly suffice for most Amateur Radio applications. After the unit was completed, I immediately set about checking some of the rf chokes, resistors and capacitors I had on hand. As many of you will appreciate, capacitor markings can be somewhat confusing, but the '5281 rapidly penetrates that cloud of confusion. Determining the values of those unmarked rf chokes in my junk box was not only fun, but enlightening: You can't "call 'em the way you see 'em" all the time! Using the '5281 is certainly a lot easier than using a GDO, some standards and a calculator to determine unknown component values.

Although no accuracy specification is given, I found that over most of the range I was able to easily interpolate the dial readings to within 10% of the actual value, and many times to within 5%. This was determined by comparing known capacitance, inductance and resistance values (measured on ARRL lab equipment) to the values indicated by the '5281. Dial markings at either extreme of the dial range are more closely spaced — and determination of the actual value somewhat more difficult — at those points. Don't forget, there also exists the ability to use an external standard (at the Z_S terminals) as a means of comparison when it is desired to closely match certain components for a specific purpose.

I feel that the low cost of this unit justifies its occupying a space on the work bench right alongside the TVOM and DMM; this is especially true if you're a tinkerer and "pack rat." Battery operation and light weight make the IB-5281 really portable — just the thing to take with you to a buddy's shack or a flea market. — *Paul K. Pagel, N1FB*

COMTRONIX-FM80 10-METER FM TRANSCEIVER

☐ With almost 400,000 amateurs in the United States, it is still a small world. After unpacking the Comtronix-FM80, I connected it to the tribander and answered WB6VZY, who was calling CQ on 29.6 MHz. We exchanged the usual information; then we found out each other's identity — I was doing a review on the FM80 and he is part owner of KonaCom, the importer of the FM80! Ten-meter fm is like that. It also has an "intercom" flavor reminiscent of 2-meter fm, but the DX aspect of it is much higher — at least while we are near a sunspot maximum.

The unit is "bare bones" with none of the bells and whistles that we have come to expect in the fm rigs designed for 2 meters. It is a 10-watt (1-watt low power), 10-meter fm-only, synthesized transceiver; the closest thing to a bell or whistle is the built-in repeater offset. It would appear that the FM80 has been built with the idea of keeping the cost as low as possible. In addition to economy, there are several advantages to taking this route. If the unit is being operated mobile, one can merely set it and forget it. This strikes me as being somewhat safer than some of the computerized rigs for 2 meters which, to be operated safely, require either a copilot to do the programming or a roadside stop to make any changes.

Comtronix FM80 10-Meter FM Transceiver (S/N 960421)

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 28.91 to 29.7 MHz.	Same
Size (less projections): (HWD) 2-1/8 × 6-1/2 × 8-3/4 inches (55 × 165 × 223 mm).	Same
Power output: 10 watts (reducible to 1 watt).	13 watts @ 13.8 V dc.
Operating voltage: 13.8 V dc (± 15%).	
Maximum current at 13.8 V dc: 2.2 A.	2.2 A
Weight: 6.5 pounds (3 kg).	
Receiver sensitivity: 0.5 µV for 20 dB of quieting.	
Price class: $260.	

In appearance, the FM80 resembles the ubiquitous imported CB rigs. Everything is broadbanded and pretuned, reducing the number of control functions to a minimum. Frequency coverage is from 28.91 MHz to 29.7 MHz in 10-kHz steps (that adds up to 80 "channels," which is presumably where the 80 comes from in the name). The 80 channels are selected by using a 40-position rotary switch to step the synthesizer up and down; in addition, two mixer crystals are switched in and out with a push-button-type switch. Two seven-segment LED displays provide readout of the "channel" number from 1 to 40. Unfortunately, there is no active visual indication differentiating between mixer crystals A and B; one must note whether the switch is "in or out." That's really a rather minor inconvenience and shouldn't be of any consequence — unless you happen to have a three-year-old harmonic who loves to push buttons (I have one). One could easily add one or two LEDs to give an active visual indication of which range the unit is tuned to.

The first nine channels of the A group are below 29 MHz, which virtually constitutes illegal operation in the U.S. FCC rules and regulations, Part 97.65(c), states: "On frequencies below 29.0 MHz the bandwidth of an F3 emission (frequency or phase modulation) shall not exceed that of an A3 emission having the same audio characteristics." It is not illegal to use fm below 29 MHz — it simply is not practical to use *legal* fm. Another problem area in terms of frequency coverage is that the satellite downlink frequencies are located in the midst of the 80 channels. Channels 10 through 20 of the B group appear on frequencies from 29.40 MHz to 29.50 MHz. Comtronix points this out in the owner's manual, but they make an error on the conservative side. They include the frequencies 29.51 through 29.55 MHz as part of the satellite frequencies. In actuality, those frequencies are in the repeater input section of the ARRL 10-meter band plan.

One of the questions that I pondered before using the rig was whether 10-kHz channel spacing had any value. (The ARRL band plan calls for 20-kHz spacing.) On a recent trip during a hand opening on 10 meters I had a chance to make some first-hand observations. As seems to be usual, stations from all over the country east of the Rockies were showing up on 29.6 MHz. Operators were politely taking turns working each other. One station that I worked suggested that we "move up 10," which we did. We then carried on a "rag chew" for nearly one-half hour. In that time, I did not notice any adjacent-channel interference from the QSOs that were continuing on 29.6 MHz. On the other hand, I have tuned up or down 10 kHz when a very strong signal was on 29.6 MHz and found those tertiary channels subject to high levels of adjacent-channel interference. Probably, the prime consideration is whether or not the sidebands (from adjacent channels) that extend into the passband of the receiver are very strong. Thus, 10-kHz steps give the FM80 additional versatility by providing *possible* simplex frequencies that are sandwiched in between repeater frequencies.

Is 10 watts enough power to be useful? There is no clear cut answer — it depends. When the band is not open, if you want wide-area, simplex, mobile-to-mobile coverage, 10 watts probably isn't enough. On the other hand, when the band is open, 10 watts is more than sufficient for long-distance communications. While mobile recently, I worked an Indiana station simplex. He was using a half-wave vertical antenna at his QTH along with an FM80. I was operating the FM80 into a quarter-wave

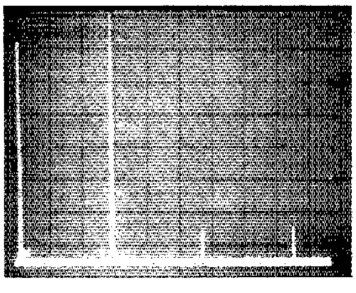


Fig. 3 — Spectral display of the Comtronix FM80 in the 10-watt position. Vertical divisions are 10 dB each. Horizontal divisions are 10 MHz each. The products close to the carrier frequency are 72 dB down. Second and third harmonics are down at least 60 dB.

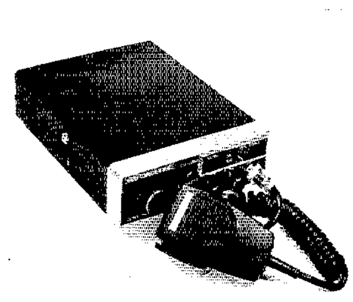


Fig. 4 — An easy way to 10-meter fm. The Comtronix FM80 presents a simple but functional control panel.

whip mounted on the bumper. He asked how much power I was using because my signal was pegging his S-meter. I replied that I was using the rig in the 10-watt position and that I would go to the 1-watt position to see if he could still copy me. I did, and he reported that the signal had fallen from S9-plus to S8, but that it was still full quieting! If an operator feels that 10 watts is not sufficient, it would be a simple matter to construct a small, solid-state power amplifier.

I am somewhat disappointed with the manual that is supplied with the FM80. Like the rig, it is "bare bones." The schematic diagram is reproduced on a single page. To say the least, the symbols on the diagram are small and densely packed. The description of the functioning of the circuits is sketchy. There are no board layout diagrams or trouble shooting hints; nor are there any alignment procedures. The manual is one place where a little elaboration would have gone a long way.

My overall impression of the FM80 is very good. It is a solid performer without a lot of frills. Additionally, it is a relatively inexpensive and easy way to get on a fun-filled band. — *Pete O'Dell, AE8Q*

THE IMPROVED BENCHER PADDLE

☐ With little fanfare and with a price increase scarcely befitting the ravages of inflation alone, Bencher, Inc., has brought out a significantly improved version of the original paddle, which was reviewed on these pages in May 1978. The improvements include: A heavier and thicker base — 5/8 in. (15.9 mm) instead of 1/2 in. (12.7 mm); crimped spring ends which pinch the adjustment screws and hold the spring captive; gold plating on the pure silver contact points; and lastly, elimination of the Achilles' heel of the basic FYO paddle design — the tendency of the mechanism to fly apart when the paddles were accidentally bumped or pushed in the wrong direction. Bencher has added pinion screws which act to limit the movement of the parts so they can never disengage from the pivots. These added screws do not interfere with the normal motion of the paddles during sending.

Some operators might prefer to have the two clear plastic finger assemblies positioned closer together than those supplied on the "stock" paddle, 11/16 in. (17.5 mm). It's an easy task to remove one of the finger assemblies and remount it on the *inside* of its metal support arm. This will reduce the spacing to 1/2 in. (13 mm).

The Bencher paddle is made by Bencher, Inc., 333 W. Lake St., Chicago, IL 60606. Price class is $43 for the steel-base model and $53 for the chrome model. — *John C. Pelham, W1JA*

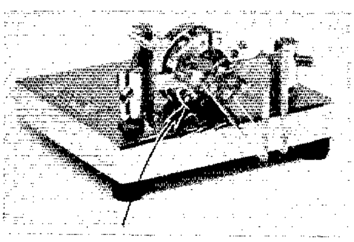


Fig. 5 — One of the two screws that secures the mechanism of Bencher's new paddle is shown by the arrow in the photo.

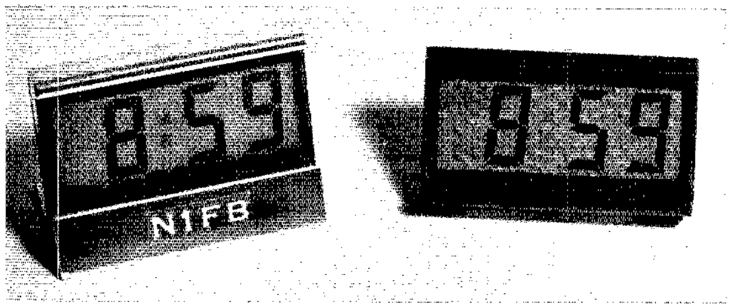


Fig. 6 — Two versions of the Mity-Time clock are shown here. The unit at the left is supported in a brushed-aluminum stand, while the right-hand unit is fitted with Velcro tape for use as described in the text.

THE MITY-TIME LCD CLOCK

☐ Timepieces have become smaller and smaller in recent years, with the advent of electronic clocks and wristwatches. The Mity-Time clock is an interesting and versatile unit, an effective timekeeper for many ham radio needs.

The clock is small — 2 × 1-1/4 × 1/2 inches (51 × 32 × 13 mm) and sports a 12-hour LCD display with 5/8-inch (16-mm)-high digits. The user has a choice of two modes of operation: The clock can either display time of day with a flashing colon for seconds, or can produce a readout with the time of day and day/month being digitally displayed. In the latter mode, the display alternates between time and date in one-second intervals. One would hope that the manufacturer would eventually produce a model with a 24-hour clock, which would be even more suitable for communications-oriented use.

The clock is supplied with a small piece of self-adhesive Velcro tape to facilitate mounting (such as on an automobile dash), and a small aluminum stand to permit desk mounting. The Mity's small size allows it to be located almost anywhere one might desire. Thanks to the Velcro tape, the clock's a natural for the car or even a motorcycle. One review unit spent some months affixed to the dash of my auto. On several occasions, the easy-to-read digits were convenient for reporting time of day when logging a repeater autopatch contact. Initially set to WWV, the clock has performed accurately within 10 to 20 seconds of that standard since then and seems to operate well despite widely varying temperature extremes. Once the display blanked out after the car had been parked in the sun for several hours. The clock was nearly too hot to touch! I turned on the air conditioner, and within a few minutes the display returned to normal; the accuracy didn't appear to have been affected at all. I haven't had the occasion to expose the Mity to extremely cold temperatures such as one would experience in a New England winter, but my initial impression is that there would be no problem.

The Mity-Time clock is made in the USA and is available from Grandview Audio Electronics, 13302 South 10th St., Grandview, MO 64030. Price class: $25. — *Sandy Gerli, AC1Y*

AEA MM-1/MK-1 SUPPLEMENT

☐ Because the reviewer initially used preliminary manuals, some discrepancies appeared in the AEA MorseMatic MM-1 and MK-1 "Product Review" in October 1980 *QST*. During memory overrun, the operator can continue loading into the MM-1 memory until the monitor frequency drops significantly. At this point, paddle entries do not enter memory, but overflow. Any message(s) loaded prior to the tone change are retained. To finish an interrupted message entry, simply clear one of the stored messages and then add to the desired message entry.

Separate audio outputs are available for the monitor and feedback tones. Either one may be independently disabled by removing a diode from the pc board. Thus, the auditory feedback need not be lost if a monitor note is not desired.

The MK-1 can key either positive- or negative-polarity key lines. Under some circumstances, it is necessary to short out a diode on the pc board. This procedure is explained in the operator's manual. — *Paul K. Pagel, N1FB*

TANDY WIRE AND CABLE RG-8/M COAXIAL CABLE

☐ A recent letter from an ARRL member inquired about the new "super coax," as he called it, referring to the RG-8/M coaxial cable offered by Radio Shack. He wrote, "The specs are better than my good . . . super low-loss RG-8/U that loses 2.0 dB per 100 ft at 6 meters. If what they say is true, than that should be front page of *QST*."

A person reading the literature about RG-8/M might well be skeptical. "Our new RG-8/M coax gives you the performance of large, bulky cable in a smaller, more flexible size — just slightly larger than RG-58/U!" Now most of us have been schooled to think "bigger is better" when it comes to coaxial line with low losses. Has Tandy Wire and Cable somehow discovered the combination of materials and manufacturing techniques to disprove the idea, showing that it doesn't necessarily have to be bigger in order to be better?

We obtained a 100-ft (30.48-m) length of Tandy's RG-8/M coax for examination. Removed from its shipping box, the roll weighed in at 3 lb 8 oz (1.59 kg). That's less than 0.6 oz per foot, or about 52 grams per meter, quite light in weight when compared to ordinary RG-8/U cable. The outside diameter of the line is approximately 1/4 in. (6 mm). Standard RG-59/U fittings may be used.

This cable bears the identification, TANDY WIRE & CABLE TYPE RG/8 MINI-FOAM, and is very flexible. It uses a low-density foam

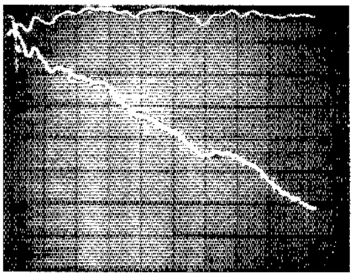


Fig. 7 — Attenuation versus frequency in Tandy's RG-8/M coax line. The line length for this measurement was 98 ft, 8-1/2 in. (30.09 m), so the attenuation data must be multiplied by a factor of 1.013 to obtain dB per hundred feet. The wavy line near the top of the photo represents the input signal level to the coax line, while the lower, thicker line in the photo represents the output into a matched load. The attenuation calibration thus is relative, rather than absolute, with the vertical scale at 2.0 dB per major division. The horizontal scale is 100 MHz per division, or 0 to 1000 MHz.

Tandy RG-8/M Coaxial Cable

Manufacturer's Original Specifications	*Measured in ARRL Lab*
Center conductor: 16 AWG, 19/29 ga. copper.	
Shield: Copper, 92.18% coverage.	
Jacket: Black PVC, 0.242-in. OD.	
Impedance: 52 Ω.	52 Ω nominal.
Capacitance: 25.5 pF per ft.	25.5 pF per ft.
Velocity of propagation: 76.4%.	76.4% at 10 MHz.
Attenuation per hundred ft.	
at 10 MHz: not specified.	1.0 dB.
at 30 MHz: not specified.	1.3 dB.
at 50 MHz: 1.5 dB.	1.5 dB.
at 100 MHz: 2.0 dB.	2.5 dB.
at 200 MHz: 2.5 dB.	3.8 dB.
at 500 MHz: 6.0 dB.	7.6 dB.
Power-handling capability: not specified.	

dielectric, but one that is quite tough and cannot be distorted by bending or scraping with a thumbnail. A short length of the line was given severe twisting motions to simulate the winding and unwinding of the line about a mast when used with a rotator, only more so. No harmful effects to the line were noted. The results of electrical measurements made in the ARRL lab are included in the accompanying chart and photograph. Our measurements did indicate the attenuation to be somewhat greater than Radio Shack originally specified. The Radio Shack catalog does not specify the power-handling capability, but similar line of another manufacturer[1] is rated at 1300 watts of input at 27 MHz, 450 W at 200 MHz, and 320 W at 400 MHz.

The manufacturer's attenuation specifications shown in the table are those published when the cable was first introduced. The manufacturer informs us now that the initial figures were in error and that the ARRL lab figures agree with measurements taken since that time.

Mini foam is available from Radio Shack stores, stock no. 278-1328. The price class in the U.S. is 21¢ per foot, with a minimum order of 25 feet. If you're planning to replace your 50-Ω transmission lines, this new "super coax" may interest you. — *Jerry Hall, K1TD*

TRIO-KENWOOD DM-81 DIP METER

□ A refreshing addition to the usual Kenwood line of transmitting and receiving equipment was released recently. It is a solid-state, self-contained dip meter — the DM-81 — which operates from 700 kHz through 250 MHz. The unit is housed in a rugged aluminum case that includes a snap-in type of drawer at the bottom end of the case. This drawer is used to store the seven plug-in coils, a grounding clip, a capacitive probe and an earphone. Two of the plug-in inductors are printed-circuit coils. They are used for the two vhf tuning ranges. The coil ranges are (± 3%): 0.7 to 1.6 MHz, 1.5 to 3.6 MHz, 3.0 to 7.4 MHz, 6.9 to 17.5 MHz, 17 to 42 MHz, 41 to 110 MHz and 83 to 250 MHz. The review model showed only one false dip of significance. This was noted at approximately 200 MHz, but it was not deep enough to impair the performance of the dipper.

The instrument employs one FET, three bipolar transistors and three diodes. The complete circuit is shown in Fig. 9, as copied directly from the instruction booklet.

Various functions can be performed with the DM-81. Among them are the field-strength (relative) and absorption frequency-meter operations. The unit can also be used as a signal generator. A mode switch enables the operator to apply modulation to the dipper signal for adjustment of a-m receivers; a 1000-Hz tone is used.

Crystals can be checked with the DM-81 by plugging them into the FT-243 and HC-25/U accommodating sockets at the top of the case. The crystal activity is indicated on the dipper sensitivity meter. Crystals can be used in this manner to generate marker frequencies, when desired; those in HC-6/U holders can be checked by holding them so they make positive contact in the FT-243-accommodating socket.

Unknown capacitances and inductances can be determined with the dip meter. The instruction book shows clearly how to conduct tests of this type. A chart provides the exact inductance of each plug-in coil. This information is useful when checking the unknown values of capacitors.

A capacitive probe ("searching needle") is provided for probing tuned circuits that can't be reached with the plug-in coils. The probe is useful for checking resonant frequencies of toroidal tuned circuits. Conventional inductive coupling is not effective because of the inherent self-shielding properties of toroids.

The dip meter can be used for the standard amateur applications of checking antenna and tuned-circuit resonances. We can't call it a GDO (grid-dip meter), because there's no tube in the oscillator, and hence no grid! A "base-dip meter" would be appropriate in this example, since the oscillator contains a bipolar transistor.

I checked the accuracy of the dial calibration in the various tuning ranges. The capacitive probe was coupled to an Optoelectronics 1.5-GHz frequency counter for this test. Calibration accuracy was outstanding for an

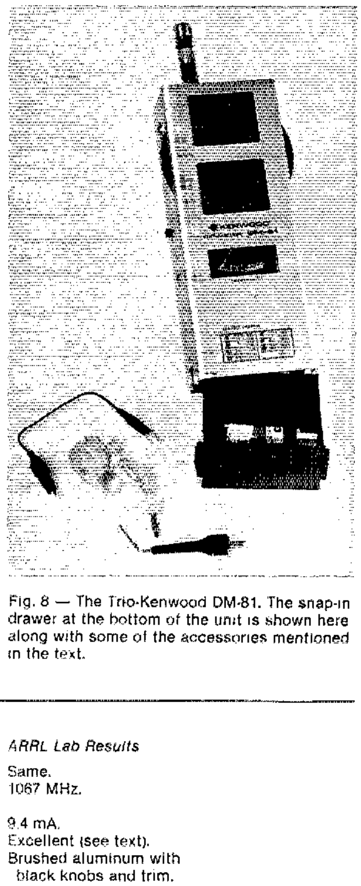


Fig. 8 — The Trio-Kenwood DM-81. The snap-in drawer at the bottom of the unit is shown here along with some of the accessories mentioned in the text.

Trio-Kenwood DM-81 Dip Meter

Manufacturer's Claimed Specifications	*ARRL Lab Results*
Freq. range: 0.7 to 250 MHz (± 3%).	Same.
Modulation tone: 1000 Hz.	1067 MHz.
Power Source: 9-volt dc (battery).	
Power consumption: 9 mA.	9.4 mA.
Dial accuracy: None stated.	Excellent (see text).
Color: None stated.	Brushed aluminum with black knobs and trim.

Dimensions (HWD): 7-1/8 × 2-3/4 × 1-3/4 inches (180 × 70 × 45 mm).
Weight: 22 oz (690 g).
Price class: $125.
Manufacturer: Trio-Kenwood Communications Inc., 1111 West Walnut, Compton, CA 90220.

[1]See "Berk-Tek RG-8X Coaxial Cable," Product Review, December 1979 *QST*, p. 55.

instrument of the DM-81 variety. For example, while checking the highest range (83 to 250 MHz) the dial inaccuracy was only 100 kHz at 83 MHz and 250 kHz at 250 MHz (1%). Some of the inaccuracy was probably caused by coupling to the capacitive probe, thereby detuning the dipper.

Dip meters have long been a "standard" item in the ham shack, even if no other instrumentation was available. A dipper is somewhat a general-purpose "do all" sort of gadget, and is a valuable tool for testing or developing antennas and rf circuits. — *Doug DeMaw, W1FB*

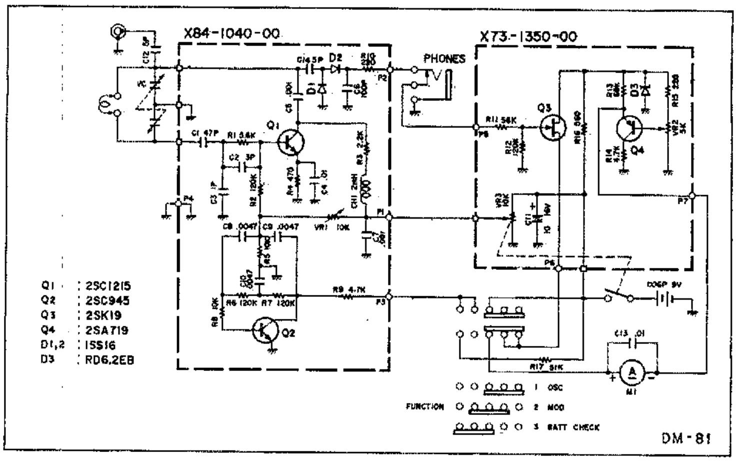


Fig. 9 — Schematic diagram of the Kenwood DM-81 dip meter. The electronic symbols do not conform exactly to those usually found in *QST*, since the diagram was taken directly from the instruction book. The dashed lines indicate individual pc-board modules.

THE MACROTRONICS RITTY RITER

☐ Are you a radioteletype aficionado who appreciates the "green key" artform? Are you using the Macrotronics M800 RTTY system with a Radio Shack TRS-80 microcomputer?

If you have answered both of these questions in the affirmative, you will appreciate Ritty Riter, Macrotronics' new TRS-80 program that provides the RTTY artist with a versatile paintbrush. Designed to be used in conjunction with Macrotronics M800 program (see the review of the M800 in November 1979 *QST*, page 50) by means of the M800 "external program" command, the key to the versatility of the Ritty Riter is the maneuverability of the TRS-80 cursor. A wide range of commands permits the user to quickly move the cursor all over the CRT display to create various kinds of RTTY art. The size of your artwork is limited by the amount of RAM installed in the TRS-80, while the creation itself is limited only by the artist's imagination.

Ritty Riter may be loaded into your computer by means of the "external program" command of the M800 or the TRS-80 BASIC "system" command for stand-alone use. In the stand-alone mode, artwork can be created, changed and saved on tape for future transmission. In the M800 mode, Ritty Riter is loaded first and then any previously recorded artwork can be loaded for transmission, or new artwork can be created on the spot. Note well — under M800, all artwork resides in the memory allocated to the M800 "big message," so do not use "big message" and Ritty Riter simultaneously.

All art created with Ritty Riter may be personalized by typing strings of the symbol "@" within the artwork. Before each transmission, the computer will ask you to personalize the artwork. By entering a call sign, name or any other statement, that entry will be repeatedly transmitted within the artwork, wherever the strings of "@" appear.

A word of advice: It is a good idea to make a hard copy of your artwork to verify that it looks like you intended it to look. My CRT display is more compact than the output of my printer and any artwork I create on the CRT tends to be elongated when a hard copy is printed. Check this out on your system and adjust your creations to compensate for any difference you may discover.

Ritty Riter is available on cassette tape and includes an adequate instruction manual. To use Ritty Riter to its fullest potential, you should have the M800 program — that requires at least 16 K of RAM, BASIC Level II and the M80 interface hardware. Ritty Riter is available from Macrotronics, Inc., 1125 North Golden State Blvd., Suite G, Turlock, CA 95380. Price class: $50. — *Stan Horzepa, WA1LOU*

ALLIANCE HD-73 HEAVY-DUTY ROTATOR

☐ When it comes to a rotator for that beam, most hams are of the opinion that "Well, you've seen one and seen 'em all." Many amateurs don't really stop to consider how a rotator is designed and what conveniences it might offer. After all, a rotator's only consideration is the capacity it'll handle, right? Wrong! Enter the HD-73.

The rotator head offers some interesting features that became apparent when I installed it. The mast clamp is designed to allow precise centering of the mast on the rotator body without the need for shims. Correct alignment reduces the possibility of undue stress and binding when the mast and antenna are rotated. In addition, a tight-fitting plastic cover surrounds the cable connections, ensuring that no moisture or dirt will harm the terminal strip. The ball race and gears are very substantial for a rotator head of its size, and the housing is cast aluminum and well-finished.

The control unit, finished smartly in black plastic with a brushed-aluminum face, contains the most interesting feature of the HD-73: There's no separate brake switch. What's more, there are two rotation speeds available on the control lever. Normal operation is about 1 rpm and the slow speed about 1/2 rpm. This feature is handy for turning an array slowly in high winds, or for more accurate aiming of narrow-bandwidth arrays such as might be found in vhf work. The automatic braking system uses a centrifugal friction brake rather than a locking-pin arrangement operated by a solenoid. It's well known that an antenna array will take longer to coast to a stop in high winds than if no wind were present. The brake in the HD-73 adjusts itself according to the turning forces against the array, to set the brake when turning has nearly ceased. Does this arrangement provide an adequate lock? I believe so. The rotator was installed in my tower to turn a Wilson System 40 tribander — about 13 square feet of antenna area including the masting. The HD-73's rated at 10.7 square feet! While working up on the tower recently, I observed some very strong wind gusts — I estimate nearly 50 mi/h. The rotator windmilled only once, and only for a few degrees. It appears to me that this indicates a good, strong braking system for the rated capacity, with some "breathing space" built in. Had the tribander been smaller, it's likely that there would have been no windmilling. This arrangement would seem to be more favorable than the solenoid type of positive lock that can be damaged permanently if the brake is set while the antenna system is still turning. A further fail-safe feature is a thermal limiter within the control unit that shuts down the rotator when the power transformer gets excessively warm from repeated operation. So far, the cutout hasn't opened up in my installation, which indicates that the transformer and power supply are more than adequate to handle loads the rotator is rated for.

In all, the HD-73 presents a well-designed unit. I was somewhat skeptical about using this system to turn an antenna and mast totaling 2 square feet more than its rated capacity. Alliance, however, had given me the go-ahead. Their confidence in the HD-73 is deserved — this rotator is entirely up to the task. The HD-73 is available from: Alliance Mfg. Co., Inc., 22790 Lake Park Blvd., Alliance, OH 44601. — *Sandy Gerli, AC1Y*

Alliance HD-73 Heavy Duty Rotator
Manufacturer's Claimed Specifications

Mast mounting size: 1-3/8" OD to 2-1/2" OD (38 × 63 mm).
Mounting: In tower (preferred) or on mast with extra brackets supplied.
Cable required: 6-conductor, equiv. to Belden-type 8448 with two wires not used.
Voltage input: 117 V ac, 60 Hz, ± 12 V.
Rotator weight: bare: 6-3/4 lbs (3.06 kg).
Rotator speed: dual — 1 rpm and approx. 1/2 rpm, selectable.
Power transformer protection: dual — fuse and thermal limiter.
Metering: north-centered.
Braking system: automatic, centrifugal.
Price class: $155.

Hints and Kinks

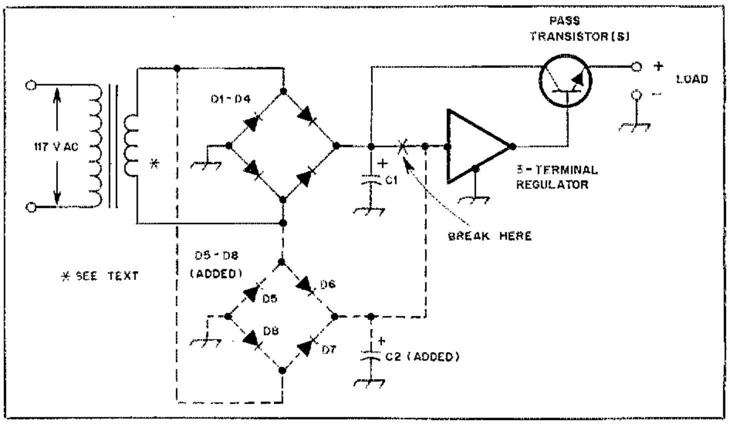
Conducted By Stuart Leland,* W1JEC

IMPROVING RIPPLE-FREE CURRENT CAPABILITY OF LOW-VOLTAGE POWER SUPPLIES

☐ The accompanying schematic diagram indicates a modification for low-voltage power supplies to upgrade their ripple-free current capabilities. If the current drain pulls the rectified voltage down to where it is insufficient for proper operation of the regulator, ripple and poor regulation will result.

Typical input requirements for a 15-volt regulator are: 17.5 V minimum, 35 V maximum and 27 V recommended. This means that ripple excursions below 17.5 V cannot be tolerated.

Addition of a second rectifier and C2 will provide adequate voltage for the regulator. C2 capacitance requirements are not high. If a center-tap transformer is used, add two diodes and C2. If the existing transformer and filter can provide the required output voltage (plus junction drop) and current to the pass transistor(s), ripple-free regulation will result. — *Howard W. Johnson, W7NU, Seattle, Washington*

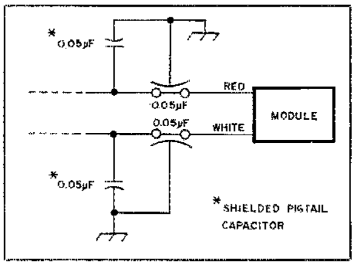


This circuit provided by Howard W. Johnson, W7NU, will furnish ripple-free regulation for a low-voltage power supply.

WHEN RF UPSETS ELECTRONIC IGNITION

☐ *QST* readers may be interested in knowing how I stopped my 130-watt low-band transmitter from affecting the electronic ignition in a 1980 Ford police patrol car. Although I have been involved in two-way radio since 1934, this was my first experience with rf disturbing the ignition system.

My remedy was to bypass the rf to the grounded side of the electrical circuit, as shown in the accompanying diagram. A 0.05-μF feed-through capacitor was placed in series with the red lead and also the white lead extending from the ignition switch to the ignition module. As a further precaution, I also installed two 0.05-μF shielded capacitors with shielded pigtails as indicated in the diagram. The latter bypass capacitors are made by Motorola (no. IV80700-A89). Since I took these corrective measures, the RFI no longer affects the ignition when the transmitter is being operated. — *Morris E. Hall, N4MH, Rock Hill, South Carolina*



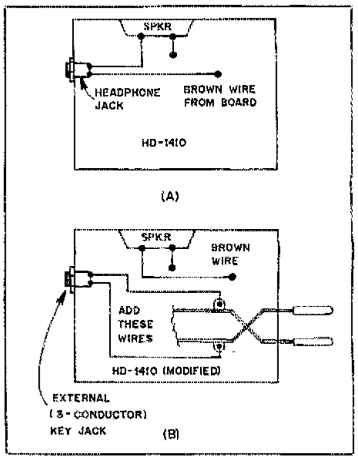
When rf from a 130-watt mobile transmitter upset the ignition system in a 1980 Ford police car, Morris Hall, N4MH, installed bypass capacitors as shown in this drawing. The remedy effectively eliminated the problem.

THOUGHTS ON THE HEATH HD-1410 ELECTRONIC KEYER

☐ I was not completely satisfied with the speed control on my Heath HD-1410 electronic keyer. Assembly instructions recommended that R9 be 10 kΩ for a speed range of 10 to 35 wpm. However, the top speed was much in excess of 35 wpm and adjustment around 20 wpm much too critical. Connecting a 5.6-kΩ resistor in series with R9 and shunting the speed control R101 with a 27-kΩ resistor brought the speed range down to 8 to 35 wpm. Also, settings of the speed control became much less critical.

Having used a single-paddle keyer for quite a while, I found I had little use for the iambic property. However, I learned that if I adjust the travel to a *minimum* and the spring tension to a very weak value, I do fine with the keyer. If the tension is too high, the darn thing jumps around on the table and if the travel is too high, using the keyer is tiring. I can do very well at 25 wpm. I'm 78 years old. Got my Extra in 1977! Earned my first ticket in 1928. — *Ira Myers, W2SVJ, Neptune, NJ*

☐ To use other paddles with the Heathkit HD-1410 keyer you only have to make the following modifications. First, disconnect and remove the headset connector on the rear of the keyer and replace it with a 3-conductor stereo 1/4-inch jack. Next, reconnect the speaker directly to the board lead removed from the headphone connector. Then solder a wire on each side terminal (no. 4 solder lug) of the internal keying paddle and connect these to the new jack on the rear panel. See the accompanying drawing. — *Jim Zimmerman, WB7DGU, Flagstaff, Arizona*



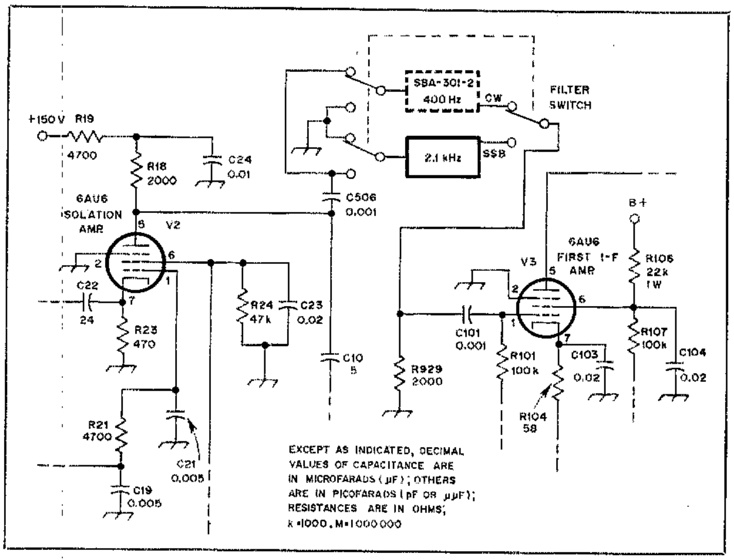
The Heath HD-1410 keyer can be modified for use with other paddles by making the changes shown. Drawing A shows the original connections to the phone-plug connector wired according to Heath instructions. The phone connector is replaced by a three-connector stereo jack and then wired as shown to the HD-1410 paddles. The external paddle key lead is then plugged into the stereo jack.

☐ Several amateurs who had HD-1410 keyers found the output would hold low when transmissions were made on the various amateur bands. The bands related to this effect were not the same at all stations but seemed rf related. I found that connecting a 0.001-μF capacitor from the output of IC3C (pin 12) to ground cured all but one case among the seven keyers so modified. — *William M. Kosturko, W1VW, Stratford, Connecticut*

*Assistant Technical Editor

HEATH SB-101, LOW SENSITIVITY AND RF DRIVE

☐ The problem of low receiver sensitivity and low rf drive was noted on two SB-101 transceivers. Replacement of weak or marginal tubes and realignment did not correct the problem. The source of this difficulty was found to be a dirty spdt switch between the 2.1-kHz filter and the first i-f amplifier, V3. The contacts presented 5- to 10-ohms resistance, which would vary when the switch was operated. Disassembly of the switch disclosed that a contact lubricant had dried to a consistency of wax, resulting in corrosion and poor continuity. After the switch was cleaned and reassembled, the receiver sensitivity increased by 10 dB and the rf drive returned to normal. Possibly this problem may be common in other equipment of the SB and HW series made in the late 1960s. — *J. M. Eaves, K5YJJ, Laplace, Louisiana*



Cleaning the filter switch, shown above, in the SB-101 at K5YJJ, restored both the sensitivity and grid drive. Because of corrosion and a wax-like residue, the resistance between contacts had increased to nearly 10 ohms.

RTTY PAPER

☐ An economical source of RTTY paper is contained in the end of roll newsprint. Our local publisher has been selling these for $2 or less depending on the mount of paper remaining. The rolls are 30 inches (762 mm) wide and, by using any method employed in sawing wood, can be cut to any desired width. I cut mine on a band saw. With a little patience you can use a hacksaw or fine-tooth carpenter's saw. A wooden cylinder, with nails as mounting pins and turned to fit the tube on which the paper is rolled is ideal for mounting in the machine. A roll mounted on a broomstick inserted in a box, allowing the paper to be fed up through the slot on the rear of the printer, will also get the job done. I operated for over 18 months on my first $4 investment. — *Col. James C. Richardson, Ret., W3CLJ, Charleroi, Pennsylvania*

SCANNING IDEA FOR THE KENWOOD TR-2400

☐ There are 10 memories in the Kenwood TR-2400 2-meter transceiver and the radio will scan all 10 channels in order, at a rate of about one per second. If you live in an area where you do not have 10 frequencies to which you wish to listen, there is no way to get the radio to scan fewer than 10 channels. However, it occurred to me that if one were to program frequency A into the odd-numbered channels and frequency B into the even-numbered channels, then the net result would be the same as if the radio were only scanning two channels. This process could be applied to any number of channels up to 10 by programming the frequencies into the radio in rotating succession (e.g., A, B, C, A, B, C, A, B, C, A). To give the user a quasi-priority function, the channel sequence might go something like this: A, B, A, C, A, D, A, E, A, F. In my area, with only two repeaters to monitor, this method enables me to listen to both repeaters with only one-second delay between listening periods. If I had 10 different frequencies programmed into the radio and someone called me just after the radio looked at that channel, they could complete their call and the repeater would have dropped out before the 10 seconds elapsed for the radio to have returned to that channel. — *Clark L. Stewart, W8TN, Ravenswood, West Virginia*

HEATH SB-104 TALK BACK SOLUTION

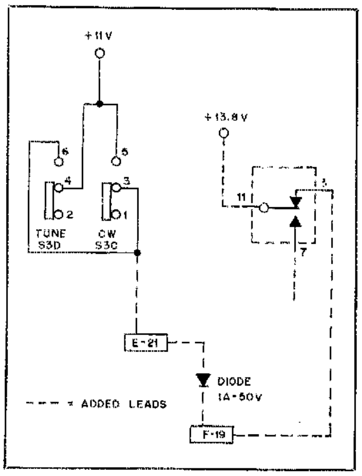
☐ After reading the SB-104 modification articles in *QST* for August 1979 (WØMYN) and May 1980 (W4YEJ) I attempted to bypass the rf on the 13.8-V line with capacitors and heavy ground connections without success. Another solution was needed in my case.

I decided that I had to remove the 13.8 V from F-19 during transmission, but I didn't particularly like the WØMYN solution because of the effect on the counter preset. The accompanying illustration shows a solution that is simple and effective. I first removed all wires from F-19 and connected them to an added tie point terminal, as suggested by W4YEJ. I then added connections, as shown on the diagram, consisting of one wire and a diode.

F-19 is held at 13.8 V except at transmit (high power) when relay contacts open and drop the voltage to zero on ssb. This eliminates the talk back. In the cw and tune modes, the voltage is approximately 10 V (11 V minus the diode drop). The purpose of the diode is to isolate the two power sources. Conduction of the diode is controlled by the polarity of voltage across it which is set by the relay mode and the cw and tune switches.

The decreased voltage at F-19 (13.8 to 10 V) does not materially affect the volume of the sidetone but the level can be readjusted. Additional loading on the 11-V supply seems minimal (approximately 50 mA).

The simplicity of the solution is apparent since it is only necessary to provide an additional tie point, connect a diode from E-21 to F-19, and a wire from F-19 to RY-3. — *Larry Tumey, K4GMZ, Lakeland, Florida*

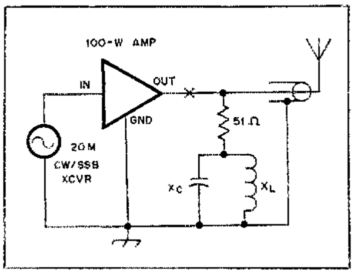


Larry Tumey, K4GMZ, developed this simple circuit modification for eliminating talkback in the Heath SB-104.

SOLVING BROADBAND AMPLIFIER HARMONIC PROBLEM

☐ After having tried to "dis-harmonic" a 100-W broadband transistor amplifier, a solution came out of my reactive bank while I was pursuing something unrelated. The objective was to terminate everything outside the 10- to 160-meter amateur bands and have the harmonic filter properly terminated (50 ohms, nonreactive) within the range of 10 to 160 meters. In commercial equipment harmonic suppression is accomplished with half-wave switched filters. However, the termination is reactive in the filter stop bands when mono-band antennas are tuned by Transmatches. Besides, the half-wave filters are low-pass only, allowing strange i-f/mf signals to pass through.

My solution is to use a diplexer like the ones I use to terminate the doubly balanced mixers



Dave Windisch, K3BHJ, solved the problem of harmonics in a broadband amplifier by using the filter arrangement indicated above. Details are in the text.

in my contest-grade station. See the accompanying diagram.

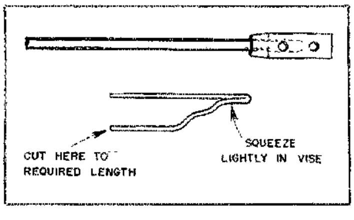
Experimentally, at 20 meters, I found a Q of 2 to be sufficient to cover the band (C ≅ 450 pF and L ≅ 0.28 μH). I recommend the application of vhf construction techniques (chip capacitors, N-connectors) and a good small tubular 50-Ω termination. A 25-W Globar resistor, 3/8 inch (10 mm) thick by 1-1/2 inch (38 mm) long, is adequate. Load the circuit with 50-ohms resistance and gate dip it to resonance. You'll find the amplifier is as broad as a barn door, adheres to the "KISS" theorem and avoids Murphy's Law. Incidentally, belt-and-suspenders types can insert your half-wave filters at point X if you insist. — *Dave Windisch, K3BHJ, Baltimore, Maryland*

A NOTE ON THE CLIPPERTON L

☐ I was having a problem with parasitic suppressors going up in smoke on my Dentron Clipperton L until I wrote to the manufacturer and received the following reply. "The Clipperton-L will heat the parasitic choke on 10 and 15 meters if it is not loaded properly. On 10 meters, the load control *must* stay above 5. On 15 meters it *must* stay above 3. If operating with the load control below these parameters, the unit will go into parasitic oscillation and cause the parasitic choke to overheat." — *Jack Schuster, W1WEF, Glastonbury, Connecticut*

MAKING HUSKY GROUND TERMINALS AND TIPS FOR YOUR SOLDERING GUN

☐ Need a cheap, yet husky ground-terminal connector? Then try this one. Cut a 1-1/2-inch (38-mm) length of 1/4-inch (6-mm) ID copper tubing. Drill a 1/4-inch hole in one wall of the tubing, placing it about 1/2 inch (13 mm) from one end. Remove 1 inch (25 mm) of insulation from the length you need of no. 6 to no. 10 stranded copper wire. Insert this end into the tubing so that 1/4 inch of the jacket is inside the end of the tubing. Now tightly squeeze the tubing onto the wire (but not the jacket) by placing the piece of tubing in your vise 1/4 inch from the end in which the wire is inserted. Solder through the drilled hole. Next, drill another 1/4-inch hole 3/8 inch (10 mm) from the flattened end. Clean thoroughly with steel wool. If you use a tubing cutter instead of a hacksaw and a hand punch instead of a drill, you will wind up with a much neater job.



Want to save on tips for your Weller (or similar) gun? Then, try this idea. Bend a length of no. 6 to no. 10 copper wire as illustrated, fashioning the wire to resemble the manufactured tip. The wire gauge depends on the capacity of the soldering gun. — *Raul Pomales Lopez, KP4EQN, Rio Piedras, Puerto Rico*

IMPROVING THE SWAN 500 CX CALIBRATION OSCILLATOR

☐ Swan 500CX owners may find the calibration oscillator will work better if the circuit is rebuilt to the improved schematic design available from the Swan factory, rather than maintaining the component values shown in the parts list of the operation manual. The procedure is to delete R1601 (1 kΩ) and C1601 (250 μF) and the line tied to the coil of K1. Tie the −12-V line of the board to pin 3 of the accessory socket for filtered, regulated dc. Change R1607 to 47 kΩ, R1608 to 33 kΩ, R1610 to 2.2 kΩ, R1612 to 4.7 kΩ. Install C1607 (0.01 μF at 25 V (dc) and replace Q7 with an RCA SK3018, an npn silicon video i-f amplifier. Finally, calibrate the oscillator with the signals from WWV. Adjust R1609 for 25-kHz calibration. This should bring the circuit up to par. — *Dave Torgenrud, WA0PDB, Thief River Falls, Minnesota*

RADIO SHACK BOARD WELL SUITED FOR CALIBRATOR

☐ Regarding the versatile calibrator described in the feature article, "Hints and Kinks from Abroad" (January 1980 *QST* pp. 42-43), I have found that the time-base-generator circuit board sold by Radio Shack is well suited for this project. I refer to their project board no. 277-115. This board has space for up to seven 7490s or 7492s (÷ 12) and jumper pads to wire any conceivable combination. In addition there is provision for a crystal oscillator. This project board is furnished with a handsome and informative manual, all for $6! — *Edward M. Roberts, Glen Head, New York*

SILICONE TREATMENT FOR SOLDERING-IRON TIP

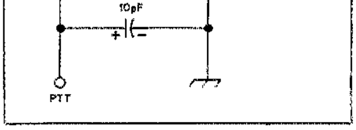
☐ One of the best favors you can do for a new soldering iron is to put a light coating of silicone on all of the surfaces that might have to be removed. Depending on the brand of soldering iron, this might involve coating setscrews or the screw thread on the soldering-iron tip. In any case, the results can be quite effective. After a year or two of use, some soldering-iron tips become so encrusted in place that they are impossible to remove. With silicone treatment, this problem is avoided. Almost any silicone compound will suffice. Dow-Corning DC-4 compound, used with heat sinks and the insulators of transistors, is one such product. — *John Schultz, W4FA, Voice of America*

REGARDING TS-520 CW MODIFICATION

☐ Here is a note of caution for those owners of a Kenwood TS-520 who may have made the cw-filter modification to their rigs according to the September 1977 "Hints and Kinks" column. According to the modification, the cw filter can be switched out of the circuit by using the CH SELECT switch on the front panel. Do not try to transmit, however, with the cw filter switched out. I find that there is a considerable power loss as a result. — *Warren Bone, KQ4X, ex-WB4OXR, Nashville, Tennessee*

ELIMINATING RF IN FT-101Z MICROPHONE CIRCUIT

☐ I had trouble with rf getting into the leads of the microphone circuit of my FT-101Z. This drawing illustrates the cure. It is simply a matter of modifying the microphone and PTT leads to coincide with the FT-101EE version. — *W. A. Wessel, W0CM, Liberal, Kansas*



CLEANING VARIABLE CAPACITORS

☐ For corroded and otherwise dirty variable capacitors, which are almost impossible to clean with a brush, I use a mixture of 4 ounces (120 ml) of concentrated lemon juice in 8 to 10 ounces (240 to 300 ml) of water placed in a sauce pan. By placing the capacitor in this mixture and boiling it for 10 to 15 minutes, the device can be made to look like new. A few drops of liquid detergent might be helpful. A drop or two of oil should be placed on the bearings when dry. — *Bill Pickens, WB5NGF, Leland, Mississippi*

KB6DQ placed his dummy antenna load in one of these attractive flower pots outside his den. This solved a problem of seeping oil. His XYL added the final touch by placing synthetic flowers around the dummy load.

IMPROVING TUBE VFOs: A NEW LOOK AT AN OLD PROBLEM

☐ The heart of any modern transmitter is the VFO, where the quality and stability of a signal begins. Modern technology has made significant improvements in this area in comparison with older VFOs that sometimes drift or chirp. Owners of older tube-type VFOs can alleviate the problem of chirp by making the circuit modification I have provided. I find it useful also in QSK operation.

Many chirps are not caused by the power amplifier pulling on the VFO. An inadequately rated power supply more likely is at fault. Such a supply can struggle to supply the VFO with a steady voltage when the transmitter is switched from standby to operate mode. This can cause the VFO frequency to slide considerably before arriving at a stable condition. Reworking the power supply is the best solution, but that involves considerable expense and often changing the physical layout of the VFO. My circuit is simple and inexpensive, and it can be added easily to many older VFOs.

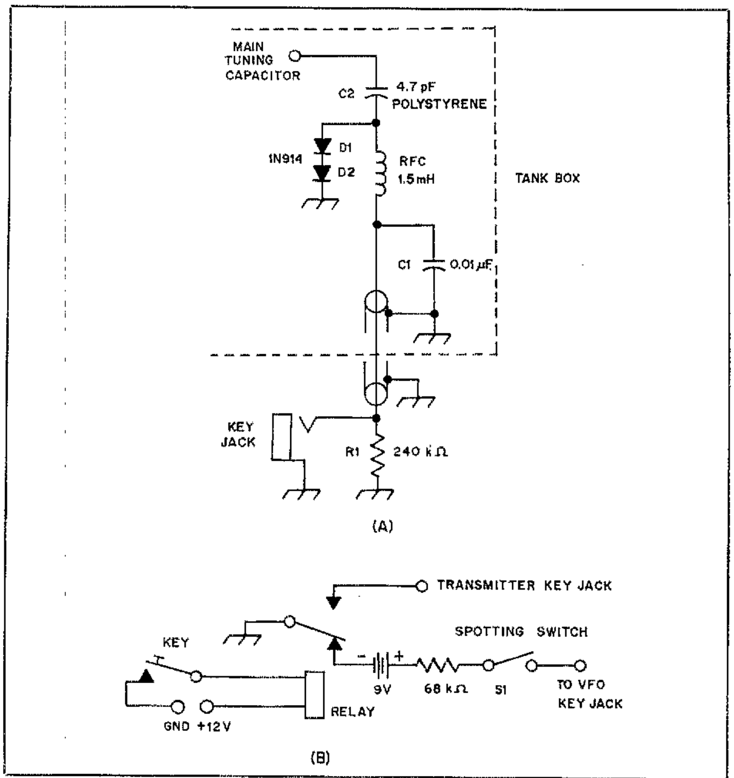
Frequency offsetting is popular in many new rigs because it helps maintain stability. It stops load variations on the power supply by ensuring that the VFO is always on. The circuit described here shifts the frequency of an Eico 722 VFO about 50 kHz on the 80-meter band, enough to take it entirely out of the Novice portion when on standby. It therefore cannot be heard during reception. Neither will it cause any QRM on the air.

Physical changes to the VFO were minimal. A terminal strip mounted in back of the tank-circuit box, a new "normally open" phone jack and rewiring the standby/operate switch were the only chassis additions.

The circuit only affects the frequency of the tank circuit when it is grounded as a result of the diodes being forward biased by a voltage greater than 1.4. Two diodes are necessary to raise the diode bias above the tank operating voltage. A shielded cable provides the path through the rf choke for the voltage to be applied to the diodes. C1 bypasses the rf and R1 bleeds the capacitor so that a frequency glide with each voltage shift is avoided. When a positive voltage is applied to the diodes, they become forward biased, grounding C2. The added capacitance shifts the frequency of the VFO downward.

All components in the dashed line of the drawing are soldered to a terminal strip mounted behind the main tuning capacitor in the rear of the tank circuit box. The terminal strip is secured by one of the screws holding the tank circuit housing to the chassis. C2, a polystyrene capacitor, stretches from the tuning capacitor to the terminal strip. I routed the shielded cable against the walls of the box through the chassis at the hole for the band switch. The normally closed phone jack was replaced with one that is normally open. To have the oscillator cathode always grounded when transmitting, I rewired the mode switch. Recalibration is performed according to EICO's recommended procedures.

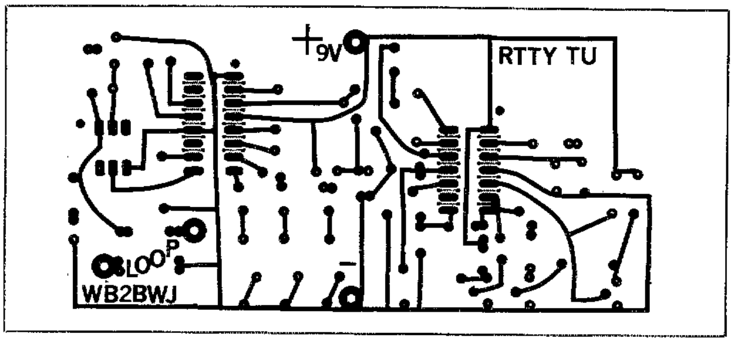
The keying circuit, shown at B, is connected to a grounded cathode circuit in my transmitter. Current drawn by the diodes is limited by the resistor. S1 permits spotting of the VFO without undesired transmission. Before the modification it took the VFO several seconds to stabilize when placed in the transmit mode, a handicap when working in the Novice bands. QSK was impossible. Since installation of the offset circuit, the VFO has been chirp-free and clean. QSK is a welcome bonus. — *Thomas D. Cook, N3AXN, Pittsburgh, Pennsylvania*



Thomas Cook, N3AXN, gave his Eico 722 VFO added stability with the circuit modification shown above. Frequency offset during standby enables the VFO to run continuously without reception interference. This stabilizes the oscillator. His keying arrangement (B) permits spotting by using S1.

THE OLD TIMER'S NOTEBOOK: A GOOD USE FOR OLD COAXIAL CABLE

☐ If you have or can find some old coaxial cable that's become too lossy for use as transmission line, use it for radials in your ground system. Lengths of the sheathing can be removed from the cable and installed as ground or bonding straps around your equipment, in your boat or on your car. A length of such cable makes a good shielded lead from your car battery to your mobile radio. — *E. A. "Whit" Whitney, W1LLD, Milford, New Hampshire*



Circuit-board etching pattern for the "State-of-the-Art Terminal Unit" (see Fig. 3, p. 22 of this issue). Black represents copper. The pattern is shown at actual size from the foil side of the circuit board.

Technical Correspondence

Conducted by
Jerry Hall,* K1TD

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MODIFICATIONS TO THE 144-MHZ "PLUMBER'S SPECIAL" AMPLIFIER

☐ Two problems with the popular "plumber's special" 144-MHz kilowatt amplifier are the difficulty of making a reliable lead-screw tuning mechanism and critical adjustment of the output-coupling link.[1] Both problems can be overcome by the modifications given here.

Very large circulating currents flow through the plate tuning capacitor and its associated lead-screw mechanism, and any form of sliding contact will eventually corrode and cause trouble. The problem can be avoided by using a completely insulated vane to alter the plate-to-plate capacitance.[2,3] Although the tuning range is smaller than that of a lead-screw capacitor it is still quite adequate if the length of the lines is correct.

As K2RIW has pointed out,[4] coupling is critical to adjust the maximum rf output. He solved the problem by using capacitor output coupling, and later designs have adopted the idea for single-ended amplifiers on 144 MHz.[5,6]

Capacitive output coupling can also be used for push-pull amplifiers such as the "plumber's special." Fig. 1 shows the electrical circuit of my amplifier, and Fig. 2 is an "exploded" mechanical sketch; everything else is the same as described in Ref. 1. C1 is the floating-vane tuning capacitor; C2A and B comprise the twin-gang output coupling capacitor. The push-pull outputs from C2 are combined in a half-wave coaxial balun. This output coupling arrangement maintains correct balance with respect to ground, and is adjusted easily. Increasing the coupling capacitance brings a progressive increase in plate current at resonance, and the rf output rises to a maximum, then falls as the amplifier becomes overcoupled to the antenna. It's just like an rf rig, and so different from the hit and miss of link coupling. There is a small power loss in the balun, though RG-8/U cable gets only slightly warm on prolonged tune-up. The power loss is far outweighed by the improved efficiency that comes from optimum output coupling.

The control shafts should be made from a good rf insulator; polystyrene works fine (if it tends to soften, maybe you need a bigger blower!). When the moving vanes of C1 and C2 are parallel with the stator plates, the spacing should be about 6 mm (1/4 inch). It doesn't matter if the vane of C1 accidentally touches the plate lines or the outer case, but C2 must be prevented from closing and shorting out the high-voltage. As a further precaution a shorted quarter-wave stub provides a dc ground to the output circuit.

If you are having trouble with lead-screw tuning and want to try the C1 arrangement, you'll probably have to alter the length of the plate lines to bring the system back to resonance. I found no need to change the plate lines after removing the old coupling link and installing capacitive coupling, though it may prove necessary to trim both stator plates of C2 to obtain the correct capacitance range. — *Ian White, G3SEK, 83 Portway, Didcot, Oxfordshire OX11 OBA Great Britain*

*Technical Editor, QST

References

[1] *The Radio Amateur's VHF Manual*, ARRL, all editions.

[2] RSGB *VHF Handbook*, 1st and 2nd editions only.

[3] *The Radio Amateur's VHF Manual*, 2nd edition.

[4] Knadle, "432-MHz Parallel Kilowatt," April and May 1972 *QST*.

[5] Gross, W9OJI, "A Parallel 4CX250B Amplifier for 144 MHz," May 1975 *QST*, p. 11.

[6] Merry, "Stripline Kilowatt for Two Meters," October 1977 *Ham Radio*, p. 10.

TRANSMISSION LINES, SWR AND SUCH

☐ Referring to the very informative and well-presented article "The Imperfect Antenna and How It Works," *QST* for July 1979, and metaphrasing the concluding paragraph — "In the case of your antenna system, be it 'perfect' or 'imperfect,' a little of the transmitter output energy gets changed into heat in the feed line and antenna wires. The rest — all the rest — is radiated into space by the antenna."

There are other energy losses whose total is greater in magnitude than the transmission line energy loss, such as ground resistance, corona, eddy currents induced in neighboring masts, guy wires and other conductors and dielectric losses arising from imperfect dielectrics, such as insulators and trees in the near antenna field. These losses can be represented by a resistance, R1, which, when inserted in series with the antenna, consumes the same amount of energy as that which is dissipated by the sum total of the lossy elements mentioned above. The total resistance component of antenna impedance is the sum of Rr + R1, Rr being the radiation resistance.

The antenna radiated energy efficiency is the ratio of radiation resistance to the total resistance, i.e., Rr/(Rr + R1). This is the fraction of the total energy supplied to the antenna, which is converted to radiated "communication" energy. — *John J. Glauber, W4OB, 1536 Orangewood Circle, Zellwood, FL 32798*

☐ The "The Imperfect Antenna System and How It Works," July 1979 *QST*, is a very good tutorial article on the subject. There are three statements in the text which I take issue with, but these do not appreciably affect the overall objective of the presentation.

The first is "In reality, power does not travel down the line." Power certainly does travel down the line to the antenna. If the line is lossless all power arrives at the antenna. If the line is lossy, some is dissipated in the line as it passes.

The second is the statement in the seventh paragraph, "The answer is that the load will dissipate, not 100 watts, but 75 watts." The real answer is that the result cannot be predicted! The transmitter is a highly nonlinear source! Sparks and grief could result unless the transmitter is retuned!

The third comment I have is on the last two lines of the third paragraph from the end, "however, if the line losses are taken into account, . . ." If these words are deleted, the

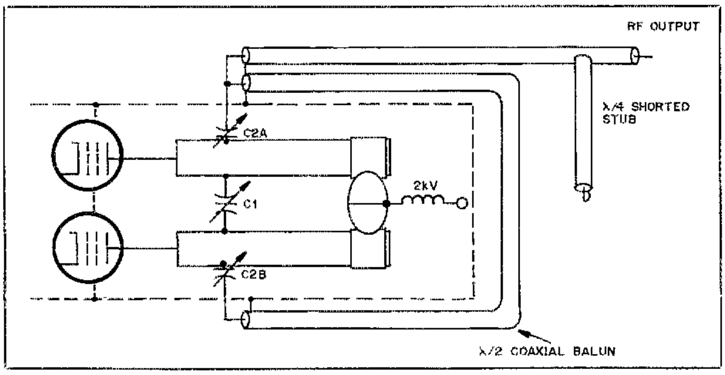

Fig. 1 — Details for modifying the amplifier for capacitive-output coupling.

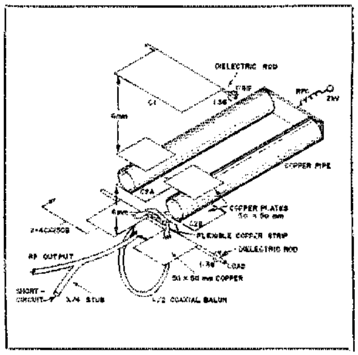

Fig. 2 — Exploded sketch of the amplifier tank with modifications.

sentence is correct. The difference between "forward" and "reflected" power is the power delivered to the load connected to the "wattmeter" output, and thus the power delivered by the transmitter (assuming the wattmeter is dissipationless!). I use quotes around "wattmeter" because I'm about to suggest changing the name of these SWR meters, reflectometers, etc. to "Whatmeters." — *J. T. Kroenert, WA1YTC, 349 New Meadow Rd., Barrington, RI 02806*

TX LINE Z_0 — IS IT REALLY 50 Ω?

☐ Some time ago, while on active duty with the U.S Coast Guard, I encountered an unusual situation while measuring the antenna impedance of a loran "A" tower at a U.S.C.G. loran station. The tower for several years had an SWR of 1.22, even though the antenna had been bridged and tuned to 50 + j0 ohms. The SWR meter was always calibrated prior to the measurement to ensure it was accurate. It was never understood why an SWR of 1.0 could not be obtained.

During a station visit intended for antenna-bridging measurements, several attempts at determining the cause of the "non-1.0 SWR" after tuning were made. One such attempt involved placing a homemade time-domain reflectometer in the signal-power building to check the transmission line and antenna system for reflections along the line. The homemade TDR was used in conjunction with a USM-117 scope. Although one might think the idea too crude to be useful, it does provide reliable information and is a valuable tool in determining changes of impedance in the transmission line and antenna[1].

The TDR indicated a mismatch at the junction of the transmission line and the input to the tuning unit. Since the antenna had just been bridged and adjusted to 50 + j0 ohms, I concluded that the connectors were causing the mismatch indicated by the TDR. The connectors were removed, cleaned, and resoldered to the transmission line (this is no easy task). The line itself was inspected for breaks and corrosion of the wires along the section on which the connectors are fitted. The TDR was used again to check for mismatch. Nothing had changed in the pattern on the scope. When the transmitter was put on the air, the SWR was still 1.22:1.

If the antenna was 50 + j0 ohms and the connections were good, then something must have been wrong with the transmission line itself. All this time it was assumed the transmission line was 50 ohms (RG-19/U).

Network theory was then employed to determine the characteristic impedance of the line:

$$Z_o = \sqrt{Z_{sc} \times Z_{oc}}$$

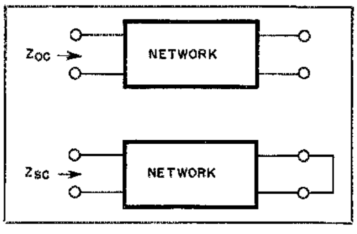

Fig. 3 — Conditions of measurement for determining the characteristic impedance of a network. The "network" may be a length of transmission line.

Table 1
Specified vs. Measured Cable Impedances

Cable Type	*Freq. Measured*	*Manufac. Z_o*	*Measured Z_o*
18 feet RG-58C/U	4 MHz	50 ohms	53.5 ohms
	29.5 MHz	50 ohms	40.9 ohms
36 feet RG-8A/U	4 MHz	52 ohms	54.0 ohms
	29.5 MHz	52 ohms	57.6 ohms
16 feet RG-213/U	4 MHz	50 ohms	52.6 ohms
	29.5 MHz	50 ohms	
15 feet RG-58/U	4 MHz	53.5 ohms	53.4 ohms
	29.5 MHz	53.5 ohms	58.3 ohms
51 feet RG-213/U	4 MHz	50 ohms	49.8 ohms
	29.5 MHz	50 ohms	48.6 ohms

0.3048 × feet = meters

Z_{sc} is the measured input impedance of the network (transmission line) with the output shorted. Z_{oc} is the measured input impedance with the output terminals open (Fig. 3).

The transmission line was disconnected from the antenna tuning unit and from the transmitter. Then Z_{oc} and Z_{sc} were measured using the same test equipment which was used to measure and set the antenna impedance at 50 + j0 ohms. The equipment involved a Stoddart NM-20A detector, URM-25 rf generator, and General Radio 916AL impedance bridge. The line impedance was measured at the loran frequency, 1850 kHz in this case. The characteristic impedance was found to be 61 ohms! The results were so startling that the equipment was moved to the other end of the RG-19/U transmission line and the impedance measured again. Still 61 ohms. If one calculates the SWR of a 61-ohm transmission line terminated in a 50-ohm load (by formula or Smith Chart), the result is 1.22 — exactly as the SWR meter had been indicating previously.

On another loran station, a similar experiment was conducted on a 12-foot (3.65-m) length of RG-8/U cable used inside a transmitter. The cable appeared to be an original component, about 25 years old. The impedance was measured at 95 ohms instead of the 52 ohms intended during manufacture.

Several other types of coaxial cables were measured to determine their characteristic impedances. A URM-25 was again used as the rf generator, but a General Radio 1606 bridge and a Hallicrafters SX-111 receiver were used as the bridge and detector. Z_o was checked at two frequencies far removed from the standard loran frequencies. The results of the measurements are tabulated in Table 1. Most manufacturers allow a tolerance of ± 2 ohms within the published characteristic impedance, so some of these cables are within specifications at some frequencies.

Thus, one should be careful to consider the transmission line's *actual* characteristic impedance when performing antenna tuning or impedance-matching techniques requiring precision. — *Clifford J. Appel, WB6AWM, 9436 South Wales Way, Elk Grove, CA 95624*

[1]See Jochem, "An Inexpensive Time-Domain Reflectometer," *QST*, March 1973.

TESTING SSB TRANSMITTER LINEARITY

☐ Most methods used for testing an ssb transmitter require either expensive test equipment or expertise for evaluating the results. The technique I devised uses a single audio tone of 1.5 kHz, 100 percent amplitude modulated with 20- to 60-Hz triangular voltage, obtained from a Hewlett-Packard 3312A function generator. A convenient substitute can be jury-rigged from any audio oscillator, complemented with a 566 IC as a triangular-wave oscillator and an MC1496 IC as a modulator.

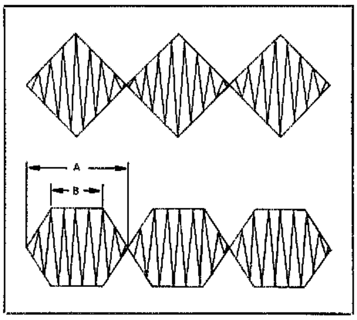

Fig. 4 — Test signal waveforms. The upper drawing shows a triangular-modulated wave from the signal source. The lower drawing shows how the clipping level of a speech compressor may be measured. (See text.)

The upper drawing of Fig. 4 shows the waveform of a test signal. The waveform of an ssb signal should be the same: Any nonlinearity in the system shows in the envelope. The rising part of the envelope can be treated as a static input-output characteristic. At frequencies greater than the bandwidth of the oscilloscope, the scope may be used to display the i-f voltage of a presumably linear receiver.

The lower drawing illustrates the case of measuring the clipping level of an hf speech processor. After measuring the lengths of A and B, the clipping level in dB can be determined from

$$L = 20 \log \frac{A}{A - B}$$

where L is the clipping level. — *R. J. Wolski, SP9AGQ, 9 Jaworowa, 41902 Bytom, Poland*

FREQUENCY-BLOCK PROGRAMMING OF CES 800 SCANNERS

☐ The Communications Electronics Specialties 800 series scanners are used with Clegg and other 2-meter synthesized transceivers. They are extremely versatile and convenient accessories. When programmed for repeater or simplex frequencies in your area, these scanners leave nothing to be desired in operating convenience. When they are used in areas where active repeater frequencies are unknown, however, scanning the entire

2-meter band is very time consuming.

The following program allows you to scan one or more continuous frequency blocks. No wiring changes are required. First, set all push buttons on the scanner to the outer, or released, position. Set the transceiver frequency to 144.00 MHz. Then:

1) Erase memory by pressing SCAN and DELT. Wait until the display "races" before releasing DELT. (It may be necessary to press RSME if the scanner was previously in the HOLD mode.) If you wish to retain the channels already in memory, you may skip this step.

2) Release SCAN. Set the lower limit of the desired block with the transceiver frequency controls, and press ENTR (for example, 146.00). Now set the upper limit of the block (for example, 147.00) and press ENTR.

3) Reset frequency controls to 144.00 MHz, then press SLOW and SCAN. The display will alternate between the upper and lower limits you have chosen. When the display shows the lower limit, press HOLD. Press ALL. Now hold down ENTR while pressing RSME. Continue holding ENTR while the frequency scans up from the lower limit; when it reaches the upper limit, press HOLD.

4) Release ALL and SLOW.

The unit will now scan only from the lower to the upper limits. It still may be programmed to add or delete additional frequencies in the usual manner. Additional blocks may be entered by repeating steps 2 through 4, with new upper and lower limits. — *Samuel Bases, K2IUV, 19 Standish Ave., Yonkers, NY 10710*

MORE TUNE-UP BRIDGE NOTES

☐ N8AJV's statement ("Don't Break the Seal," May 1980 Technical Correspondence) about the disastrous effects of grinding down 47-ohm resistors to a 50-ohm value was unsubstantiated by any data, so I made a few simple tests of my own. To produce a worst-case condition, I ground down a 30-ohm carbon-composition resistor until it measured 58.6 ohms on my Leeds and Northrup precision bridge. This big increase in resistance assured me that a large amount of the carbon resistance element would be exposed to moisture. Therefore, any effects would be magnified over the small change I had made from 47 to 50 ohms in the resistors I had ground down for my bridge.

Then I fully immersed the ground-down resistor in a glass of tap water for 24 hours so that if the resistance element was going to absorb moisture it would do so. At the end of this time I took the resistor out. I just shook the water off and immediately measured its resistance. It showed a resistance of 58.4 ohms, or a negligible decrease of 0.34%. When the resistor later dried out at ambient room conditions, the resistance again measured 58.6 ohms. So actual measurements showed there were no detrimental effects of moisture on ground-down resistors. I also made further checks on the bridge I built almost a year and a half ago, and two other units built later, all of which had ground-down resistors. All of them showed no change in their ability to obtain a satisfactory null at a load impedance of 50 ohms.

I would say that moisture, absorbed or surface, might present a problem if the resistances were of very high value. But for the 47-ohm value specifically mentioned in N8AJV's letter, I could find no significant change. He also stated that it would be better just to use 20%-tolerance resistors. Using 47-ohm, 20%-tolerance resistors would lead to an uncertainty factor, however, where a balance thought to be at 50 ohms could actually be at anywhere from 25.1 to 84.6 ohms. Simple bridge calculations will easily verify these figures of uncertainty.

Also, because so much interest has been shown in my bridge, I'd like to pass along a simplified switching circuit that eliminates D1, R1 and C1 of the original circuit ("Tune Up Swiftly, Silently and Safely," *QST*, December 1979) without degrading or changing the basic concept of the device. It is shown in Fig. 5.

I've also experimentally eliminated the entire toroid coil and used instead a carbon resistor as a pick-off device. The resistor is connected between points A and B of the diagram. The value and wattage rating of the resistor naturally depend on the power level in use, but for 100 watts of output, I found a 3.9-kΩ 2-watt resistor satisfactory. — *William Vissers, K4KI, 1245 S. Orlando Ave., Cocoa Beach, FL 32931*

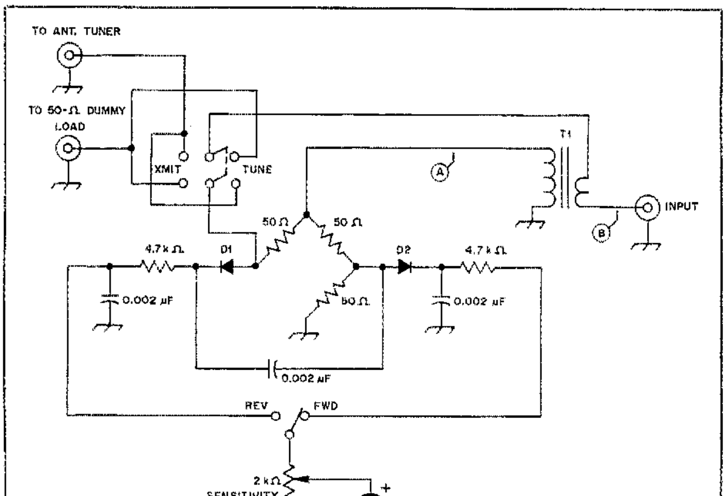

Fig. 5 — The simplified tune-up bridge schematic diagram. See the original December 1979 *QST* article for T1 specifications and additional information. A further simplification of the circuit is possible by installing a carbon resistor between points A and B, and omitting T1. See text for details.

IC SUBSTITUTION FOR THE MC1385P

☐ Regarding my article, "The Audiobox — An Amplifier with a Twist," which appeared in the August 1978 issue of *QST*, here is some updated information. It concerns the IC used in the original circuit.

Motorola discontinued manufacture of the MC1385P which was used in my *QST* circuit. I was going to redo the pc board to use another Motorola IC; however, there now is a simpler way. National Semiconductor introduced the LM383 — an 8-watt power-amplifier IC — which requires fewer external parts to provide the desired result.

I am including a schematic diagram (Fig. 6) which replaces the amplifier portion of the original circuit. Although I do not plan to make a revised pc board, it should be possible to install this circuit on the original board and hand-wire the components in place. — *Eric J. Grabowski, WA8HEB, 30312 Arnold Rd., Willowick, OH 44094.*

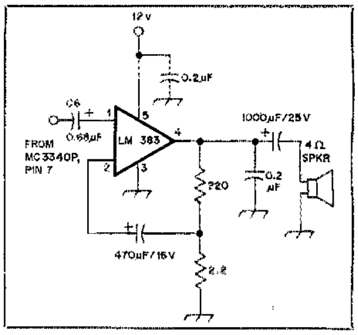

Fig. 6 — Schematic diagram of the revised circuit, which uses an LM383 IC.

Feedback

☐ Fred Brown, W6HPH, offers the following clarification for his article, "A Reflectometer for Twin-Lead," October 1980 *QST*. The last sentence in the first paragraph under *Checkout and Operation* on page 17 should read: R5 should then be adjusted to give the same voltage at its wiper as the collector voltage of Q2 before the meter is connected.

☐ The call of Leo Legleiter was incorrectly listed in the November "Silent Keys" column. It should have read WØKGJ instead of WØFIR.