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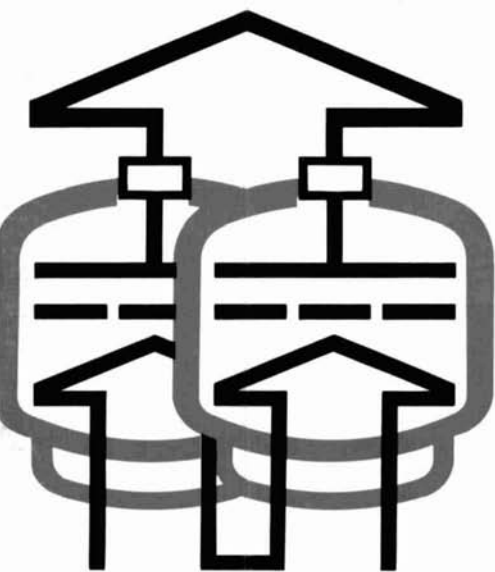
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focus  
on  
communications  
technology . . .

# *ham* **radio**

*magazine*

SEPTEMBER 1975



inductively-tuned  
**six-meter  
kilowatt**

## *this month*

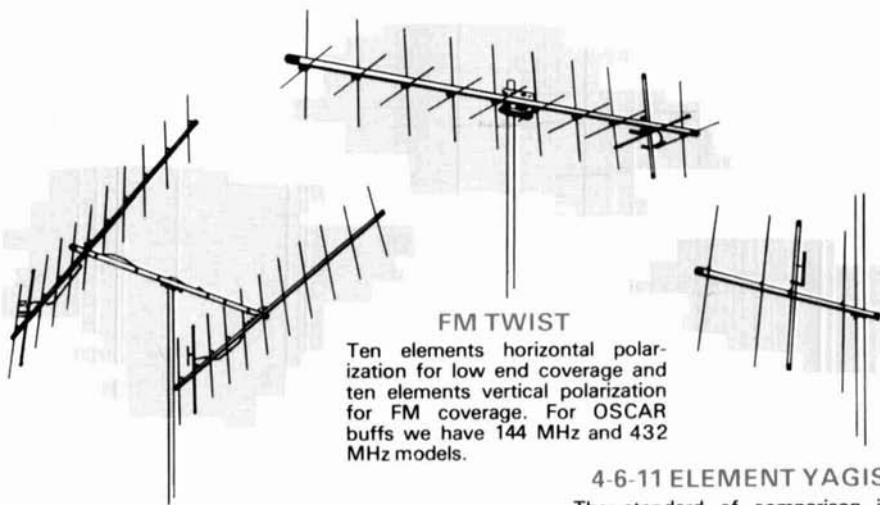
- RTTY terminal unit 22
- ssb speech splatter 28
- 432-MHz power amplifier 36
- hand-held touch-tone 44
- vhf mobile antenna 54

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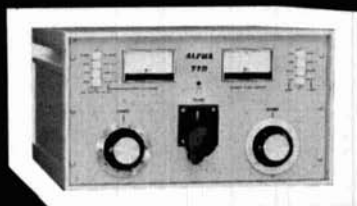
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September, 1975  
volume 8, number 9

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# contents

**8 inductively-tuned six-meter kilowatt**

Donald J. Cook, K1DPP

**16 tunable notch filter**

Courtney Hall, WA5SNZ

**22 optimizing the phase-locked loop  
RTTY terminal unit**

P. Edward Webb, W4FQM

**26 toroidal coil inductance**

Charles G. Miller, W3WLX

**28 single-sideband speech splatter —  
its causes and cure**

Robert P. Haviland, W4MB

**36 100-watt solid-state power  
amplifier for 432 MHz**

R. Keith Olsen, WA7CNP

**44 hand-held touch-tone**

Albert L. Lowenstein, K7YAM

**48 how to use meters**

Guy Black, W4PSJ

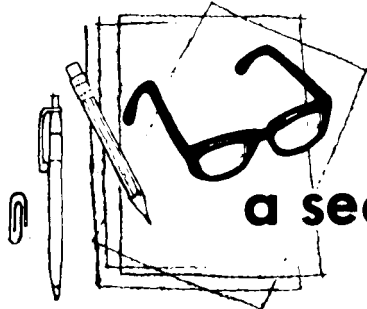
**54 magnet-mount vhf mobile antenna**

George R. Allen, W1HCI

**58 300-Hz crystal filter for  
Collins receivers**

James R. Fisk, W1DTY

- |                              |                           |
|------------------------------|---------------------------|
| <b>4 a second look</b>       | <b>68 new products</b>    |
| <b>110 advertisers index</b> | <b>110 reader service</b> |
| <b>62 comments</b>           | <b>67 short circuit</b>   |
| <b>99 flea market</b>        | <b>6 stop press</b>       |
| <b>66 ham notebook</b>       |                           |



# a second look

by Jim Fisk

Recently there has been rising concern over the possible harmful effects to living tissue due to heating by electromagnetic radiation in the frequency range from 10 MHz to 100 GHz. Although microwave engineers have been aware of the potential hazards of working around high-power microwave transmitters for 25 years or more, few people expressed much concern about the possible radiation hazards of lower-frequency equipment. However, from 150 to 1200 MHz the internal body organs are susceptible to damage from rf heating, and the eye is especially prone to damage from radiation above 1000 MHz.

The scientific community is not at all satisfied that there has been sufficient research for formulating rf exposure standards, but based on present knowledge, various governmental and industrial organizations involved in establishing radiation safety standards have recommended exposure limits referred to as Radiation Protection Guide Numbers (RPGN). At the present time the generally accepted RPGN value is 10 milliwatts per square centimeter, and the Occupational Safety and Health Admin-

istration (OSHA) has promulgated a standard which limits exposure to power densities greater than 10 mW/cm<sup>2</sup> of body area.

Authorities generally agree that rf power levels one-tenth the OSHA standard (1 mW/cm<sup>2</sup>) do not have any noticeable effect. Using this as a basis, what are typical safe distances from a high-frequency amateur antenna?

Since the safe distance from an antenna depends on its radiated power in a given direction, the most direct approach to finding the distance is to use a graph such as that shown in fig. 1. These curves are based on an isotropic radiator so antenna gain (power ratio, *not* dBi) must be factored in for the practical case. A half-wave dipole, for example, has a power gain of 1.64 over an isotrope (2.14 dBi). Assuming 1000 watts into the antenna, what is the minimum safe distance? The effective isotropic radiated power (EIRP) is 1.64·1000 or 1640 watts and the distance for a power density of 1 mW/cm<sup>2</sup> is about 24 feet.

Since most dipoles are installed at least 25 feet above ground, they obviously pose little threat at amateur power levels, but what about multi-element beams and stacked arrays? Assuming the array is at the top of a 54-foot tower, and not facing into a building, an EIRP of about 29 kW would be required to produce 1 mW/cm<sup>2</sup> in the center of the main lobe 100 feet away. With 1000 watts into the antenna, this corresponds to a power gain of 29 or 14.6 dBi.

Few amateur antennas exhibit this much gain, but EME operators who use large arrays or big parabolic reflectors should use caution. A 30-foot dish with only 10 watts input at 432 MHz, for example, is hazardous at distances of less than 18 feet!

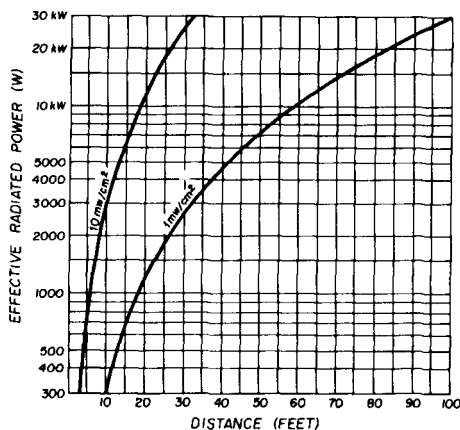


fig. 1. Minimum distances from radiators at which Radiation Protection Guide Numbers are not exceeded vs effective isotropic radiated power (EIRP).

Jim Fisk, W1DTY  
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# presstop

AN IMPORTANT STORY is still Prose Walker's decision to step down as chief of the Amateur and Citizens Division on July 31st. Deputy Division Chief Dick Everett is presently serving as Acting Division Chief.

In The Long Term the question of who'll be filling Prose's shoes is a tough one. Ideally the job requires an engineer-ham with strong managerial experience — plus appropriate Civil Service status. Though the new chief is likely to come from within the Commission it isn't an absolute must. However, candidates without Civil Service Ratings must establish their qualifications with Civil Service before they can be considered for the post.

CB RESTRUCTURING — DOCKET 20120 — has been partially decided in a recently released Report and Order. Most important change is a sharp relaxation of prohibited communications effectively permitting the hobby use of CB that has already characterized the service legal or not.

Also Relaxed are identification procedures, with an operator required to give only his callsign instead of both; the "quiet" period between five-minute series of transmissions has been reduced from five minutes to one minute; inter-licensee communications are now permitted on all 23 channels. Channel 9 continues to be classified as the emergency calling channel, and channel 11 has been designated a general calling channel.

Notable Emissions from this initial Report and Order on the Docket are the expansion to additional channels above the present band and the proposed conversion to all SSB. Though action on these can be expected eventually, it will probably rest to some degree on what happens with Class-E CB.

MANDATORY REVIEW OF LOGGING TAPES for repeaters operating under "automatic control" will not be required as a result of recent FCC decision. Logging tapes must still be made and kept for 30 days, and if any operating problems are reported to the control operator or licensee during that period the tapes must be reviewed and corrective action taken within 72 hours or the system must shut down.

This Easing Of Requirements for repeater operators takes most of the sting out of the Commission's Report and Order — mandatory review had been the principle objection raised by the repeater fraternity.

AMSAT MEMBERS not planning to attend AMSAT's annual meeting at the ARRL Convention in September are reminded that their ballots for the Director's election are needed to insure a quorum. The annual meeting is scheduled Sunday, September 14, at Reston, Virginia.

New Two-Color Bumper Sticker Decals are now available from AMSAT. They are being sent free to new members and renewing old members, or sold three for \$1 plus SASE from AMSAT, Box 27, Washington, DC 20044.

TV TUNER WITH MEMORY has some interesting design features for Amateur radio applications. Announced in July by General Instrument, the tuner uses a non-volatile memory chip that contains 100 lines of 14 bits each. Each line can be programmed for one TV channel, and when needed the memory information is fed to a 14-bit CMOS D/A converter to produce an analog voltage which is applied to a varactor diode and tunes in the station.

HAM GEAR SHORTAGES have been plaguing dealers for some time and are likely to get worse before they get better. The major cause of the problem is the CB explosion, since many manufacturers — particularly those in the Far East — supply both the Amateur and CB markets and it pays them to put their major effort in the market with the most money.

TYPE ACCEPTANCE OF AMATEUR GEAR is still a hot issue around the FCC. Don't be surprised to see a Notice of Proposed Rule Making come out of the Commission soon.

Continued Abuses By CBers using Amateur transceivers and manufacturers building "broadband" linears for the "Amateur Radio market" that just happen to deliver full output with only 4 watts drive (on ten meters, of course) have pretty well forced the FCC to act.



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#### Heavy duty 2-element 40-meter Beam

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TB-3HA	8 dB	20-22 dB	16' x 1.5"	28'-2"	16'	100 mph	110 lbs.	4 sq. ft.	44 lbs.
TB-2A	5 dB	16-18 dB	6.5' x 1.5"	27'-8"	14'-3"	80 mph	60 lbs.	1.8 sq. ft.	18 lbs.
MB-40H	4 dB	16-18 dB	15.75' x 1.5"	30'-4"	17'-6"	100 mph	80 lbs.	2.5 sq. ft.	40 lbs.

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## inductively-tuned six-meter kilowatt

Construction details  
for a high performance  
grounded-grid  
six-meter linear  
using 3-500Zs

At one time or another most serious six-meter operators have appreciated the value of having a high-power amplifier for extending their communications range — scatter, extended ground wave and aurora contacts are enhanced considerably by the proper use of an amplifier. I decided to build a two-kilowatt PEP linear amplifier around a pair of grounded-grid Eimac 3-500Zs because I have a Swan 250C which easily provides the 100 watt PEP input drive requirement. In addition, I have two other rf power amplifiers using 3-500Zs which have given me trouble-free service for

the past several years. A spare pair of tubes that were sitting on the shelf helped convince me to go in this direction.

After acquiring operating manuals from different manufacturers and going through the various amateur magazines, scanning articles and circuits which used 3-500Zs, I built the six-meter kilowatt described here.

The 3-500Z tubes are air-cooled power triodes designed for zero bias operation and are rated to 110 MHz. They are cathode driven with the grids at rf and dc ground. The tuned-cathode input circuit (fig. 1) provides good linearity and minimizes the drive requirements. The filaments are isolated from rf ground with the high-current bifilar rf choke, RFC1. The tuned plate circuit in this amplifier, however, is a bit unusual — the normal pi-network tuning capacitor has been replaced by an inductively-tuned or shorted-turn plate tank coil. Most circuit losses at 28 MHz and up are due to residual circuit capacitance and much of this undesired effect is due to the pi-network input tuning capacitor commonly used at lower frequencies.<sup>1</sup>

Donald Cook, K1DPP, 628 Rindge Road, Fitchburg, Massachusetts

In this circuit the pi-network input capacitance, C5, consists of stray circuit and tube capacitance.

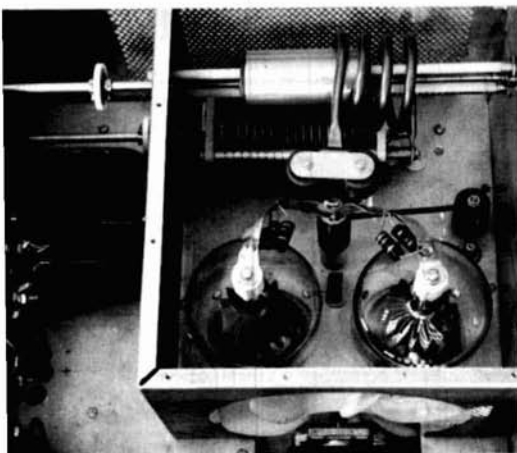
The control relay, K1, which switches the amplifier into the circuit and shorts out the 10k, 10 watt resistor, allowing normal plate and grid current to flow, is operated from a low current dc supply derived from a winding on the filament transformer. External interlocks (not shown here) make it impossible to apply plate voltage without first turning on the filaments and blower.

The two meters on the front panel of the amplifier shown in the photographs are used to read the grid and plate circuits. Since the meters I used had 100-milliampere movements, I used resistance shunts to provide a multiplier of five for the grid current meter (500 mA) and ten for the plate current meter (1 ampere).

## construction

The pi-network inductor is wound from ¼-inch (6.5mm) diameter copper tubing and the shorted turn is made from a section of 1½-inch (38mm) copper water pipe. This slug is moved in

**Plate compartment of the six-meter kilowatt showing construction of the pi-network inductor, parasitic chokes and RFC2. The neutralizing capacitor is located between the two tubes. The pi-network loading capacitor is positioned underneath the tunable inductor.**



and out of the inductor to tune the plate tank circuit to resonance. Construction details for this assembly are shown in fig. 2.\* Although I used a simple spinner knob on the inductor tuning screw, a turns-counting dial could be used to provide a logging reference for various operating frequencies.

The grid pins on the 3-500Z sockets are directly grounded to the chassis with ¼-inch (6.5mm) wide copper strap. One end of the strap is soldered to the socket pins and the other end is attached to the chassis with 6-32 (M-3.5) screws and nuts. Make sure that both contact surfaces are clean for low-resistance, trouble-free grounding. The homebrew filament choke consists of 12½ bifilar turns number-12 (2.1mm) Formvar on a ½-inch (13mm) diameter ferrite rod (suitable filament choke kits are available from Amidon Associates†).

The shunt-feed rf choke, RFC2, is connected directly across the plate tank circuit, so it must provide good isolation over the entire six-meter band. Hand winding, as described here, is highly recommended as no commercially available rf choke is apt to provide as good performance. The winding is most easily accomplished by feeding two number-20 (0.8mm) wires through one hole in the coil form and winding a bifilar coil of 30 turns, ending at the other hole in the form. Remove one of the bifilar windings and you will have a tight, evenly spaced winding that makes an excellent six-meter choke. The cold end of the rf choke is bypassed to ground with a 500 pF TV-type doorknob capacitor.

The 500-pF dc blocking capacitors, C3 and C4, are mounted between two

\*Major components for the shorted-turn inductor are available from Edward A. Stoltzfus, Engineering Machinist, Beacon Light Road, Parkesburg, Pennsylvania 19365.

†Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607. Filament choke kit is \$2.50, postpaid.



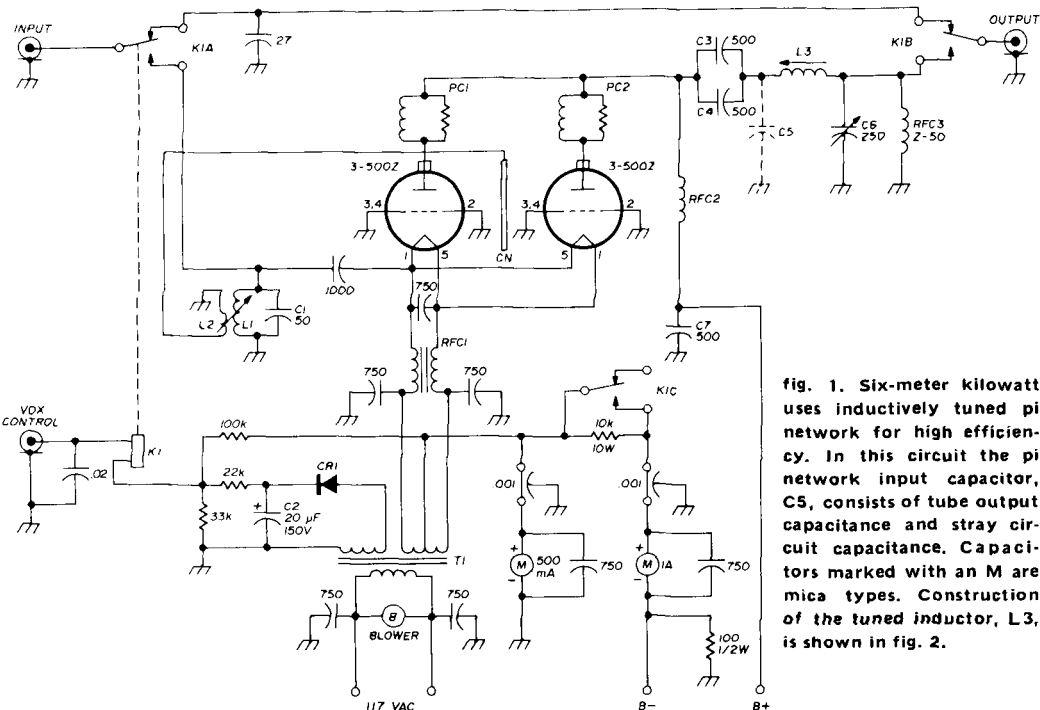


fig. 1. Six-meter kilowatt uses inductively tuned pi network for high efficiency. In this circuit the pi network input capacitor, C5, consists of tube output capacitance and stray circuit capacitance. Capacitors marked with an M are mica types. Construction of the tuned inductor, L3, is shown in fig. 2.

- |       |   |       |   |
|-------|---|-------|---|
| C1    | 50 pF compression mica trimmer (AR-CD 462). Adjust L1 for resonance with C1 compressed 90 percent     | L3    | 3½ turns ¼" (6.5mm) copper tubing, 3" (76mm) long, 2-1/8" (54mm) inside diameter. Tuning slug details are shown in fig. 2.  |
| C3,C4 | 500 pF, 5 kV doorknob capacitor (Centralab 858S)  | PC1,2 | Parasitic suppressors, Each consists of three 50 ohm, 2 watt resistors shunted across ½" (13mm) wide copper plate strap, install as close to the plate cap as possible (see photo)  |
| C5    | residual circuit and tube output capacitance  | RFC1  | 12½ turns no. 12 (2.1mm) Formvar, bifilar wound on ½" (13mm) diameter, 3½" (89mm) long ferrite rod (Amidon Associates filament choke kit)   |
| C6    | 250 pF air variable (E. F. Johnson 154-1)   | RFC2  | 30 turns no. 20 (0.8mm) enamelled wire, space wound on ¾" (19mm) round, 3-¾" (95mm) long ceramic or Teflon rod. Drill holes for wire ends ½" (13mm) and 2-¾" (70mm) from top or rod |
| C7    | 500 pF, 10 kV doorknob capacitor (TV type)  | T1    | dual secondary transformer. 5 Vac at 30 amps (filaments), 120 Vac (relay K1 dc supply)  |
| CN    | Neutralizing capacitor, copper strap ½" (13mm) wide by 3½" (89mm) long                                |       |   |
| CR1   | Silicon diode, 600 PIV, 1 A   |       |   |
| K1    | 110 Vdc relay, 3 pole, double throw (Potter & Brumfield KA14DG or Heath 69-55)                        |       |   |
| L1    | 3 turns no. 14 (1.6mm), airwound, ½" (13mm) diameter, 5/8" (16mm) long                                |       |   |
| L2    | 2 turns no. 18 (1.0mm) insulated wire, ½" (13mm) diameter, placed between turns of L1 (note polarity) |       |   |

brass plates, one of which is attached to the top of RFC2. The other plate is connected to the pi-network inductor L3 (see photo of the rf compartment).

The amplifier is built on a homemade

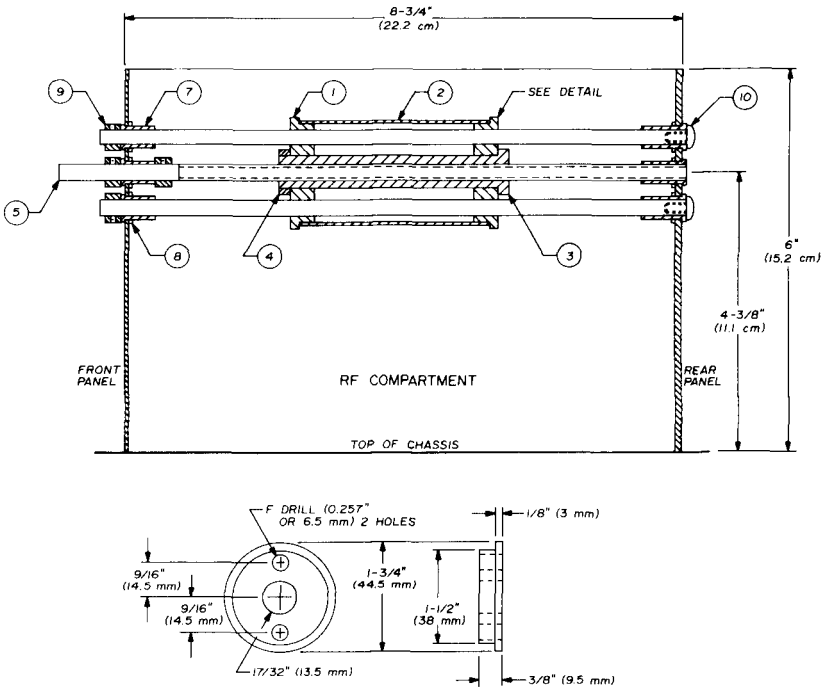
chassis made from 3/32-inch (2.5mm) thick aluminum sheet and is 1-¾ inch (4.5cm) high, 12 inches (30.5cm) wide and 13 inches (33cm) deep. The front and rear panels are 1/8-inch (3mm)

thick aluminum, 8 inches (20.5cm) high by 13 inches (33cm) wide. The inner right- and left-hand panels are 1/16-inch (1.5mm) thick aluminum, 7½ inches (19cm) high by 13 inches (33cm) long. These two panels can be made from perforated stock or solid sheets can be drilled to provide for ample air intake and exhaust to cool the plate and filament seals.

The rf compartment is 10 inches

(24.5cm) wide, 8-3/4 inches (22cm) deep and 6 inches (15cm) high. The top cover for this compartment is made from perforated aluminum sheet and should be installed at all times to protect the operator from the lethal voltages which are used to operate this equipment.

The bottom cover is 1/16-inch (1.5mm) thick aluminum, 13 inches



1. Insulating disc, 1-3/4" (44.5mm) diameter, 3/8" (9.5mm) long (2 required).
2. Tuning slug. 1-5/8" (41.5mm) OD, 1/16" (1.5mm) wall copper water pipe, 3" (76mm) long.
3. Tuning mechanism, make from brass rod, 1/2" (13mm) OD, 3-5/8" (92mm) long. Drill and tap for 1/4-20 (M7) thread for full length. Thread outside diameter 1/2-13 (M12) 1" (25mm) on both ends.
4. Brass nuts, 1/2-13 (M12), split into two pieces about 3/16" (5mm) long.
5. Lead screw. 1/4" (6.5mm) diameter brass rod, 9-7/8" (25cm) long, threaded 1/4-20 (M7) for 8" (21cm).
6. Guide rods. Plastic or fiberglass rods, 1/4" (6.5mm) diameter, 9 1/4" (23.5mm) long (2 required). Drill and tap one end 1/2" (13mm) deep for 6-32 (M3.5) machine screw.
7. Panel bushings for 1/4" (6.5mm) shaft (6 required).
8. Panel bushing nuts (6 required).
9. Shaft stops, for 1/4" (6.5mm) shafts (4 required).
10. Machine screws, 6-32 x 1/4" long (M3.5x6.5) (2 required).

fig. 2. Construction of the tuned pi-network inductor, L3. This arrangement requires a minimum of machine work and uses readily available materials.

(33cm) wide by 14 inches (35.5cm) deep with 1/2-inch (13mm) lips formed on two sides to provide a mating surface for the top cover. The U-shaped top cover is also made from perforated alu-

minum. The trim around the raw edges on the top and bottom covers is car door protective edging that is available from most department and automotive stores; it is very easy to work and cut

with simple hand tools. The vox connector and power plugs are all brought out on the rear panel along with the input and output coaxial connectors. Cooling air must be provided to

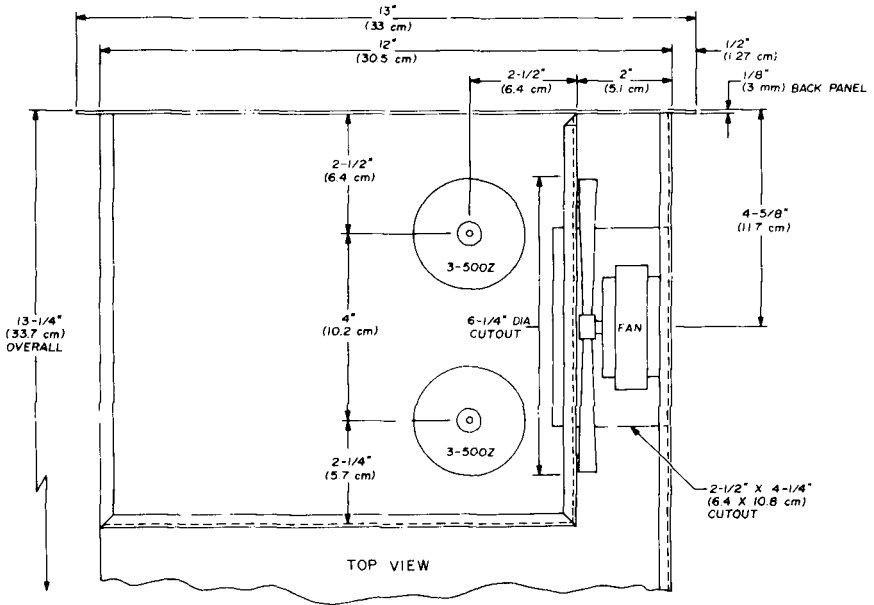
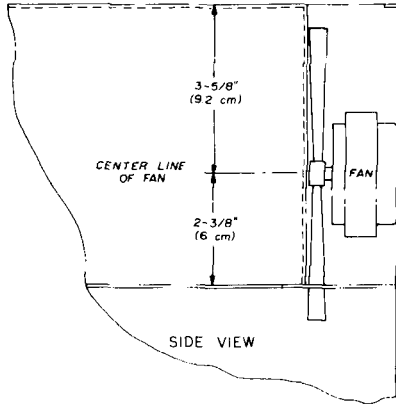


fig. 3. Air-system layout. The cooling air passes across the tube envelopes and the warm air exhausts out the side of the amplifier enclosure. Fan should provide 13 CFM at 0.2 inch (5mm) back pressure. Author used a 6" (15cm) diameter, six-bladed fan (Heath 266-259) and Heath 420-83 fan motor. Suitable substitute is a no. 3 impeller at 3100 rpm (Ripley 8472, Dayton 1C180 or Redmond AK-2H-01 Ax).



maintain the plate seals of the 3-500Zs below 225°C and the filament seals below 200°C. Many 3-500Z power amplifiers are designed around a system of air-system sockets and chimneys, along

minum. The trim around the raw edges on the top and bottom covers is car door protective edging that is available from most department and automotive stores; it is very easy to work and cut

with a centrifugal blower. The noise generated by the blower motor and air movement through the cooling system, however, is very distracting. Extensive tests by Eimac have shown that for CW

Eimac HR6). The Johnson 122-275-1 ceramic tube sockets are mounted off the chassis about 1/8 inch (3mm) to allow air flow around the base of the tubes to cool the filament pins.

**table 1. Typical operating data for the 3-500Z in rf linear amplifier service, class B (two tubes).**

Dc plate voltage	1500	2000	2500
Zero signal plate current (mA)	130	190	260
Single tone dc plate current (mA)	800	800	800
Single tone dc grid current (mA)	260	260	240
Two-tone dc plate current (mA)	520	540	560
Two-tone dc grid current (mA)	160	160	140
PEP useful output power (watts)	660	1000	1200
Intermodulation distortion products (dB)	-46	-38	-33

and ssb operation at legal amateur power limits the 3-500Zs may be adequately cooled by a lateral air blast blown against the tubes by a small, properly positioned rotary fan.<sup>2</sup>

The arrangement of the cooling fan in the six-meter kilowatt is shown in fig. 3. The fan is mounted in the rf compartment wall, between the tubes, in line with the center of the glass envelopes, and blows cooling air across the envelope and plate caps (use a good heat-dissipating plate connector such as the

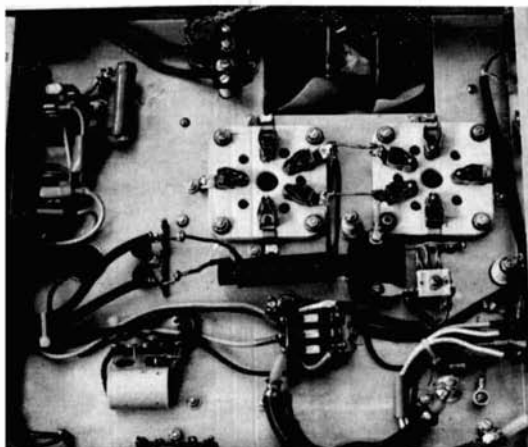
With this arrangement maximum plate dissipation of about 450 watts per tube is achieved for the 3-500Z. While this is about 10 percent short of the maximum rating, dissipation is sufficiently high that the pair of tubes will easily handle the maximum amateur power limit for CW or ssb operation under normal operating conditions. For continuous operation (RTTY or sstv, for example) the power input must be reduced to about 750 watts.

### neutralizing

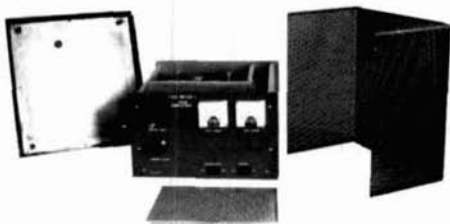
The neutralizing capacitor, CN, is formed from a 0.032-inch (0.8mm) thick copper strip, 1/2-inch (13mm) wide and 3½-inches (89mm) long into an L-shape with the foot of the L about 3/8-inch (10mm) long. The foot is drilled for mounting to the threaded stud of a small ceramic feedthrough bushing. The feedthrough bushing is centrally located between the two 3-500Zs and in line with the socket mounting holes toward the rf choke (see photograph). This capacitor is adjusted to lean in toward the center line of the tubes.

Inductor L2 is inserted between the turns of L1, the input circuit coil, and adjusted until the amplifier is neutralized (stabilization occurs when maximum grid current, maximum output

**Under-chassis view of the six-meter kilowatt showing placement of major components. The tuned cathode circuit is located at right center.**



and minimum plate current all are reached at one setting of the plate tank circuit). With the amplifier turned on but with no drive signal, grid current should be zero. I used an insulated rod to adjust L2 through a small hole in the bottom compartment. The neutralizing capacitor should be adjusted with the power turned off.



Two views of the power amplifier which show the various pieces of metalwork which were used in its construction.

## tune up

Before applying any voltages to the amplifier, carefully check all the wiring. Then install the two tubes and use a grid-dip oscillator to approximately set the tuned cathode circuit and pi network output circuit to the desired operating frequency. I used 50-ohm resistors across the input and output coaxial fittings during the grid-dipping operation and made sure that all relay contacts were closed.

After the amplifier has been cold tuned with the grid-dip meter, remove the 50-ohm resistors and connect the six-meter exciter to the input and a dummy load (or antenna) to the output. A monitor scope or relative power meter (an swr bridge works well) will provide a good output indication during initial testing of the amplifier.

First tune up the exciter for full normal CW output with the amplifier switched out of the line. Reduce exciter output, apply power to the amplifier and tune the amplifier for maximum output with reduced B+. Gradually in-

crease the excitation and high voltage to get the feel of a very smoothly tuning six-meter power amplifier.

For CW operation with a 2500-volt power supply tune the plate circuit and adjust the exciter drive for a plate current reading of about 400 mA (about 125 mA grid current). I am using a power supply with a tapped primary which I can switch from 2300 volts for CW and tuning, and then to 2800 volts for ssb operation.



I usually tune for maximum output with the lower voltage and then switch to the higher voltage for ssb. Apply ssb drive from the exciter and advance the microphone gain control for an average plate current reading of 350 mA. An occasional voice peak may boost this up to 600 mA. A monitor scope will show you more than any plate meter can be expected to, and should be used at all times when you are running high power. The manufacturer's operating data for the 3-500Z is published in most handbooks and should be consulted as a guide for proper use of these tubes in amateur service.

## references

1. William Orr, W6SAI, "Inductively-Tuned High-Frequency Tank Circuit," *ham radio*, July, 1970, page 6.
2. William Orr, W6SAI, *Radio Handbook*, 19th edition, Editors and Engineers, Indianapolis, 1972, page 22-35.

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# tunable RC notch filter

Discussion of an  
RC notch filter  
which can be tuned  
with a single  
variable resistor

Of the host of RC notch filters that have been devised, the twin-T (also called parallel-T) has enjoyed the greatest popularity by far. This is surprising because, in order to make this circuit adjustable or tunable, three components, either resistors or capacitors, must be varied simultaneously. To make matters worse, these three components don't all have the same value as shown in the basic circuit of fig. 1. One of the resistors is one-half the value of the other two, and one capacitor is twice the value of the others. Therefore, an adjustable twin-T notch filter requires a three-gang potentiometer, and the tracking and alignment problems can be troublesome if not expensive.

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There is another circuit, however, which has performance comparable to the twin-T, but which can be tuned over a wide frequency range by means of a single potentiometer. Although this circuit has been around for about 20 years, it has seldom appeared in the electronics literature and is not widely used.

To my knowledge, this tunable notch filter first appeared in print in 1955 when it was mentioned by Henry P. Hall of the General Radio Company in the September issue of *IRE Transactions on Circuit Theory*. He discussed it further in the July, 1961, issue of the *General Radio Experimenter*. That same year, General Radio brought out its Type 1232-A Tuned Amplifier and Null Detector; this instrument used Hall's tunable notch filter as a feedback element around an amplifier to produce a continuously tunable, narrow-band audio amplifier. General Radio still markets this instrument for about \$700.

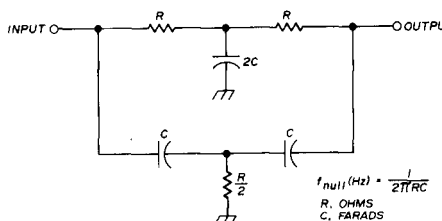


fig. 1. The twin-T notch filter is difficult to tune because three components must be varied simultaneously.



In the October, 1969, issue of *EEE Magazine*, Ralph Glasgal, in his article, "Tunable RC Null Networks," referred to the circuit as a "bridged differentiator." These articles are the only ones on this circuit of which I am aware. The following sections describe my own investigations.

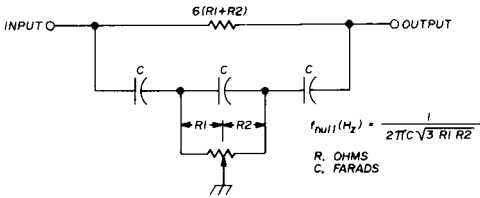


fig. 2. Basic circuit for a tunable RC notch filter which requires only one variable resistor.

### the circuit

Fig. 2 shows the basic configuration of Hall's tunable notch filter. The tuning pot is composed of R1 and R2, R1 being the resistance between one end of the pot and the wiper, and R2 the resistance between the other end of the pot and the wiper. The other resistor in the circuit must have a value equal to six times that of the pot. All three capacitors have the same value, which simpli-

fies things if you want to match them for best performance.

The null frequency equation in fig. 2 may be solved for different values of R1 and R2, and the results plotted to show how the notch frequency changes as the wiper is moved from one end of the pot to the other. Fig. 3 shows the result if the pot is assumed to be linear. When the wiper of the pot is at its mid-position (50 per cent of rotation) the notch frequency has its lowest value, and very little change in null frequency occurs in the middle section of the pot. As the wiper approaches either end of the pot, however, the null frequency begins to increase quite rapidly and would theoretically become infinite at the ends of the pot.

From the curve of fig. 3 it can be seen that, in a practical tuned notch filter, the tuning pot need only cover a relatively small percentage of the range shown. In other words, if the actual pot were used with fixed series resistors so that the pot covered only the range from 1 to 10 per cent, the relative frequency range would be from 10 to 3.3, or a 3 to 1 frequency range. Fig. 4 shows a schematic of how this would be implemented. Once the value of the pot has been selected, the values of the

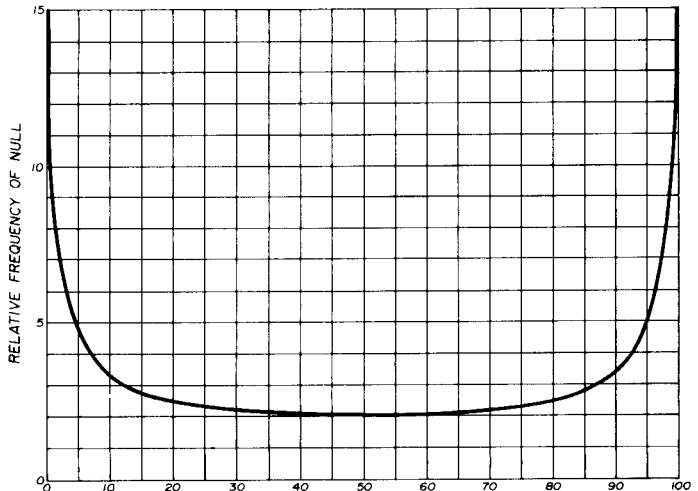


fig. 3. Relative notch frequency of the circuit shown in fig. 2 vs the rotational position of the potentiometer wiper.

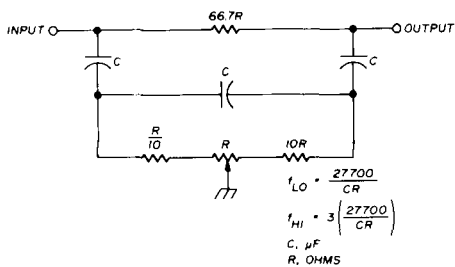


fig. 4. Relationship of resistance values for a 3:1 notch-filter tuning range.

three resistors may be calculated from the relationships shown.

It can be shown that the lowest notch frequency is given by

$$f_n = \frac{27700}{CR} \quad (1)$$

where  $f_n$  is in Hertz,  $C$  is in microfarads, and  $R$  is the resistance of the pot in ohms. The highest frequency to which the notch may be set is equal to three times the value given by eq. 1.

### practical examples

As a starting point, I had on hand a 20k pot and some 5 per cent, 2000 pF dipped-mica capacitors. These components would give a lowest notch frequency of

$$f_n = \frac{27700}{(0.002)(20 \times 10^3)} \approx 693 \text{ Hz}$$

The highest notch frequency should be three times this value or about 2079 Hz.

Using the resistor relationships of fig. 4, the circuit design was completed as

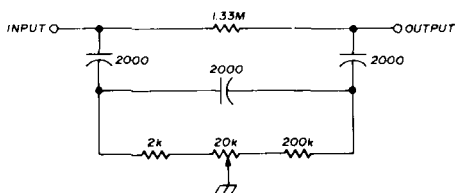


fig. 5. Notch filter which tunes from 693 to 2079 Hz. Performance of this circuit is plotted in fig. 6.

shown in fig. 5. It was necessary to connect resistors in series to arrive at some of the values shown, and the pot had a tolerance of at least  $\pm 10$  per cent. Fig. 6 shows the response of this filter with the tuning pot set at each end of its rotational range. Depth of the notch varies, but is greater than 50 dB in all cases; at 1160 Hz, the notch depth is 54 dB. Actual notch frequencies at the ends of the pot match the calculated values reasonably well, and the tuning range is slightly over 3 to 1.

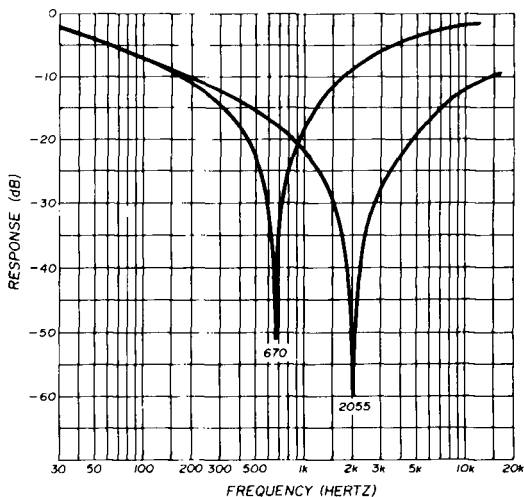


fig. 6. Frequency response of the notch filter of fig. 5 with the potentiometer set at each end.

The response curves of fig. 6 point out the value of tuning capability in notch filters. Because the notch is so sharp and narrow at the point of maximum attenuation, it is difficult to get the peak right on a particular frequency with a filter built with fixed-value components. With a tunable notch, however, it's a simple matter to set the notch right where you want it.

An example of a tunable notch filter for 60 Hz is shown in fig. 7. Such a filter can often be useful in high gain audio and sub-audio circuits to mini-

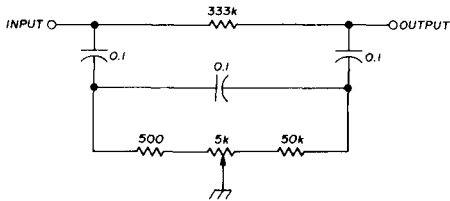


fig. 7. Tunable notch filter for 60 Hz can be used to minimize hum pickup from the ac line (circuit tunes from 40 to 120 Hz).

mize the effects of stray pickup from the ac power line. This circuit tunes from about 40 to 120 Hz.

In the examples above, the tuning ranges can be easily changed by multiplying or dividing the capacitor values by a factor. For example, doubling the capacitor values of fig. 5 would result in a tuning range of about 335 Hz to 1028 Hz, while cutting the capacitor values in half would give a tuning range of about 1340 to 4110 Hz.

### optimizing notch depth

Greatest notch depth will result when the ratios of component values approach the exact theoretical design values. In this regard, there are two requirements: the capacitors should all be exactly equal in value, and the large-value resistor connected from input to output should be exactly six times the resistance in the variable-resistance branch of the network.

Capacitors may be matched by measuring them on a capacitance bridge or a

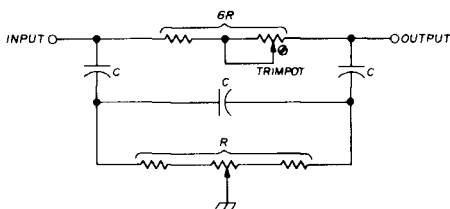


fig. 8. Notch depth may be optimized by using a trimpot to set the series resistance to exactly  $6R$ . Notch depth of the 60 Hz filter in fig. 7 was increased from 44.5 to 57 dB using this simple technique.

direct-reading capacitance meter and selecting those most nearly equal in value. An easy way to optimize the resistance ratio is to replace the resistor connected between the input and output with a trimpot and fixed resistor, or simply a trimpot, as shown in fig. 8; the trimpot can then be set for the deepest notch. Since changing this resistance also affects the notch frequency, it will be necessary to repeatedly adjust first the trimpot and then the tuning pot until the notch can no longer be improved.

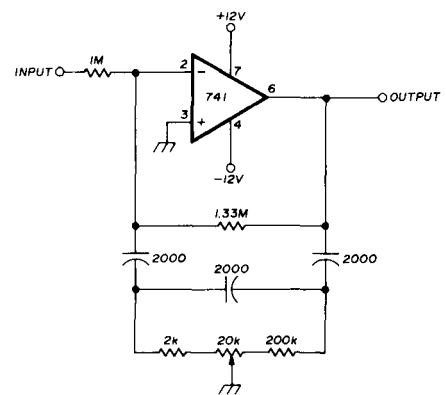


fig. 9. Tunable bandpass audio amplifier uses RC notch circuit as the feedback element. Tuning range of this circuit is 700 to 2000 Hz. Frequency response at 1000 Hz is plotted in fig. 10.

Once the trimpot has been set, however, it needs no further adjustment when the tuning pot is set to another frequency.

As an example of what this optimization can mean, the 60 Hz notch filter of fig. 7 was first built as shown with unmeasured ceramic disc capacitors and 5 per cent resistors; at 60 Hz it had a notch depth of 44.5 dB. By selecting capacitors with equal values and replacing the 333k resistor with a 500k trimpot, I was able, by careful adjustment, to increase the notch depth to 57 dB.

### tuned amplifier

The tuned notch filter can be used as

the feedback element with an op amp to produce a continuously tunable narrow-band audio amplifier. I used the circuit of fig. 5 in conjunction with a 741 op amp to build a tunable bandpass audio amplifier which will tune from about 700 to 2000 Hz. This circuit is shown in fig. 9. With the tuning pot set for a center frequency of 1000 Hz, the 3 dB band-

cause the bandwidth is quite narrow as it stands.

Although I used plus and minus 12-volt power supplies for the 741 op amp, two 9-volt batteries should work okay; battery drain should be about 1 mA or less with a 2000 ohm load.

I have found that trying to increase the tuning range of this amplifier by in-

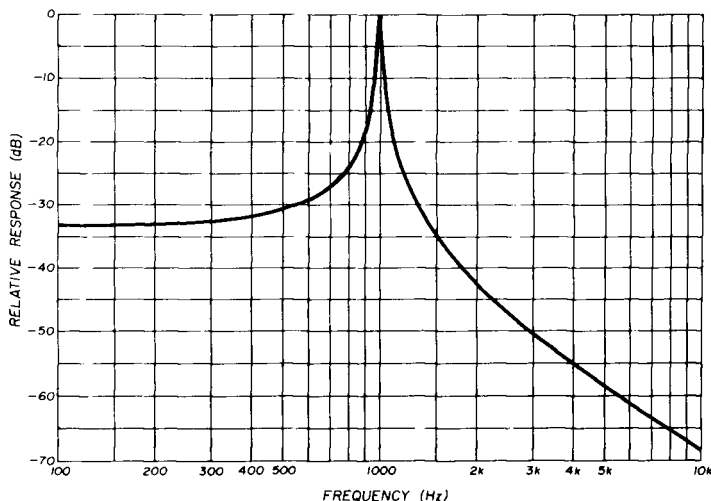


fig. 10. Frequency response of the tunable bandpass audio amplifier when tuned to 1000 Hz. Bandwidth at -3 dB points is 23 Hz; at -30 dB the bandwidth is approximately 773 Hz.

width is 23 Hz, the 6 dB bandwidth is 39 Hz, and the 10 dB bandwidth is 68 Hz. At 1000 Hz, the voltage gain of the circuit measured 36 dB.

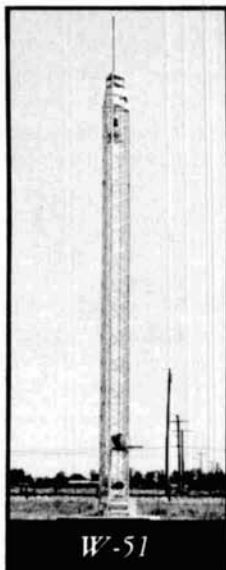
Fig. 10 shows the frequency response of this circuit when tuned to 1000 Hz. High-frequency rolloff is quite good, being about 43 dB down at 2000 Hz, so this circuit can convert a 1000 Hz square wave into a very nice sine wave. Low-frequency response flattens out, however, to a value determined by the ratio of the 1.33 megohm resistor to the 1 megohm input resistor. Some highpass filtering would improve the low-frequency skirt considerably, however. No attempt was made to optimize this notch circuit as described previously be-

creasing the value of the tuning pot and decreasing the value of the 200k resistor results in self-oscillation when the pot is set near its low frequency extremity.

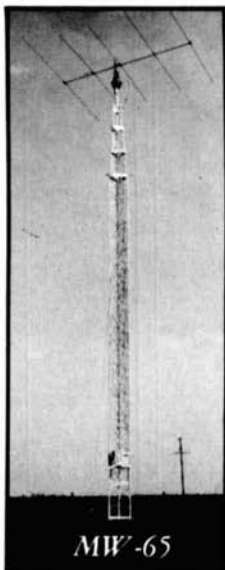
This article contains everything I know at the present time about this tunable notch filter circuit and its applications. I hope I have presented enough information for those interested to make good use of this valuable but little known circuit. All data was taken using a 600-ohm audio generator and an ac vtvm with an input resistance of 10 megohms. If readers have questions or can further enlighten me on these circuits, I would be pleased to hear from them.

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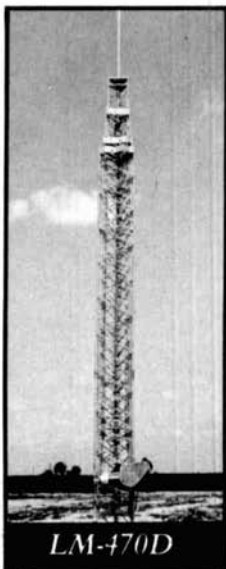
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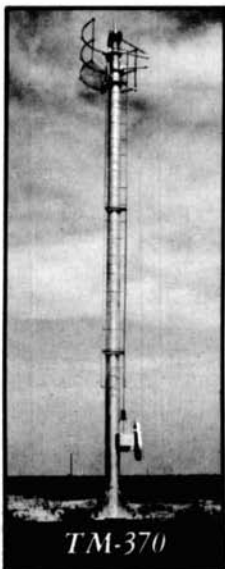
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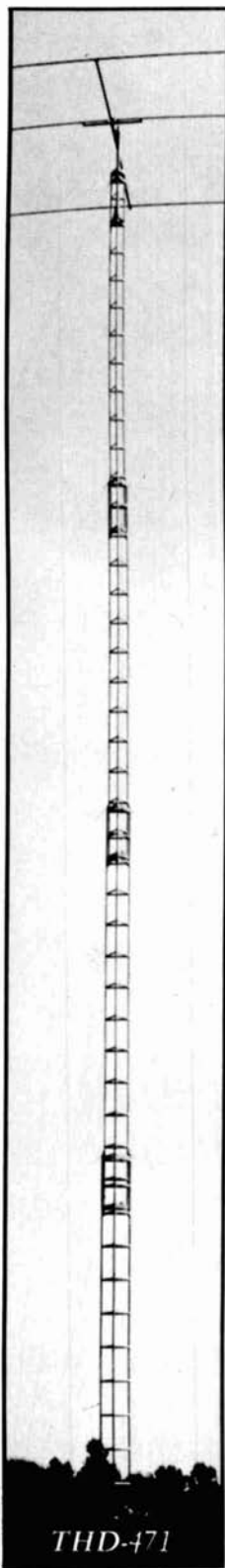
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# optimization of the phase-locked RTTY terminal unit

The original design concept of the phase-locked loop RTTY terminal unit included totally automatic and universal operation requiring a minimum of adjustment. The initial design would copy any afsk shift between 150 and 100 Hz, operate at data rates up to 110 baud, and automatically track a drifting signal.<sup>1</sup> Another publication described a modified autostart system that incorporated an anti-CW feature.<sup>2</sup>

Since the original article was published there have been two distinct developments in amateur RTTY operation:

1. Wide shift (850 Hz) has almost completely disappeared from the high-frequency amateur bands with the exception of some operation on 80 meters (and, of course, wide shift is still the rule on two-meter fm).

2. The continued use of 60 wpm for 95 per cent of amateur RTTY operation, even with the availability of 75- and 100-wpm speeds.

This latter development is undoubtedly because of the vast amount of 60-wpm teleprinter machines available and the fact that most RTTY operators can't type more than 60 wpm.

With these two developments in mind, and in response to requests from readers, I've attempted to optimize the detector circuit to decrease the required minimum input-signal-to-noise ratio of 6 dB (for 99 per cent correct copy). In

consideration of users having commercially made printed-circuit boards,<sup>3</sup> one constraint was placed on the modifications: no printed-circuit changes would be necessary — only parts substitutions, deletions, and parts value modifications would be used.

## modifications

For the phase-locked loop detector (fig. 1) changes are shown circled. In the original loop, the lowpass filter capacitor, C7, was selected to give a loop bandwidth of approximately 400 Hz. This value was selected in compliance with Shannon's rule for operation at the highest data rate of 110 baud:  $110 \text{ baud} \div 2 = 55 \text{ Hz signaling rate}$ ;  $55 \text{ Hz} \times 7 = 385 \text{ Hz}$ , or the required minimum loop bandwidth. But for 45-baud (60 wpm, 5 level), a 22.5-Hz signaling rate results, thus requiring a loop bandwidth of only 157.5 Hz. A 180-Hz loop bandwidth was used because 0.22  $\mu\text{F}$  was the nearest standard value capacitor to the design value for C7. To complement the preceding change, the phase-locked loop output RC ladder filter cutoff frequency was also lowered by increasing the value of C8, C9, C10 and C11 from 0.01 to 0.022  $\mu\text{F}$ .

The ssb position of the mode switch, S1, is now used for 170-Hz shift, and the vco frequency-set pot, R5, is adjusted for a natural vco frequency of 2210 Hz at TP-2 with no audio input applied to the TU. This new frequency setting allows the vco to swing symme-

P. Edward Webb, W4FOM, Digicom, 22 Hartshorn Avenue, Worcester, Massachusetts 01602

trically to either side of its natural frequency, thus reducing the probability of the loop unlocking on noise.

The *normal* position of the mode switch, S1, is used for 850-Hz shift and its pot, R6, is adjusted for a natural vco frequency of 2550 Hz at TP-2, as in the original article. Other shifts, such as 425 or 85 Hz, can be copied simply by adjusting the receiver frequency so that the shift is centered on the appropriate vco natural frequency.

In the tracking comparator, an RC network consisting of R11 and C12 is

C12 has been changed to a 0.33  $\mu\text{F}$  mylar, and R11 has been changed to 1 megohm to maintain the same time constant. To take advantage of the higher impedance presented by this RC network, U2 has been changed from a N5741T to a NE536T, an fet input op amp. The minimum detectable shift was measured at 40 Hz with an input-signal-to-noise ratio of 10 dB and a noise bandwidth of 3 kHz.

The tracking comparator output low-pass filter cutoff frequency has been decreased to 30 Hz to optimize the

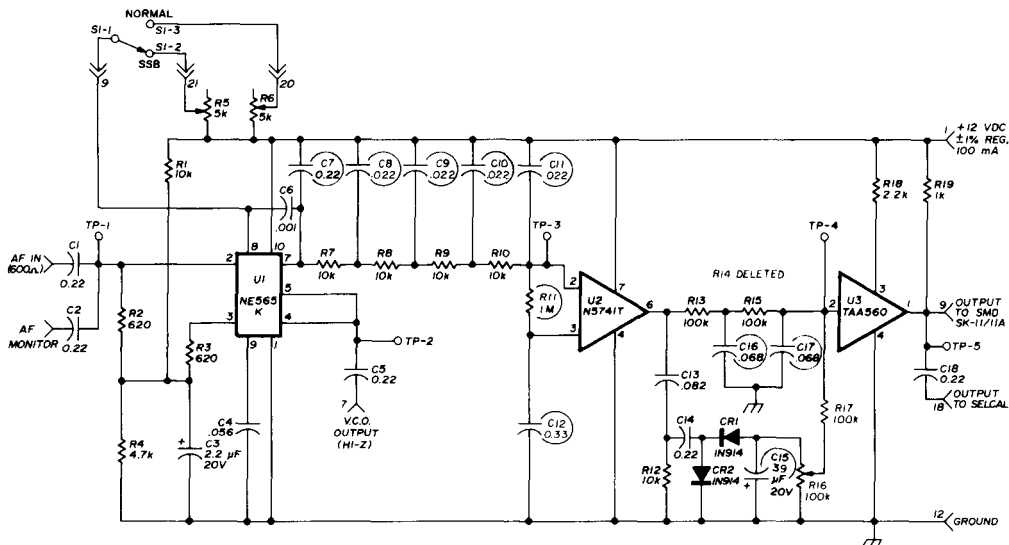


fig. 1. Circuit modifications to the phase-locked loop RTTY terminal unit for improved performance. New circuit values are circled. All resistors are 5%, 1/2 watt unless otherwise specified.

used to produce a signal-derived reference voltage for the noninverting input of U2. The RC time constant was selected to be 2.5 times that of the longest *space* condition at 60 wpm, which is the *blank* key having a *space* duration of 132 milliseconds. Accordingly R11 and C12 were selected to give a time constant of 330 milliseconds. However, the leakage path through electrolytic capacitor C12 limited the minimum detectable shift to approximately 150 Hz. Thus

section for the 22.5-Hz signaling rate used with 60 wpm, 5-level RTTY. To accomplish this frequency change, capacitors C16 and C17 were increased from 0.033 to 0.068  $\mu\text{F}$ . Also affected was resistor R14, which was deleted to produce a higher voltage to the input to the Schmitt trigger, U3, so that its operation on marginal signals would be improved. The noise rectifier in the noise squelch circuit was changed. The output filter capacitor, C15, was in-



creased from 10 to 39  $\mu\text{F}$  to provide a longer time constant, which reduced the effects of static crashes.

### experimental procedure

The phase-locked loop<sup>2</sup> TU was connected to a test setup (fig. 2). A Wavetek model 134 function generator was used to generate a 22.5-Hz square wave to simulate a 60-wpm, 5-level RTTY signal. This signal was fed through an

10, 1610, and 1960 Hz was imposed by the use of a Krohn-Hite dual electronic variable filter with both sections connected in series for highpass operation. These instrumentation methods gave simulated receiver bandpasses of 3000, 1200 and 500 Hz respectively.

All tests were started at a 10 dB s/n ratio, which was then reduced until the output of the Schmitt trigger (fig. 3, Channel 4) exhibited excessive jitter or

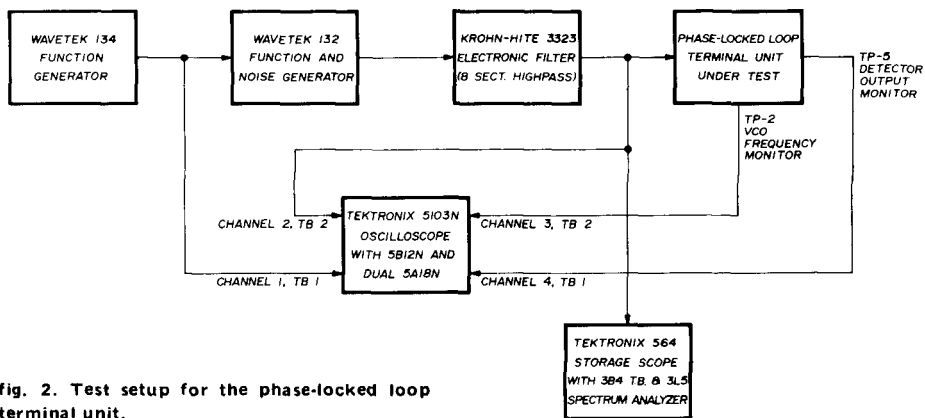


fig. 2. Test setup for the phase-locked loop terminal unit.

attenuator to the voltage-controlled generator input of a Wavetek model 132 function and noise generator. This latter instrument could simultaneously generate both a signal as well as random noise in a front-panel controlled, calibrated ratio. In these tests the signal used was an afsk sine wave shifted 170 Hz between 2125 and 2295 Hz, and a random noise sequence of  $2^{20} - 1$  was used at a maximum noise clock frequency of 48 kHz, thus ensuring that a random noise sequence could not repeat in a time period of less than 21.85 seconds.

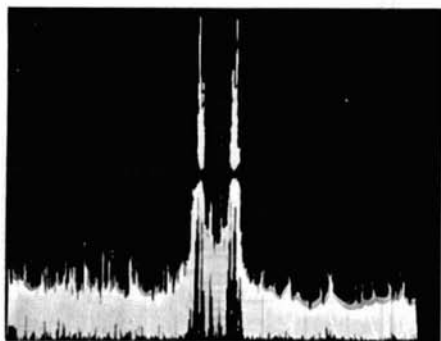
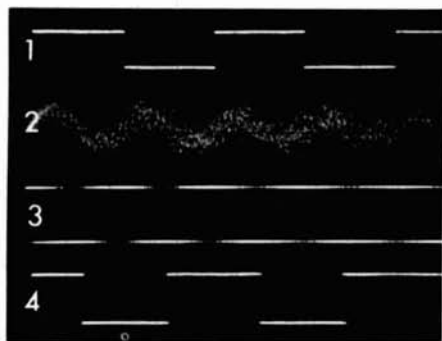
Noise clock frequencies of 48, 45 and 39.3 kHz were used to produce upper noise bandwidths of 3, 2.81, and 2.46 kHz so that the signal-plus-noise bandwidth was always centered on 2210 Hz, which is the shift midpoint and the natural frequency of the phase-locked loop<sup>2</sup> vco. A lower bandwidth limit of

failed to follow the afsk keying signal (fig. 3, Channel 1). This s/n ratio was considered to be the minimum usable input signal for a given simulated receiver bandpass. The test results were: 0 dB minimum s/n for a simulated receiver bandpass of 3 and 1.2 kHz. For 500 Hz, it was -3 dB.

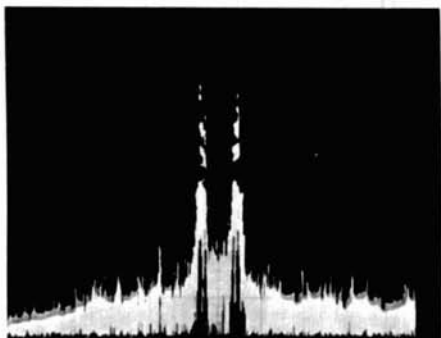
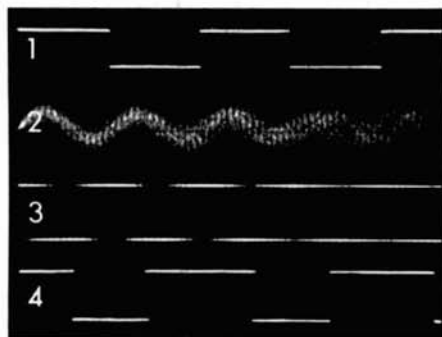
### conclusion

Figs. 3A, 3B and 3C illustrate the input and output waveforms for the test setup and TU with input s/n ratios of zero and -3 dB and simulated receiver bandpasses of 3, 1.2, and 0.5 kHz. These figures represent a 6-dB improvement for the worst case and a 9-dB improvement for the best case over the original design.

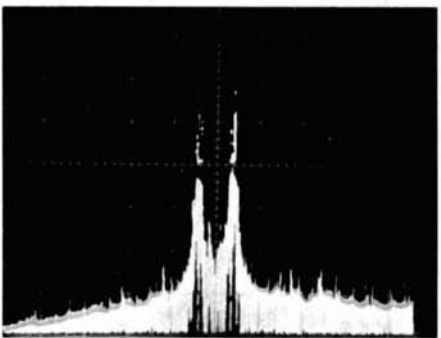
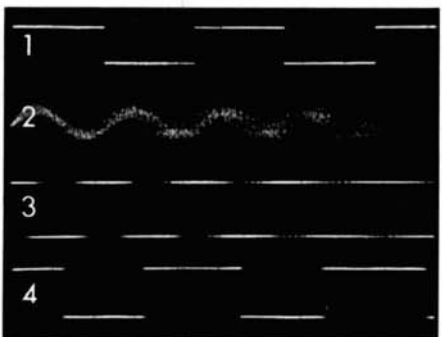
Comments, contribution of ideas, and criticism are welcome from users of phase-locked loop terminal units.



A. 3-kHz noise bandwidth; signal-to-noise ratio, 0 dB.



B. 1.2-kHz noise bandwidth; signal-to-noise ratio, 0 dB.



C. 500-Hz noise bandwidth; signal-to-noise ratio, -3 dB.

Center frequency, 2200 Hz; dispersion, 200 Hz/cm; sweep speed, 5 sec/cm; vertical sensitivity, 200 mV/cm.

fig. 3. Input and output waveforms from test setup show improvements of 6 and 9 dB over original design for worst- and best-case conditions.

Channel 1: afsk keying voltage; horizontal, 10 ms/cm; vertical, 50 mV/cm.

Channel 2: signal + noise at 3 kHz bandwidth; horizontal, 0.2 ms/cm; vertical, 100 mV/cm.

Channel 3: PLL vco at TP-2; horizontal, 0.2 ms/cm; vertical, 10 V/cm.

Channel 4: Schmitt trigger output; horizontal, 10 ms/cm; vertical, 10 V/cm.

## acknowledgement

I'd like to express my gratitude to the Wavetek Corporation for making a Model 132 VCG/noise generator available for this and other research work in the biomedical field. The work reported here was greatly simplified by the use of this instrument.

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1. P. Edward Webb, W4FQM, "A Phase-Locked Loop RTTY Terminal Unit," *ham radio*, January, 1972, page 8.
2. P. Edward Webb, W4FQM, "An Anti-CW Autostart System For the PLL TU," *73*, May, 1972, page 39.
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ham radio

## toroidal coil inductance

Toroidal inductors are being used more and more in amateur communications equipment because of their small size, high Q and self shielding properties. Michael Gordon's article\* makes it relatively easy to determine the number of turns to wind a coil on a particular core. He includes numerous core constants and a helpful equation necessary to achieve a specific inductance. Fig. 1 contains much of that information in graphical form and was developed for builders who tend to shy away from using mathematical formulas. To determine the required number of turns on a particular toroid core, simply locate the

desired inductance, L, on the vertical axis, draw a horizontal line through L to where it intersects the appropriate core line, and read off the number of turns, N, on the horizontal axis, beneath the intersection point.

The graph of fig. 1 can be expanded to include more core types and a greater number of turns if desired. Fortunately, Gordon's expression  $N = K\sqrt{L}$  plots as a straight line on log-log graph paper; therefore, by using paper with more cycles, a more complete nomograph can be obtained. I constructed the original graph by rearranging the above formula into the form  $L = N^2/K^2$ , where K is one of the core constants, and then solved the equation for L when N is 20 and 100. This gives two points which can be connected by a straight line.

The dashed line shows actual measured values for an Amidon T50-2 core. Four test coils were wound using number-26 (0.4mm) enamel covered wire. A commercial Q meter was used to measure Q, and the inductance was calculated from the resonant frequency formula. The small discrepancy noted between the measured and calculated inductance values could have been due to connecting lead length and Q-meter accuracy.

Charles Miller, W3WLX

\*Michael Gordon, WB9FHC, "Calculating the Inductance of Toroids," *ham radio*, February, 1972, page 50.

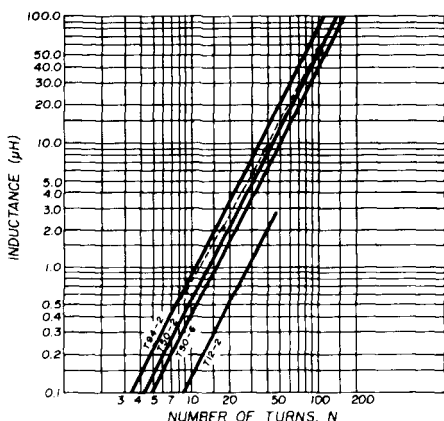


fig. 1. Inductance vs number of turns for four popular Amidon toroidal cores. Dotted line shows actual measured inductance values for a T50-2 core; discrepancy from calculated values is small.

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# single sideband speech splatter

An informative  
discussion of  
nonlinear ssb operation  
and what to do  
about it

If you've listened on the low-frequency end of the 20-meter phone band when two or three rare DX stations are coming through, you've probably noticed a steady, noise-like signal between the DX stations. Under good conditions the noise may be S2 or S3; more likely it's S9 or more. This steady noise seems to come from no particular station; in fact

it seems to emanate from all stations of the band. The noise is caused by splatter.

When only one station is causing splatter, it's a good bet the operator will be told his transmitter is at fault. Sometimes this brings an apology and an immediate resolution; often it brings a protestation of innocence based on the equipment in use: "My so-and-so off-the-shelf rig has super automatic level control; it can't be me." A cop-out response? Perhaps not. The fellow in question may not understand the causes and cure of splatter.

This article presents some hints on the causes, cure, and source of splatter interference and what can be done about it to help alleviate the noise problem in the congested amateur phone bands.

## source of splatter

Splatter comes from a single source; in fact a rather simple one. There is a relationship between the way a signal changes and the bandwidth it occupies. The relationship is easily described mathematically, but this does not lead to a good understanding of the process. For this discussion let's look at some

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special types of signals and use these as analogies.

A simple example of a signal with a high rate of change is a pulse of width  $\Delta t$ , corresponding to a dot of a CW signal or to an ideal radar pulse. With respect to time, the signal is off for a long period, then on at constant strength for a period  $\Delta t$ , then off again for a long period. With respect to frequency, the relative strength of this signal varies with frequency; its spectrum is shown in fig. 1. Most of the signal energy is contained in the bandwidth defined by  $f = 1/\Delta t$ .

For example, suppose the pulse represents a dot with a width of 50 milliseconds and a dot speed of 24 words per minute. Most of the energy will be contained within a band 20-Hz wide. If the pulse is from a radar, having a width of 0.2 microsecond, most of the signal energy will be contained within a band 5-MHz wide. On a relative basis, the shape of these two signals is the same.

Both of these signals have additional peaks extending outward from this central band, as shown in fig. 1. These additional components are the source of key clicks on CW signals and the typical buzz of a radar signal when a receiver is tuned well away from center frequency.

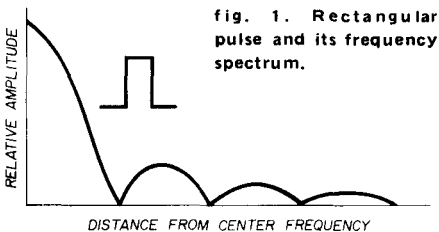


fig. 1. Rectangular pulse and its frequency spectrum.

The components extend far from the center frequency.

For a perfectly rectangular pulse, the magnitude of the components is defined by the relationship  $(\sin X)/X$ . This relationship is called the aperture function and is the envelope of the spectrum

amplitude for a single square pulse. The  $X$ , in this case, is  $\pi T_0 f$ , where  $T_0$  is the pulse duration (seconds) and  $f$  is the frequency (Hz) at which it is desired to know how much signal amplitude exists. If the pulse duration is 0.1 second and you want to know how much splatter

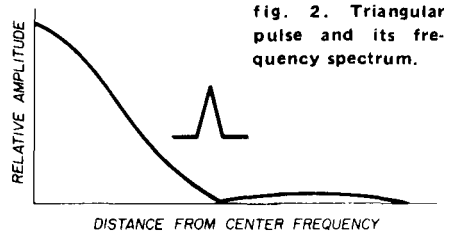


fig. 2. Triangular pulse and its frequency spectrum.

exists at, say, 100 Hz from center frequency, then

$$\pi(0.1)(100) = 10\pi$$

and

$$\frac{\sin 10\pi}{10\pi} = 0$$

There is no splatter at all at exactly 100 Hz from center frequency. However, if you ask about splatter 5 Hz from center frequency,

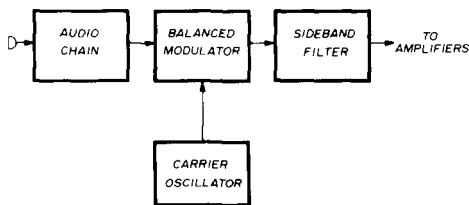
$$\pi(0.1)(5) = 0.5\pi$$

and  $(\sin \pi/2)/\pi/2 = 1/\pi/2 = 2/\pi = 0.636$ , or about two-thirds the signal you'd hear exactly on frequency.

The influence of this idealized signal extends over the entire band, from dc to infinitely high frequencies. The change in signal strength with frequency is slow. For example, if the maxima have a strength of 100 mV at 10 kHz from the center of the CW signal, they will have a strength of 50 mV at 20 kHz from the signal, 25 mV at 40 kHz, etc.

For a given pulse width and amplitude, the only way we can change the signal spectrum is to change the rate of change of the signal or rise time. This affects the strength of components far

from the center frequency of the signal without changing the main part of the signal very much. For example, suppose the pulse were changed from a perfect rectangle to the triangle of **fig. 2**. The energy distribution is now described by the relationship  $[(\sin X)/X]^2$ , but the



**fig. 3.** Block diagram of the basic filter-type ssb transmitter.

peak amplitudes far from center frequency decrease twice as fast as before. If the maxima are 100 mV at 10 Hz from center frequency, they will be 25 mV at 20 kHz; 6.25 mV at 40 kHz, etc. The energy very close to the center frequency is identical for the triangle and the rectangle. Other wave shapes can show greater reduction of the "far-out" components.<sup>1</sup>

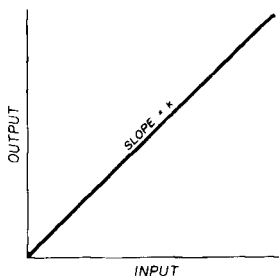
This modification of wave shape and its effect on far-from-center frequency components is the principle of the key click filters used in CW. Note that the shaping can't stop key clicks — all it can do is reduce their strength and, in particular, reduce the strength of the components relatively far from the signal. For the 20-wpm signal, clicks beyond a few hundred Hz can be brought to the noise level or below.

The important point of this discussion is that any signal that goes on and off will spread across a band of frequencies. How far it spreads and how much energy occurs at each frequency is determined by the interval between on and off, the rate of change of the signal during the on period, and the maximum amplitude the signal reaches.

## ssb signal generation

Now let's apply these principles to ssb phone signals. We'll ignore some "fine structure," such as the effect of turning the transmitter on at the beginning and off at the end of a transmission. What we want to look at is how a signal supposedly contained within the speech bandwidth can appear many kHz from this nominal band: in other words, we want to know where splatter comes from. To do this let's look at how the signal is formed and processed.

**Fig. 3** shows, in block diagram form, an elementary single-sideband transmitter. Audio and carrier are processed by the modulator to produce a double sideband suppressed-carrier signal. The modulator also produces distortion products at twice the frequency of the carrier, three times its frequency, etc. However, all of the signal outside the passband of the filter is rejected; therefore, only speech products lying between about 300 and 2400 Hz, plus the small amount of distortion that lies within this range, are passed on to the following amplifiers. At the output of



**fig. 4.** Ideal amplifier has linear relationship between input and output.

the filter the signal is free of widespread spurious components: it is splatter-free.

This nearly ideal signal is then amplified and finally transmitted. If the amplifiers are linear, no energy will exist outside the passband. That is, the amplifier output signals must bear a direct relation-



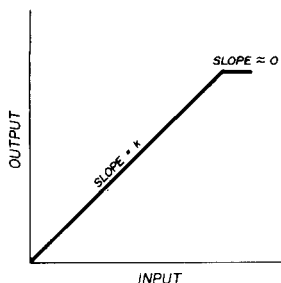
ship to the input signals. Each amplifier must follow the law

$$e_{out} = k(e_{in})$$

The transfer function of the amplifier must look like **fig. 4**. Unfortunately, most amplifiers don't attain this ideal relationship and this is where the trouble comes from. In looking at this, let's again remember we're not interested in "fine structure;" that is, distortion close to the transmitted signal or regeneration of the rejected sideband, or things of that kind.<sup>2</sup> We want to know the *source* of splatter.

### splatter due to flat-topping

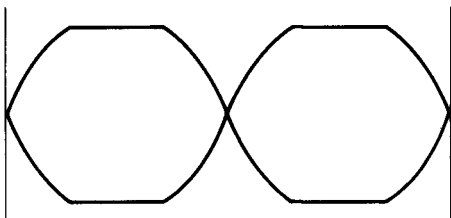
One characteristic of practical amplifiers is that they saturate. The output reaches some maximum level then doesn't increase further. Instead of being linear they have the relationship shown in **fig. 5**. The effect on a typical signal is shown in **fig. 6**; it becomes amplitude-limited and is usually called flat-topped. The effect of flat-topping is the same as if the transmitter were putting out an ideal signal plus a



**fig. 5.** Input-output relationship of an amplifier which saturates.

negative-going pulse that cancels the top of the signal (**fig. 7**). The transmitter is now transmitting its intended signal and is also transmitting a radar-like pulse. Flat-topping generates splatter. Since speech waveforms last for relatively

short periods, and since only the tip of the wave is cut off, the radar-like pulse formed by peak clipping has a very short duration. Therefore, it spreads a long way from the desired signal and repeats at each voice peak, generating the sound amateurs call "buckshot".



**fig. 6.** Ssb two-tone test with saturation.

Note that the signal close to the center frequency is perfectly good. Don't ask the station you are working if you are splattering; he can't tell since he hears a perfectly good signal. It's the station well removed from the center frequency who hears the splatter.

### splatter due to bias-off

Another characteristic of practical amplifiers is the tendency to ignore small signals. For a small input they show no output for a time. The transfer function tends to look as in **fig. 8**, which causes the bottom end of the signal to be clipped. Again, this is equal to a normal signal plus a distortion term. In audio amplifiers, where push-pull operation is common, this clipping is called crossover distortion. It also exists in single-ended amplifiers and is the result of improper bias adjustment — the bias is set too high — often in an attempt to reduce the tube idling current.

This form of distortion is less likely to cause trouble than that from positive peaks, since only a small part of the signal is affected. However, evidence indicates that the importance of this form of distortion has recently in-

creased as power companies lower line voltage or allow poorer line voltage regulation. These acts reduce the plate voltage (unregulated) but usually don't affect the bias voltage, since it is regulated. Effectively, the reduced line voltage increases the bias on the tube and therefore increases this type of distortion.

### splatter due to parasitics

Another characteristic of practical amplifiers is a tendency to oscillate, often at a frequency far from that at which they are designed to work. Sometimes this parasitic oscillation starts at a specific plate voltage and dies out when the voltage increases beyond this level or when it decreases below this level again. The effect on the input-output relationship can be as in fig. 9. Either of these oscillations will create splatter as the parasitic turns itself on and off. Very similar effects can appear if the

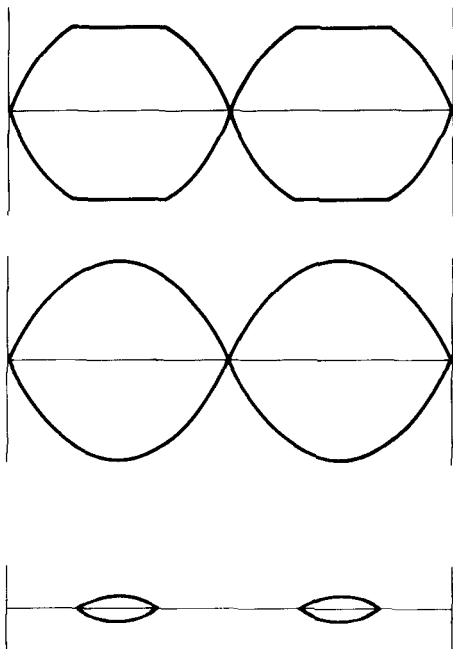


fig. 7. Flat-topping as the sum of an ideal signal plus pulses.

amplifier is merely unstable instead of oscillatory. This action causes the amplifier output to increase beyond its normal value, then level off, or perhaps even drop back to normal.

Problems of these types are very common when amplifiers are first tuned

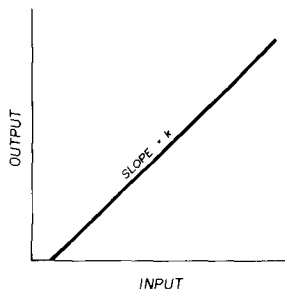


fig. 8. Input-output relationship of an amplifier with crossover distortion.

up. They may arise again because of components that become defective or change values: more commonly, they arise when an amplifier isn't adjusted properly or if it's operated with voltages appreciably different than those for which it was adjusted. It's likely that the really bad cases of splatter are due to such parasitic oscillations or instability.

### splatter due to level control

Let's go back to the flat-topping situation, which is the most common problem. A number of automatic means of preventing flat-topping have been developed. Most work by detecting a particular level of signal at the final amplifier and feeding the signal back to an earlier amplifier to reduce the gain. This scheme is called automatic level control, ALC, or overdrive detection. The intent of these systems is to reduce the value of  $k$  in the linear input-output relationship,  $e_{out} = k(e_{in})$ , to the point where linear operation is maintained — by keeping all peaks below the overload point.

Unfortunately there can be some problems with these automatic circuits. It takes a finite time for the overload signal to be detected, fed back, and for it to reduce the gain of the earlier stage. This time delay can also introduce a problem, as shown in **fig. 10**. The relatively sudden decrease from the initial value of  $k$  to a second value is just as effective in producing splatter as any other change of equal rate and magnitude. An associated splatter source may be the click of the vox relay pulling in: it's gone before the ALC circuits can act, but it can still produce splatter.

Some transmitters incorporate circuits to prevent these sudden changes from occurring. There may be several gain-controlled stages, or several control sources, with different time constants. These complex circuits definitely help prevent the rapid changes shown in **fig. 10**; however, even they can't cope with the results of a wide-open gain control. The transmitter struggles zealously but just can't prevent splatter from occurring.

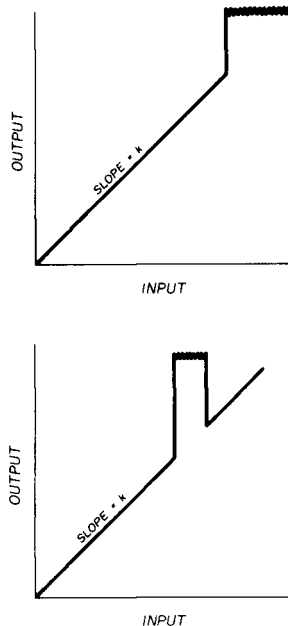
### splatter due to the receiver

To be complete, we should note that receivers also include some linear stages, and can have almost identical problems. Problems arise if these stages are overloaded, unstable, or if the automatic gain control circuit time constants don't match the rate of change of a particular signal being received. Splatter reports can be generated in the receiver, so that a false report is perfectly possible. If you're told you're splattering, it's in order to ask about the precautions against receiver overload, assuming your transmitter is operating linearly.

### detecting your own splatter

Many stations are equipped with an oscilloscope or monitor. This is by far the best way to operate, but it's necessary to be cautious. A scope won't show all splatter problems. Example: suppose

two transmitters are operating. One is an ssb transmitter with two-tone modulation. The second is an a-m transmitter 100 percent modulated by the unfiltered output of a full-wave rectifier. As seen on a monitor scope, what is the difference between these two signals?



**fig. 9.** Input-output relationships of an amplifier with parasitic oscillations.

The answer is that, to casual inspection, there is absolutely no difference. Both look like the ideal signal of **fig. 7**. Even detailed inspection of the envelope will not show any difference. The only way a scope can detect the difference is to look at the rf waveform. When this is done, a phase reversal will be found at each zero crossing of the envelope for the two-tone test: the rf wave of the a-m signal doesn't show this reversal. This very small difference won't show up on any of the usual types of signal monitor; yet the difference as seen by outside receivers is enormous. The two-tone ssb signal is clean while the recti-

fier-output modulated a-m signal spreads to many, many times the frequency of the modulating sine wave.

Fortunately this situation is artificial but it does show that casual observation of the scope is not enough; some attention to detail is necessary. The first

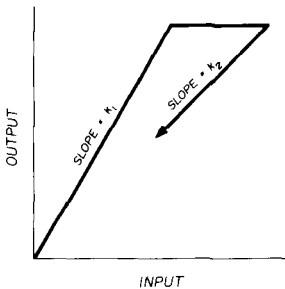


fig. 10. Input-output relationship of an amplifier with poor automatic leveling control.

point to watch for is flat-topping, usually the only item observed. Sharp peaks of the voice signal are a good indication that splatter is not occurring from flat-topping. However, splatter due to parasitics or to instability can cause a pattern that resembles, very closely, the sharp peaks of a voice pattern. It takes careful examination of the signal, and, in particular, examination of the *rate of rise* around the midpoints of the signal, to detect splatter-producing parasitics. The type of splatter that arises from sharp changes at the lower signal levels is also detectable on the scope, but also only by careful observation. The rule should be, inspect the *entire* signal, not just peaks.

Many operators with stations using transmitters incorporating automatic level control (ALC) eliminate the scope and place their dependence on the automatic circuits. As long as the circuits are working properly and the transmitter is adjusted properly, this is satisfactory. The circuits do work if given half a chance; however, the practice of turning

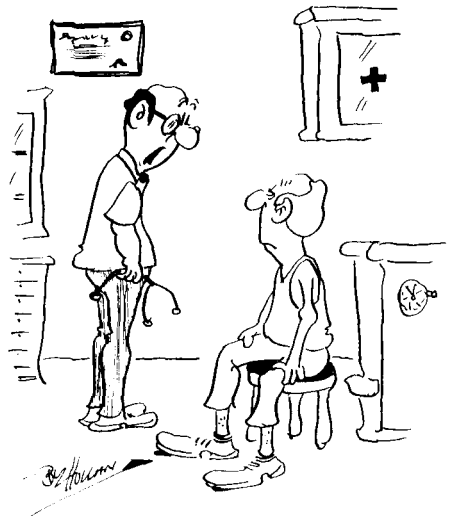
the gain fully open is responsible for much splatter. The gain control should be set to give ALC action as recommended by the instruction book.

Stations using transmitters without ALC and no scope have a special problem. It's almost impossible to detect splatter generation by reading the meters on the transmitter. About the only automatic way of preventing splatter is to choose an exciter that can't override the amplifier. In most cases, this means limiting the exciter power to about one-tenth to one-twentieth the power of the final amplifier. If the final is to run 1000 watts input, the exciter should run no more than 50-100 watts input.

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1. *Reference Data for Radio Engineers*, Fifth Edition, "Fourier Waveform Analysis," page 42-1.
2. Marv Gonsior, W6VFR, "Intermodulation Distortion Measurements on SSB Transmitters," *ham radio*, September, 1974, page 34.

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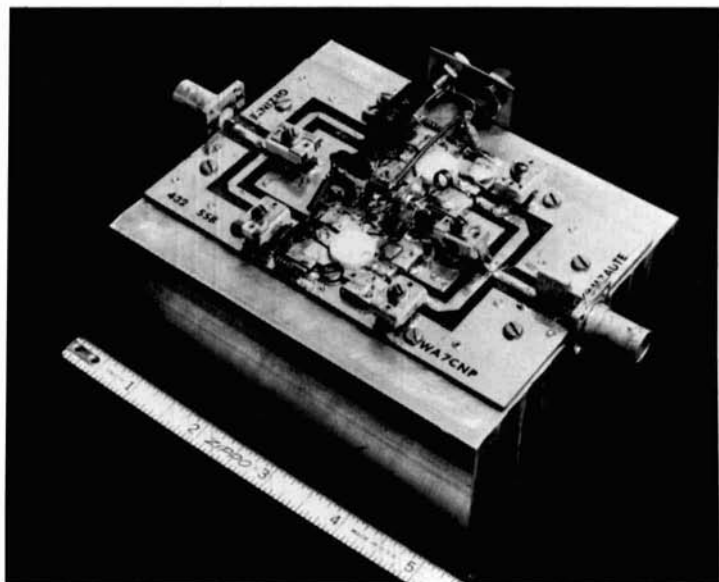
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## 100-watt solid-state power amplifier for 432 MHz

Design and construction  
of a 100-watt  
solid-state  
power amplifier  
for linear, CW,  
or fm service

There has been a tremendous increase in ssb activity on 432 MHz since the launch of Oscar 7 in late 1974. However, many amateurs who are communicating through Oscar's 432-to-144-MHz translator are using only 5 to 15 watts ssb output on 432 MHz so they must use complex, high-gain antennas to hold a good signal through the satellite. Few 432-MHz power amplifier designs have appeared in print, and because of mechanical considerations, vacuum-tube amplifiers are difficult to build at this frequency. This article describes a two-transistor, 100-watt PEP, solid-state linear amplifier which solves many of these problems. The components used in the amplifier, for the most part, are readily available.

R. Keith Olsen, WA7CNP\*

\*RF Power Circuits Engineering, Motorola Semiconductor Products Division, 5005 East McDowell Road, Phoenix, Arizona.

The transistors used in this power amplifier are the new high reliability Motorola MRF306s. The MRF306 is a 28 volt, 60 watt, 225 to 400 MHz power transistor and is unique in that it is internally matched for broadband use. Internal matching is nothing more than extending the matching network to the actual chip inside the package. This is accomplished by incorporating the bond wires and additional MOS capacitors as tuning elements between the base lead and the transistor die (fig. 1). The ladder network transforms the input impedance of the device in a controlled manner so it represents a low loaded Q at the frequency of use, hence the name, "Controlled Q Transistor."

Gold metalization is used inside the MRF306 to provide high reliability, ruggedness, and long life. The device can withstand a load vswr of 30:1 at all phase angles at 60 watts CW output. This kind of ruggedness offers burnout protection against hazards such as a forgotten antenna connector or even a mis-laid screwdriver!

## theory of operation

The power amplifier described here is essentially a narrowband, parallel amplifier that can be tuned from 420 to 450 MHz. For conventional ssb use, a push-pull configuration should be employed; in this case, however, both transistors are being driven at less than what they are capable, and operate in the class AB linear mode. Fig. 2 is a spectrum display of a two-tone test I ran on the amplifier. The center frequency is 432 MHz, the two tones are spaced 500 kHz apart, and power output is 100 watts PEP. The drive level is approximately 10 watts PEP.

As you can see, the 3rd and 5th order intermodulation products are down 28 dB. IMD responses greater than -30 dB can be attained by running the amplifier at lower power levels (see fig. 3), but since 100 watts is intended to be the "worst-case" condition, I chose

to demonstrate its response there. I might add that you should always pay very close attention to the linearity of any amplifier, especially when operating in crowded bands or when using one of the OSCAR satellites. When you operate an amplifier too close to the saturation point of the curve, you not only increase the incidence of spurious emission, your ssb signal also becomes mushy and distorted.

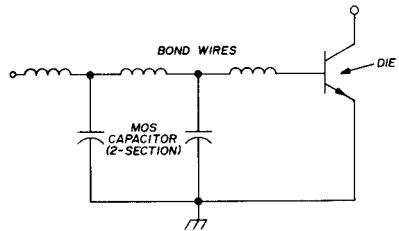


fig. 1. The MRF 306 power transistors used in this amplifier use a ladder network between the base lead and the transistor die to transform the input impedance of the device so it represents a low Q at the frequency of use.

This power amplifier can also be used on CW and fm. When I first built the amplifier I biased it into class C, and was able to drive and sustain 140 watts of output power for more than 30 minutes (I cheated a bit by using a fan because the ambient temperature of the heatsink can rise above 80°C). If you wish to use the amplifier for either CW or fm, and not on ssb or a-m, you can replace the class AB bias circuit with a ferrite bead and a four-turn inductor from the base of each device to ground as shown in fig. 5A. The devices can be driven further into class C by placing a 2.7 ohm, ¼ watt resistor between the inductor and ground (fig. 5B). This resistor is required only if you desire greater efficiency or have a greater drive level capability.

## construction

The amplifier is built on 1/16 inch (1.5mm) thick double-clad G10 epoxy-

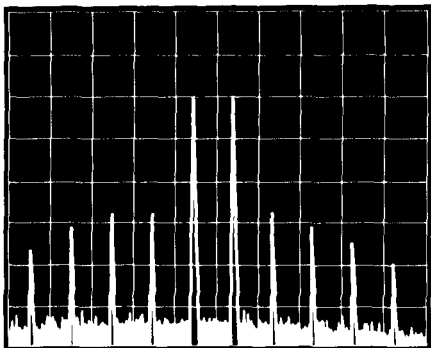


fig. 2. Spectrum display of 100-watt amplifier at 432 MHz shows 3rd and 5th intermodulation distortion products are down 28 dB referenced to 100-watt output (each vertical division = 10 dB).

glass printed-circuit board. I normally design with 1/16 inch (1.5mm) thick glass-epoxy board, but at \$135 a sheet it's a bit expensive for amateur radio projects. Epoxy-glass circuit board is somewhat lossy at 432 MHz, but is still quite acceptable for amateur use considering the cost differential.

However, it is imperative that you use double-sided board. It is also important that the ground on the bottom side be tied closely to the ground pads on the top side. This is accomplished by using either eyelets or plated-through holes from one side to the next. If you don't have eyelets you can do it by drilling holes through the board with a number-50 (1.8mm) drill; you then place number-18 or -20 (1.0 or 0.8mm) wire through the holes, solder both ends, and trim them off flush with the circuit board. I recommend that you make such a connection under each Unelco capacitor. As for the holes for the transistor flanges, a good drill, a file, patience, and a little elbow grease are all that is necessary.

The Unelco metal-clad mica capacitors have a dual purpose. Not only are they important to the input and output networks, they also serve as supports for the transistor leads. The Unelco capacitors are a bit expensive, but at these frequencies they cannot be replaced by

anything other than porcelain chip capacitors such as those manufactured by ATC.

The transistors should *always* be screwed down to the heatsink (thermal compound underneath) *before* soldering the leads as it is possible to crack or break off the ceramic cap of the device. (The clearance holes in the flange are made for 4-40 [M3] screws.) Once this is done, the base and collector leads can be connected to the microstrip with 2 to 5 mil (0.05 to 0.10mm) thick copper or brass strap. Be sure that the width of the strap does not exceed the width of the microstrip.

The Arco variable mica trimmers work surprisingly well at uhf. Piston variables are better suited for uhf work, but here again the price tag is prohibitive. When you look at the bottom of the Arco variables you will notice that there are two small grounding tabs on each side. These tabs must be soldered to the ground plane to reduce the amount of lead inductance inherent in the capacitor. Be careful, when installing the capacitor, to make sure it doesn't short out the microstrip.

The collector and base biasing circuits are best placed between the two devices in the center of the board (see fig. 6). The 580 pF feedthrough capacitor, C12, is mounted on a piece of 0.7x0.4 inch (18x10mm) copper strap.

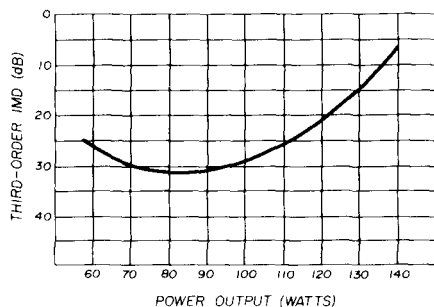
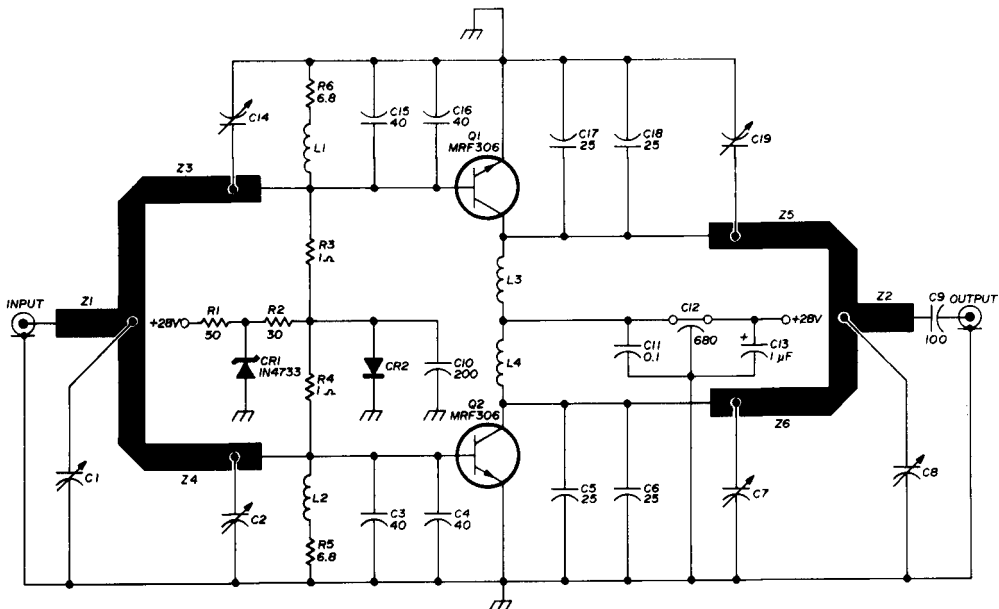


fig. 3. IMD performance of the 100-watt 432-MHz power amplifier vs output power ( $V_{CC} = 28$  Vdc, quiescent collector current = 100 mA).





- |         |  |         |  |
|---------|--|---------|--|
| C1,C2,  | 20 pF mica trimmer (Arco 402)                | C17,C18 | 25 pF metal-clad mica capacitor (Underwood)                            |
| C14     |  | CR2     | 1 amp silicon diode with 0.6 volt forward drop (Motorola MR501)        |
| C3,C4   | 40 pF metal-clad mica capacitor (Underwood)  | L1-L4   | 4 turns no. 22 (0.6mm) enameled wire, closewound on 1/8" (3mm) mandrel |
| C5,C6   | 25 pF metal-clad mica capacitor (Underwood)  | R1      | 50 ohm, 5 watt   |
| C7,C8   | 40 pF mica trimmer (Arco 403)                | R2      | 30 ohm, 1 watt   |
| C9      | 100 pF metal-clad mica capacitor (Underwood) | R3,R4   | 1 ohm wirewound, 1/4 watt  |
| C10     | 200 pF metal-clad mica capacitor (Underwood) | R5,R6   | 6.8 ohm, 1/4 watt  |
| C11     | 0.01 $\mu$ F disc ceramic, 100 V             | Z1      | Microstrip 0.11" (3mm) wide, 0.75" (19mm) long                         |
| C12     | 680 pF Allen Bradley feedthrough capacitor   | Z2      | Microstrip 0.11" (3mm) wide, 1.3" (33mm) long                          |
| C13     | 1 $\mu$ F tantalum, 50 V                     | Z3,Z4   | Microstrip 0.11" (3mm) wide, 2.3" (58.5mm) long                        |
| C15,C16 | 40 pF metal-clad mica capacitor (Underwood)  | Z5,Z6   | Microstrip 0.16" (3mm) wide, 1.7" (43mm) long                          |

fig. 4. Schematic diagram of the solid-state 100-watt linear amplifier for 432 MHz. This amplifier may also be used on fm or CW by replacing the class AB bias circuit with a ferrite bead and inductor as shown in fig. 5.

A 0.192 inch (5mm) hole is drilled through the strap for insertion of the capacitor and a small right-angle bend is placed in the strap so it can be soldered upright on the board.

The 1  $\mu$ F tantalum capacitor, C13, is connected on the side which is elec-

trically closest to the power supply. The 0.1  $\mu$ F disc capacitor, C11, is connected on the other side of the feedthrough. The collector chokes L3 and L4 come straight off the feedthrough to a point on the collector leads as close as possible to the cap of the devices.

## bias circuit

As you may or may not know, the  $h_{FE}$  (dc current gain) of transistors will vary from device to device but will always stay within a prescribed tolerance. As a result of some laborious experimentation, I have determined that the

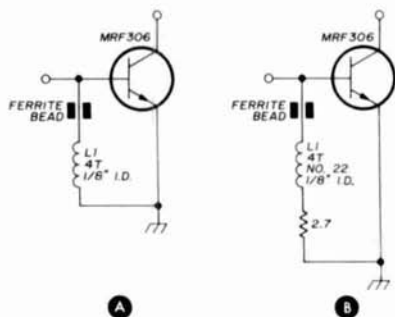


fig. 5. Power amplifier can be operated in class C for fm and CW by connecting a ferrite bead and inductor from the base of each device to ground as shown in (A). The devices can be driven further into class C by adding the 2.7 ohm series resistor as in (B). Inductor L1 is 4 turns no. 22, 1/8" (3mm) inside diameter.

biasing scheme used in this amplifier will keep the MRF306s biased between 20 and 50 milliamps of quiescent collector current. This variation in quiescent current has little or no effect in IMD performance but does have a small effect on gain.

The placement of the 1-ohm wirewound resistors, R3 and R4, is not as critical as that of the collector chokes; it is still advisable, however, to have the bias brought in as close to the transistor package as possible. Remember, too, that the 1-ohm wirewound resistor acts as an rf choke. Carbon varieties will not work in this application.

It is necessary to use approximately 100 nH of inductance in series with the 6.8 ohm resistors, R5 and R6, as they are carbon-composition resistors. The junction point of diode CR2, resistors R2, R3 and R4, and capacitor C10 use the isolated tab of the Unelco capacitor as a standoff. The anode lead of the zener diode, CR1, may be soldered directly to the circuit board. The cathode lead then serves as a tie point for

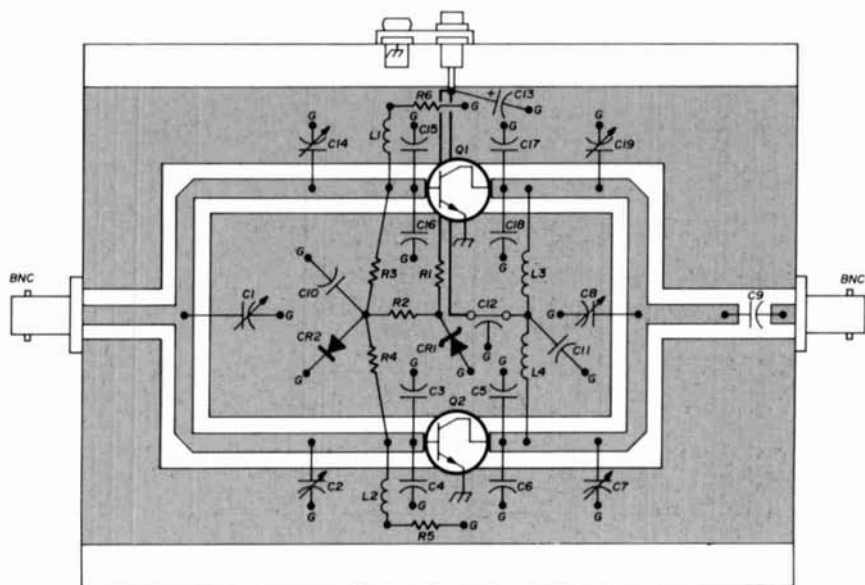


fig. 6. Component placement for the 432-MHz power amplifier. Full-sized printed-circuit board is shown in fig. 7.

resistors R1 and R2. The other end of resistor R1 is connected directly to +28 volts.

Finally, the 100 pF series capacitor in the output, C9, is mounted by placing it on its side on the microstrip with its isolated tab connected to the BNC output connector. This capacitor pre-

ments and sufficient voltage regulation to prevent gross  $V_{cc}$  fluctuations during load and no-load conditions, as encountered during modulation. Fig. 8 is a basic block diagram of a simple power supply that meets these requirements for this amplifier.

The transformer should provide from

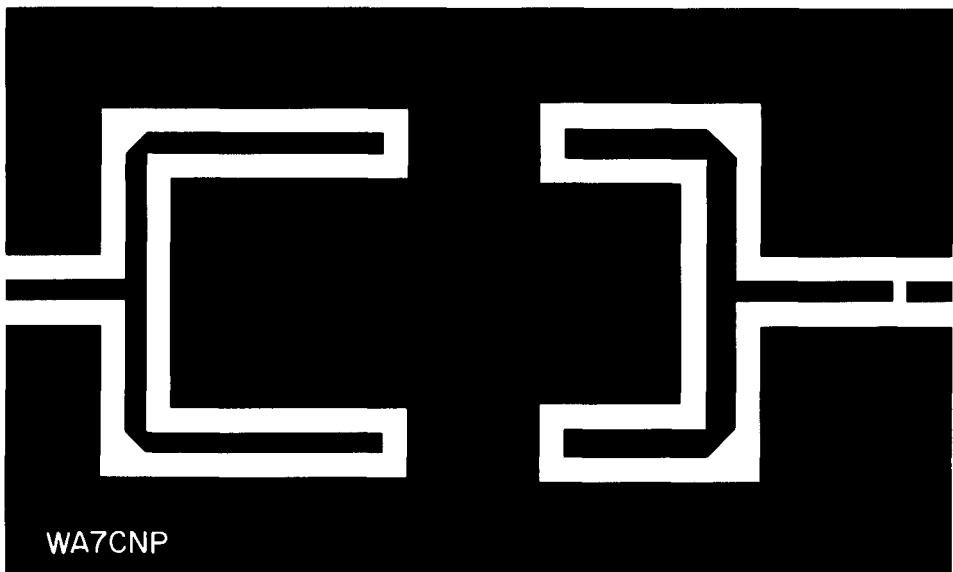


fig. 7. Full-sized printed-circuit layout for the 100-watt linear power amplifier. Component placement is shown in fig. 6.

sents only a small impedance bump in the collector load circuit. Its main purpose is to prevent shorting the dc power supply to ground when using a dc grounded antenna such as a Yagi.

### power supply

Let's digress for a moment and give consideration to a subject that is often neglected in articles such as these: A good power supply. Good IMD response is not only dependent upon bias, a good linear device, and proper collector loading, but also on a power supply that is capable of following the load changes presented by ssb operation. The power supply should have enough current capacity to handle peak current require-

26 to 35 volts with a current rating of 10 amps or greater. If you thumb quickly through practically any surplus parts catalogue you will find many suitable transformers at very reasonable prices. The bridge rectifier is anything capable of 10 amps. I recommend using the MDA962-1. A Motorola MPC1000 voltage regulator IC, followed by a large capacitor, will provide excellent regulation.

Tune-up of the amplifier is not as tricky as it may seem, although it will require a little caution at first. It is advisable, if you have a means of varying the drive level, that you begin by applying only 3 to 5 watts to the input. It is very important that you get the

collectors loaded to a "ball park" point before you start pouring on the coal.

When you first begin tune-up, adjust the input trimmers until you see a small deflection of output power. Then immediately adjust the output trimmers for peak output, ignoring the input match for the moment. The best way to adjust the output is to adjust C8 for a peak before adjusting C7 and C19. Capacitors C7 and C19 should be adjusted so that both Q1 and Q2 are equally sharing the load. Once you have a reasonably good collector load established, you can go ahead and do the same to the input match.

You will notice that, as output power increases, the output circuit will require small amounts of adjustment. This is because the required collector load impedance changes slightly as power increases. A small decrease in

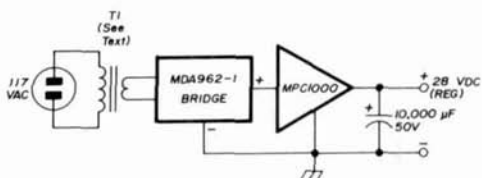
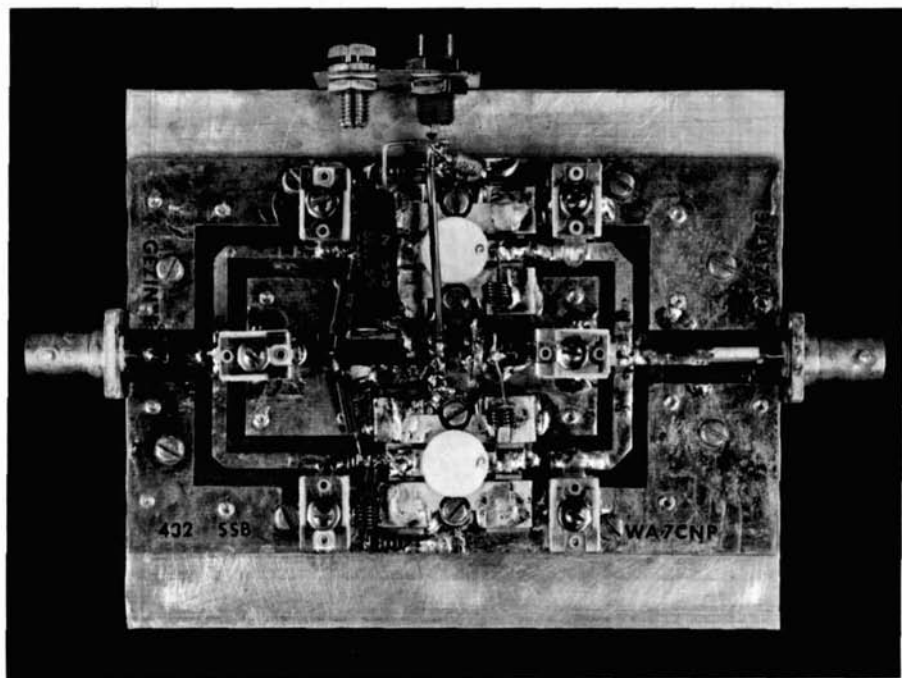


fig. 8. Basic block diagram of a regulated 28-volt supply for the 100-watt solid-state power amplifier. The Motorola MPC1000 is a positive voltage regulator designed to deliver up to 10 amps dc.

capacitance will probably be required on all the output trimmers as output power comes up. Alternately adjust the input and output circuits until you have reached your desired operating point (around 100 watts output).

The collector current should be between 6 and 8 amps depending upon the operating frequency. Capacitor C8



Top view of the solid-state 100-watt 432-MHz power amplifier, showing placement of the various components. Component designations can be easily correlated with the printed-circuit layout diagram in fig. 6. Input is at the left.

may be adjusted for slightly better efficiency but be careful not to drive the amplifier above 100 watts PEP output as severe flattopping will occur in the output waveform.

I hope you find this amplifier to be a useful tool in extending the capabilities of your 432 MHz station. There are many ways that this amplifier can be made to work even better, but it was my desire to make it as simple and in-

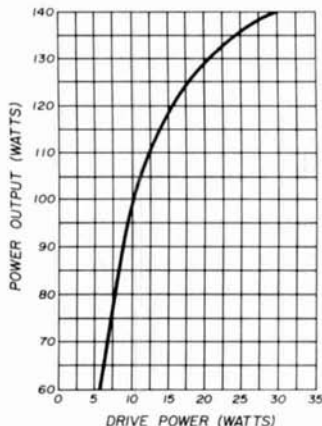


fig. 9. Plot of drive vs output power for the 100-watt 432-MHz power amplifier operating in class AB ( $V_{CC} = 28$  Vdc). Note that the knee of the curve is just above 100 watts output; this corresponds to the rolloff in IMD performance shown in fig. 3.

expensive as possible without seriously degrading performance.

A lot of the technology employed in solid-state power devices and amplifier design is new to amateur radio (and to industry as well) but as soon as technical publications and education programs can get geared up to this new technology, this type of work will become more and more commonplace. It should be the job of amateurs who are familiar with this technology to show the rest how it is done, and also to be the first ones to improve its implementation.

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Fig. 1 SSB signal before processing. See the high peaks and the low valleys. Our NCX-3 is putting out only 25 watts average power.

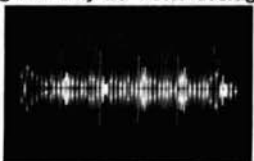


Fig. 2 SSB signal after processing with LSP-520BX. The once weak valleys are now strong peaks. Our NCX-3 now puts out 100 watts of average power.

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tone-encoder IC  
is the basis for  
this miniature  
Touch-Tone encoder  
for use in  
hand-held fm  
transceivers

Al Lowenstein, K7YAM, Motorola Semiconductor

The continuing increase in the popularity of autopatches, on both two meters and 450 MHz, coupled with the large number of hand-held fm transceivers now available, has generated the need for a truly compact tone encoder. With the introduction of a single-chip IC for this purpose, the handie-talkie Touch-Tone is now a practical achievement and for less than \$35 you can enjoy all the benefits of your autopatch while operating portable with a handie-talkie.

The Motorola MC14410 is a complementary mos IC and is functionally a 2-of-8 tone encoder or Touch-Tone.<sup>1</sup> It is available in both plastic and ceramic packages, but for amateur purposes there is no reason to pay the premium for the ceramic package. Designed for 4.4 to 6 volts, it will withstand moder-

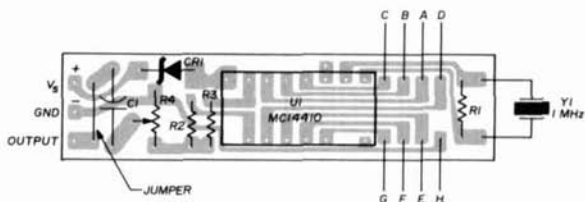
ate over-voltages. As it requires only 4 to 5 mA, it has little effect on the total current drawn by the radio and can be switched with the T-R key. The IC is complete within itself except for a 1-MHz crystal and the necessary components to limit voltage and match the output to the radio.

Unlike many other hybrids available today, the MC14410 is not susceptible to rf interference, so close proximity to the transmitter is no problem. The board shown here was designed to slide into the PL area of an Omni-housing Motorola HT220 radio. Fortunately, it is small enough to be tucked away in some corner of almost any fm transceiver. The crystal can be remoted on pigtails, and does not have to be mounted on the printed-circuit board, but can be located wherever space is available.

## construction

Any good PC board material can be used for the circuit board. Since the solder pads are small, a board with good adhering foil is necessary; the phenolic materials seem to lack this attribute. Use a number-64 (0.9mm) drill and a high-speed drill motor to avoid tearing the pads. The IC should be soldered in last to avoid any possible static build-up

fig. 2. Component layout for the miniature tone encoder. Full-size circuit board layout is shown in fig. 3. Kits and components are available from Contact Labs, 35 W. Fairmont, Tempe, Arizona 85282.



on the MOS devices. Use a soldering iron, not a gun. Pins 1 and 7 are clipped off as they are not used.

Very flexible, fine gauge wire is advised for the board-pad leads; the leads should be approximately 2-1/2 inches (6.5cm) long. Solder all the wires to the

board first; Teflon insulated wire is easier to work with because the insulation doesn't melt at soldering temperatures. The double pad on pin 11 of the IC is for the fourth column tone if you have a 4x4 keyboard — it was not needed here.

As shown on fig. 1, the 1- $\mu$ F capaci-

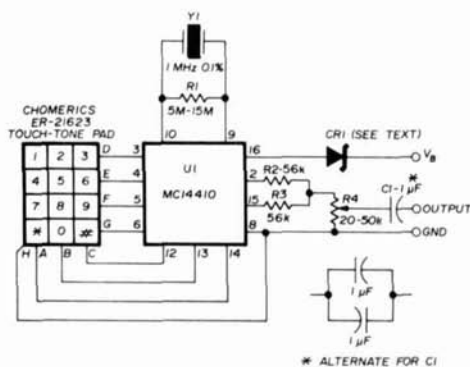


fig. 1. Schematic diagram of the miniature Touch-Tone encoder for the HT220 fm handie-talkie.

tor, C1, must be a nonpolarized unit. An alternative is to use two 1- $\mu$ F electrolytics in parallel with reversed polarity. Since the output is approximately 25 kilohms to ground, the capacitor can be tied directly into the audio line.

A zener diode, CR1, is used to limit the voltage to the IC at high battery

conditions; it should be picked so that  $V_{bat(h)} - V_z = 7$  volts. For the HT220, since the battery goes to approximately 16 volts at full charge, a 9-volt zener is used. Then, when the battery is low, there will still be 4.5 volts (13.5 - 9 = 4.5 Vdc) available for the encoder.



fig. 3. Full-size printed-circuit board for the miniature tone encoder.

The Chomerics ER-21623 pad pins must be clipped to approximately 1/8 inch (3mm) so they will clear the components of the HT220. Remove the fuse in the HT220 front cover from its clip while cutting the slots for the pins. An Xacto saw works well after pilot holes have been drilled; a Dremel Mototool could also be used. Extreme neatness isn't necessary as the Chomerics pad will completely cover the slots after it is epoxied into place.

The four plastic pins at the corners of the pad should be cut off and filed flush with the case. Fit thin pieces of cardboard around the pin areas to support the pad (see fig. 4). The pad is then epoxied to the front of the radio. Be sure to roughen the plastic of the radio with fine sandpaper to insure a good bond. Also, be careful to only epoxy the four edge rails of the pad. A little goes a long way, and epoxy can seep around the inside edges of the pad and make it inoperative.

After the epoxy has hardened, you are ready to put it all together. The pins of the pad should be tinned using a good clean hot iron. Do not overheat the pins as they will come free internally from the pad, resulting in erratic or no operation. The eight wires from the circuit board can then be soldered

to the keyboard. The B+ supply, ground and audio are picked up as shown in the photograph. The difficult part is stuffing all those wires in. A gentle loop between the front cover and main circuit board will suffice, and there don't appear to be any detrimental effects from having the eight wires right next to the radio circuitry.



Interconnect points for the Touch-Tone encoder installed in a Motorola HT-220.

The output potentiometer, R4, should be adjusted to produce a 4 to 5 kHz final frequency deviation when one key is depressed. This assumes, of course, that the radio's modulation causes a similar deviation during normal voice operation. Note that the microphone is live, so use precautions while dialing.

#### reference

1. Jon DeLaune, W7FBB, "Digital Touch-Tone Encoder for VHF FM," *ham radio*, April, 1975, page 28.

ham radio

CHOMERICS  
ER-21623

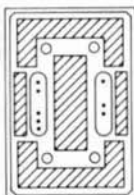


fig. 4. Cardboard inserts (hatched areas) are used to support the Chomerics Touch-Tone pad (see text).



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# Vhf engineering

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# how to use milliammeters

A discussion of  
meter shunts  
and other techniques  
to adapt surplus  
panel meters to the  
operating requirements  
of your own circuits

Quite often neither your junkbox nor the local surplus outlet has the meter you need for some new piece of equipment. It is very easy to substitute low-range microammeters or milliammeters where higher range milliammeters are wanted, or voltmeters in some cases. Meters have a generally-unknown internal resistance and a shunt resistor will divide the total circuit current flow between the meter and the shunt according to Ohm's law.

Guy Black, W4PSJ, 12317 Hanger Road, Fairfax, Virginia 22030

It is not necessary to determine the meter resistance to apply this ancient trick, although that is not particularly difficult, and meter shunts can be satisfactorily made with readily-available materials. For example, on a recent rig I shunted a 60 mA meter to read 600 mA, a 200  $\mu$ A meter to read 20 mA and a 100  $\mu$ A meter to read 10 mA. The basic test setup for current-meter shunting is a variable current source and a calibrated meter, either a small battery, with a series variable resistor, or an adjustable current-limiting power supply such as the Heath HP-28 which can be set at the desired full-scale current.

For milliammeters, shunt resistances are often very small: a 10 mA meter, for example, is likely to have about 2.5 ohms internal resistance and a 200 mA meter, about half an ohm. In the resistance ranges desired, copper wire makes quite satisfactory shunts.

## meter shunt theory

For full-scale meter readings there will be an IR drop across the meter. If it is desired that the meter read full scale when the total circuit current is higher, the shunt must have whatever resistance

will pass all the additional current at the same IR drop. For example, a 10 mA meter with 2.5 ohms internal resistance will have an IR drop of  $(0.01 \times 2.5 = 0.025 \text{ volt})$ . If you wish the meter to read full scale when the circuit current is actually 100 mA, the shunt must pass 90 mA at 0.025 volt, which calls for a 0.278 ohm shunt  $(0.025\text{V} \div 0.09 \text{ mA} = 0.278 \text{ ohm})$ . A standard-value 0.27 ohm resistor will do the trick.

It is not difficult, however, to zero in on the right shunt value without knowing the internal resistance by taking a random length of small copper wire, placing it in series with the constant-current source, connecting the meter to one end and tapping it (with a needle-tipped probe) along the shunt wire until the meter reads full scale. Number-30 enamel wire, for example, has about 0.1 ohm per foot (3.28 ohm per meter) and the resistance and current-carrying capacity of other wire sizes appear in the ARRL Handbook. Thus, 2.8 feet (85.3cm) of number-30 wire wound in a small coil would make a suitable shunt for the previous example.

A lot of trial and error can be saved, however, by some simple calculations. Start by making a trial shunt, erring on the low resistance side if you have limited control over your constant-current source. Here is how it went shunting a 60 mA meter to 600 mA. With about 3 inches (76mm) of resistance wire, 60 mA in the circuit produced a meter reading of 15 mA, meaning that 45 mA was being passed by the shunt. As the IR drop across the meter and the parallel shunt is the same, two Ohm's law expressions can be stated in terms of three unknowns: the meter resistance,  $R_m$ , the test shunt resistance,  $R_s$ , and the common voltage across the meter and shunt,  $E$ ,

$$\begin{aligned} E &= 0.045 R_s \\ E &= 0.015 R_m \\ R_s &= 0.333 R_m \end{aligned}$$

When this meter is used in the 600 mA circuit the required current division between the meter and the shunt is 60 mA through the meter and 540 mA through the shunt. Using the same set of equations, the relationship of the meter resistance to the desired shunt resistance,  $R'_s$  is calculated as follows:

$$\begin{aligned} E &= 0.540 R'_s \\ E &= 0.060 R_m \\ R'_s &= 0.111 R_m \end{aligned}$$

Since the meter resistance,  $R_m$ , is an unchanging value, the *desired* shunt resistance,  $R'_s$ , compared to the *test* shunt resistance,  $R_s$ , is:

$$\frac{R'_s}{R_s} = \frac{0.111 R_m}{0.333 R_m} = 0.333$$

This is the same as saying that the wire in the desired shunt should be exactly one-third the length of the wire in the test shunt. The unknowns are still unknowns, but the desired result has been achieved.

When shunting sensitive milliammeters or microammeters, a low-range resistance decade is nearly essential because the resistance values are too high for lengths of copper wire. Alternatively, a small-value potentiometer can be used as a variable shunt, the value set for full-scale reading at the desired circuit current and then measured with an ohmmeter.

The approximate shunt values can be estimated by noting that 1 mA meters typically have about 30 ohms resistance; 500  $\mu\text{A}$  instruments, about 90 ohms; 100  $\mu\text{A}$ , 500 ohms; and 50  $\mu\text{A}$ , about 2500 ohms. (If a decade resistance box is used, be sure it has shorting contacts or the full circuit current will instantaneously go through the movement during switching!) With this technique, the actual value of the desired shunt is determined and it is possible to select series or parallel combinations of stan-

dard-value resistors that will closely approximate the desired shunt value.

Note that decade resistance boxes can be constructed with only four resistances by using the Mallory type 154L switch, which automatically arranges a 1-ohm, two 2-ohm and a 5-ohm resistor so as to provide the entire decade range. In the one-tenth to one ohm range switch contact resistance is not likely to be serious. Such a decade will be very convenient if you plan to design shunts for very many meters.

There is less chance of blowing out meters accidentally in test set-ups if you wire the shunt in series with the current source and tap the meter around the shunt, rather than the other way round.

You will probably find that resistance wire is a bit hard to come by, and generally bare wire intended for heating elements is all that can be found. Standard Scientific Supply\* carries Chrome-A resistance wire (80 percent nickel and 20 percent chromium) which has the best temperature/resistance relationship. Its resistance characteristics are listed in table 1.

### critical damping resistance

If a meter is heavily shunted, the movement will be severely damped by self-induced current, and this may be undesirable in applications such as measuring the plate current of a linear, or VU instruments. The amount of damping can be reduced by putting a small resistor in series with the movement and shunting the combination of that resistor with the movement

An interesting experiment with a sensitive high-quality meter is to vary the shunt resistor with a potentiometer and observe how the needle oscillates before finally coming to rest. The largest resistance for which the needle approaches the final setting without overswing is

called the critical damping condition. With more resistance there will be a slight overswing, and with less resistance the final setting will be approached more slowly.

In amateur applications there is no particular need to achieve critical damp-

table 1. Resistance characteristics of Chrome-A nickel-chromium resistance wire.

B&S gauge	diameter	resistance per foot (ohms)	resistance per meter (ohms)
18	0.0400" (1.02mm)	0.406	1.332
20	0.0320" (0.81mm)	0.635	2.083
22	0.0253" (0.64mm)	1.017	3.337
24	0.0201" (0.51mm)	1.610	5.282
26	0.0159" (0.40mm)	2.570	8.432
28	0.0126" (0.32mm)	4.100	13.451
30	0.0100" (0.25mm)	6.500	21.325

ing, but it can easily be approximated by making the series combination of the shunt and resistance in series with the coil equal to the critical damping resistance.

### meter multipliers

Voltmeters can also be multiplied using additional series resistors, and low-current milliammeters or microammeters can be easily converted to voltmeter use. In this use, it is well to operate far below the wattage rating of the shunts because the temperature coefficient of standard carbon resistors is not the best. In addition, the maximum voltage across any one resistor should be kept below about 400 volts.

One of the best uses for shunts is for multi-circuit metering of equipment where different current or voltage ranges are desired for each circuit. In such configurations it is very useful to mount the shunts on the switch — generally a non-shorting type. You must watch the voltages on the various circuits, and on the meter as well. Current production panel meters from Weston and other firms built to government

\*Standard Scientific Supply Corp., 808 Broadway, New York, New York 10003.

specifications are tested at 3000 volts (actually 2600 volts rms) between the movement and the case, but very old meters with metal zero-adjust screws should be used in high-voltage circuits only with great caution.

If a multiplier resistor is used to expand the range of a voltmeter which is switched off the multiplier, leaving the multiplier resistor floating, it will assume the full voltage potential which may be more than the switch insulation can stand. A better approach is to run the multiplier to ground, taking the voltage off a tap on the multiplier resistor. With this arrangement, the voltage across the switch contacts will be far less.

### Ayrton shunt

You can easily convert a sensitive meter into a multirange milliammeter with a few standard-value resistances and a switch using the configuration known as the Ayrton shunt shown in fig. 1. The values given will yield full-scale readings of 10, 100 and 1000 milliamperes within a few percent from a 1 mA meter with 50 ohms internal resistance. If your meter has less internal resistance, add enough resistance in series to bring it up to that value. A

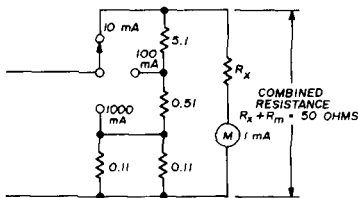
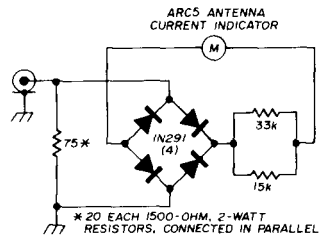


fig. 1. Using the simple Ayrton shunt circuit shown here, a 1 mA meter with 50 ohms resistance can be used to measure 10, 100, and 1000 mA.

rough way to measure internal meter resistance is to adjust a constant-current source through a resistor to bring the meter to full scale, and then add enough resistance in parallel to bring the meter

to half scale. The *added* resistance then equals the meter resistance.

Meters are sometimes found with non-linear movements, and they can be particularly useful in some applications (and of course internal resistance cannot be found in the manner just described).



CALIBRATION	
SCALE	POWER
1	40 mW
2	150 mW
3	330 mW
4	610 mW
5	1.65 W
6	2.70 W
7	3.00 W
8	8.60 W
9	16.9 W
10	≈ 45 W

fig. 2. This wide range rf wattmeter uses surplus non-linear "antenna current indicator" meter used in Command Set transmitters.

Many amateurs have such meters in their junkboxes which were salvaged from war surplus Command Sets, a 2½-inch (64mm) meter with a zero-to-ten indication labelled, "antenna current indicator." Half-scale of this meter is about 5 milliamperes, but it is very sensitive at the low range and very insensitive at the high range. Built into the rf wattmeter shown in fig. 2, a scale reading of 1 corresponds to 40 milliwatts on my instrument, 5 corresponds to 1.6 watts, and 9 corresponds to 17 watts. This wattmeter is for 75-ohm systems but a similar arrangement could be built for 50 ohms (I often use 75-ohm coax, as low-loss 75-ohm CATV cable is often available on the surplus market.

If you cannot find a non-linear meter you can achieve the same result by shunting any meter with diodes and add-

ing enough series resistance to the movement to bring the combined IR drop to about the contact potential of the diode. **Table 2** gives the full-scale IR drop of a common (and typical) series of panel micro/milliammeters. Since silicon diodes start to conduct at about 0.6 volt, nonlinearity is achieved by adding enough series resistance to the movement at  $R_V$  in **fig. 3** so that the combined IR drop is in this general range.

If too large a resistance is added the meter will not reach full scale; if just enough resistance is added so that full scale can be achieved the reading will be very nonlinear, and by adding less the linearity is improved. In fact, merely adding a protective diode alone will produce some degree of non-linearity, although it is not likely to be noticeable except in microammeters.

Parenthetically, meters are protected only up to the point where the shunting diode blows out, and with high-current

**table 2. Internal resistance of Simpson type 1212C panel milliammeters (typical of quality panel instruments).**

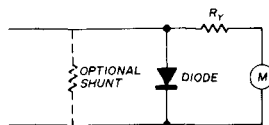
full-scale reading	internal resistance (ohms)	full-scale IR drop (volts)
50 $\mu$ A	5000	0.250
100 $\mu$ A	2000	0.200
200 $\mu$ A	1000	0.200
500 $\mu$ A	200	0.100
1 mA	46	0.046
5 mA	23	0.115
25 mA	3	0.075
50 mA	1.5	0.075
100 mA	0.75	0.075
200 mA	0.6	0.120
1 amp	0.05	0.050

diodes available so inexpensively on the surplus markets, it makes sense to use a 10-ampere diode in any setup (such as an experimental bench supply) where short circuits are occasionally possible. These diodes need not be heatsinked.

Nonlinearity of the opposite sort can be achieved by putting zener diodes in series with meters, and some very odd

curves of current versus needle deflection can be obtained by various combinations of zeners and shunt diodes. All of these effects, of course, ruin the original scale calibration.

Zener diodes in series with milliammeters result in expanded-range volt-



**fig. 3. Simple circuit for non-linearizing meter movements uses semiconductor diode (see text).**

eters. For example, a 150 volt, 10 watt zener such as the 1N3011, in series with a 1N4007 and 100-ohm resistor, spreads out 100 to 130 volts over the entire scale of a 50 mA meter. The amount of resistance determines the amount of compression. Lower voltage zeners — typically just above the target voltage — are very useful for expanded scale monitors of battery packs and transmitter filament voltages. The additional series diode is only necessary when monitoring ac.

## summary

Liberal use of meters can be one of the design features where the home builder can outshine the commercial source. Good quality panel meters are still in abundant supply in surplus and at flea markets, often at very low prices. Changing scales and ranges is not very difficult for many types, though it is not possible to open up the newer hermetically sealed-instruments. The more odd-ball the scale, of course, the lower the selling price.

## bibliography

1. Ernest Frank, *Electrical Measurement Analysis*, McGraw-Hill, New York, 1959.

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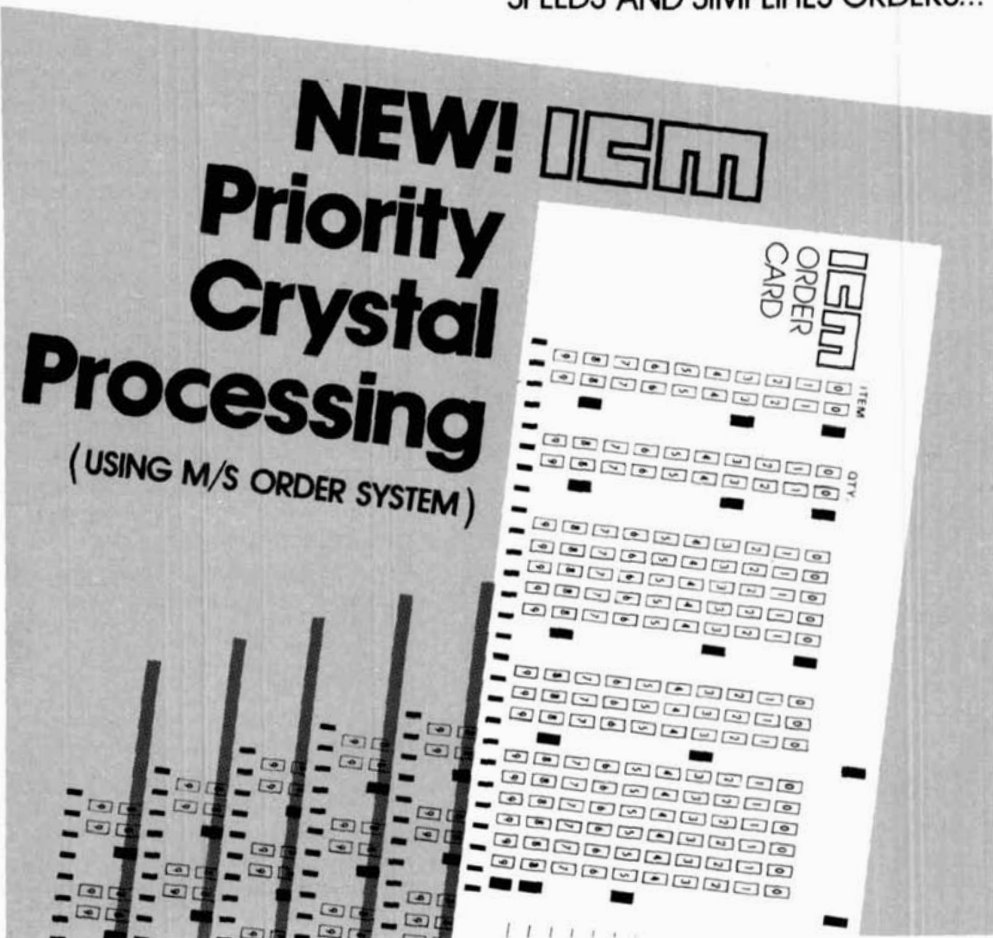
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# magnet-mount mobile antenna

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for temporary  
mobile operation  
where a permanently  
mounted antenna  
is not available

A magnet-mount antenna is an indispensable item for anyone currently working vhf fm on 144, 220, or 450 MHz. When used in conjunction with a cigarette lighter adapter to provide 12 Vdc for the fm rig, it permits mobile operation from almost any vehicle at a moment's notice. Thus, from an emergency standpoint, you are not restricted to a vehicle already equipped with a vhf antenna. In addition, the magnet mount is useful for those who do not wish to cut a hole in their car to operate mobile.

Unfortunately, commercially available magnet-mount antennas are expen-

sive, and up to now it has been difficult to obtain magnets with the right surface area, the right holding power, and the right price. This article describes a very simple quarter-wave magnet-mount antenna which can be built in about a half hour for any of the three vhf bands mentioned. The total cost of the antenna, not including coaxial cable, is less than \$6.00. All parts are readily available, and the magnets can be obtained locally.\*

The magnet-mount antenna is really too simple for words; **fig. 1** shows a drawing of the antenna. It simply consists of a good quality magnet, a 1½-inch (38mm) long 6-32 or 8-32 (M3.5 or M4) flat-head screw, three nuts, a lock washer, coax connectors, and a cable clamp.

## construction

To build the antenna, connect a female uhf chassis connector to the magnet as shown in **fig. 1**. Run the coax under the cable clamp (or tape the coax to the screw if you don't have the clamp), and connect the inner conductor to the center of the coax connector and the shield to the flange. Take a piece of brazing rod of the proper length (see **fig. 1**), and solder it to the male uhf connector. Use some silicone

\*If you can't find a local source, the 1½ inch diameter magnets are available for \$3.95 plus postage from George Allen Engineering, 80 Farmstead Lane, Windsor, Connecticut 06095. Connecticut residents add 6% sales tax.

George Allen, W1HC1, 80 Farmstead Lane, Windsor, Connecticut 06095



bathtub caulking such as that made by GE to fill up the male connector to provide a good seal. The brazing rod can be obtained from any welding supply house.

In regard to the magnet, use round button or shallow pot Alnico magnets or equivalent of 1¼ or 1½ inches (32 to 48mm) diameter. Magnets of this size provide enough holding power, while smaller magnets won't hold well and will blow off your car at high speeds. Note that when your antenna is not being used, make sure that the "keeper," the small metal piece provided with the magnet, is placed across the poles of the magnet. The use of the keeper prevents loss of magnet power.

## tuning

Although this simple magnet-mount antenna will give you good results, it is not quite as efficient as a quarter-wave antenna permanently mounted on your car. In most cases, however, you probably couldn't see the difference between the magnet-mount antenna and one that is permanently mounted. In regard to feedline matching, it is difficult with

this type of antenna to get the swr down to 1:1. However, this really doesn't matter since your feedline is very short and the overall losses will be small.

To tune the antenna, place the antenna on the center of the car roof or trunk and connect an swr bridge in the line between the transmitter and the antenna. Start snipping off pieces of brazing rod by 1/8 inch (3mm) at a time until the swr falls between 1.5:1 and 2:1. At this point the antenna is tuned, and the only remaining thing to do is to put some silicone seal or tape on the end of the antenna to protect against injury. Note that the swr may vary when the antenna is used with different cars.

## performance

I have been doing quite a bit of traveling in the last six months and have been taking this antenna with me. It is convenient to use, works well, and has yet to come off a car roof at speeds up to 80 mph. I have been using the antenna on all sorts of rental cars and have had no problems except where the car has a vinyl roof. In those cases I place the antenna on the trunk. The magnet won't hold well through the thickness of the vinyl.

In practice, I place the antenna on the center of the roof or trunk and run the coax through a window, leaving the window slightly open so as not to damage the cable. I connect the coax to my rig and I'm on the air! It does not appear to be necessary to protect the car paint from the magnet. I have been using these mounts for four years and have yet to scratch the paint with a bare magnet.

I hope that this short article gives you the incentive to build this simple antenna; it's handy either for daily use or to keep in the closet for use in that emergency when you can't use your own car.

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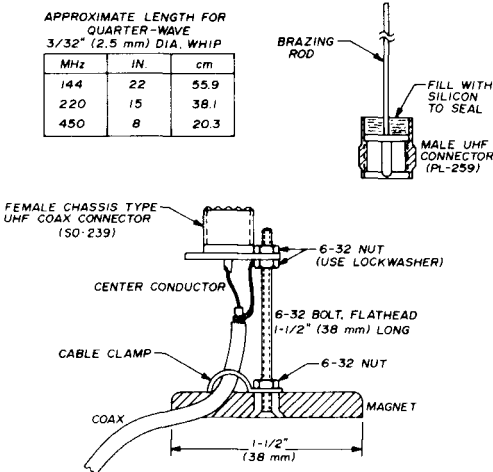


fig. 1. Construction details of the simple magnet-mount mobile antenna. Dimensions are given for quarter-wave operation on 144, 220 and 450 MHz.

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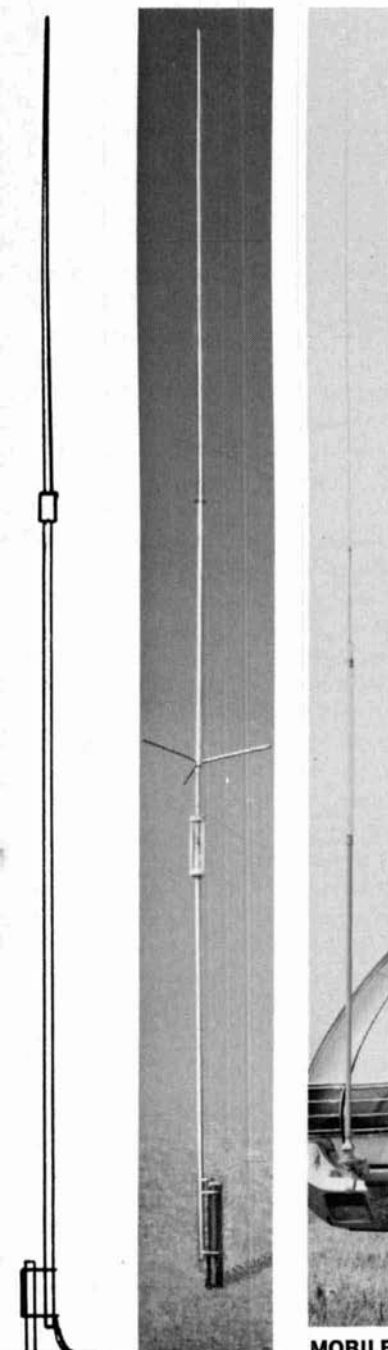
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# 300-Hz crystal filter for Collins receivers

Recently a number of 455-kHz Collins crystal filters with a 6-dB bandwidth of 300 Hz have become available on the surplus market.\* These filters, which were built to military specifications, have a 60-dB bandwidth of 1200 Hz and maximum insertion loss of 5 dB, are designed for a source and load impedance of 2000 ohms, and do not require any resonating capacitors† (mechanical filters for Collins receivers are designed for terminations of 50 kilohms or greater and require external capacitance to resonate the transducer coils). If the crystal filter is not terminated with 2000 ohms, passband ripple will be on the order of 6 dB or more and spurious response will seriously degrade skirt selectivity.

Since the filters in Collins receivers are isolated by dc blocking capacitors, the required terminations for the crystal filter are most easily provided by simply connecting 2200-ohm resistors across the input and output terminals. Be sure to remove the 100 pF resonating capacitors from the circuit, however, as they will cause excessive passband ripple and unwanted spurious response. When terminated with 2200-ohm resistors passband ripple is nil and the skirts roll off smoothly to 80 dB or more.

Unfortunately, however, this simple resistive loading results in a serious impedance mismatch which manifests itself as 10 to 12 dB of additional circuit loss. Increasing the terminating resistors to 3900 ohms will reduce the loss about 3 dB, but passband ripple starts to suffer. A better solution is to drive the

crystal filter with the simple emitter follower circuit shown in **fig. 1**. This circuit, which requires only 10 mA of current, reduces circuit loss to 3 dB or less and provides the filter with the required source impedance.

The emitter follower can be built on a small section of perforated circuit board which is supported by the input and output wiring. Power is derived from the screen circuit of the mixer tube. Make sure that the emitter follower is properly isolated with dc blocking capacitors as any dc voltage on the filter transducers will damage them (the filter switch has shorting contacts, so any voltage on the switch may damage adjacent filters as well). However, if you follow the circuit shown in **fig. 1**, which is completely isolated, you will have no difficulties.

Installation of the filter in 75S3B and later model S-line receivers requires only a length of number-20 (0.8mm) tinned bus wire, a lockwasher, and a 4-40 nut. The filter is installed below the chassis, on one side of the filter shield compartment, as shown in **fig. 2**

\*The Collins 300-Hz crystal filters, X455KF300, with data sheets, are available from Gary Fertik, W1EBC, 40 Pilgrim Trail, Woodbury, Connecticut 06798. Price is \$49.95, postpaid.

†XF455KF300 filters, Collins part number 526-7073-010. Other Collins crystal filters with the same generic nomenclature but with different part numbers are designed for 20k terminations; some require external capacitors. Although the filter described here is the most common, check the data sheet which comes with your filter.

Jim Fisk, W1DTY, Ham Radio Magazine, Greenville, New Hampshire 03048

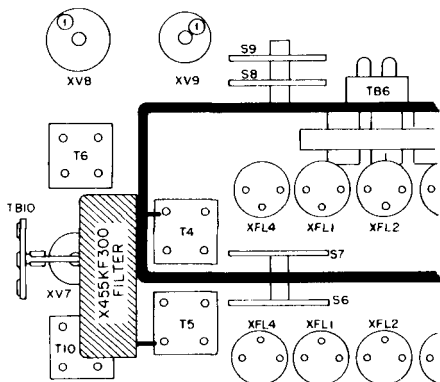
(installation suggested by WA8OBG). Three holes are required: two for the electrical terminals and one for the mounting screw. Since these holes are below the chassis the filter installation does not deface the receiver.\* The filter is symmetrical so either end may be used for the input or output.

### Collins 75A4

Owners of Collins 75A4 receivers should be particularly interested in the 300-Hz crystal filter as the narrowest bandwidth filter designed specifically for this receiver has a 3-dB bandwidth of 500 Hz, and these filters are very difficult to find on the open market. Although there are two methods of installing the 300-Hz crystal filter in the 75A4, the installation shown in the photograph is recommended because it provides maximum isolation between the input and output (this same method is also recommended for Collins type-FA mechanical filters).

Turn the 75A4 upside down on your bench (front panel forward) and remove the bottom cover. The three filter sockets are in the front right-hand corner next to the selectivity switch. The crystal filter is installed in the shield which crosses the three filter sockets. Two 1-inch (25mm) deep slots must be cut in the shield as shown in **fig. 3**. Use *sharp* tin snips and place rags underneath the work area on both sides

of the shield to catch any debris. After cutting the slots, bend the tab toward the rear of the receiver so it forms a 90-degree angle with the shield. A hole for the filter mounting screw is drilled in the center of the tab, 1/4 inch (6mm)

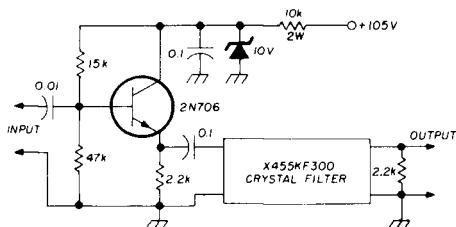


**fig. 2.** Installation of the Collins X455KF300 crystal filter in S-line receivers.

from the end (the threaded stud on the other end of the filter is not used).

After the tab is finished, temporarily set the filter in place to check for clearance between the top of the filter and the bottom cover of the receiver (if you follow the dimensions shown in **fig. 3**, the top of the filter should be approximately flush with the top of the shield).

Locate the input and output wires to filter socket A (underneath switch S2) and their respective connection points on the switch wafers (note that one of the wires is grounded). Remove the two 100-pF resonating capacitors. Install the emitter follower circuit shown in **fig. 1** between switch S2 and the crystal filter. The emitter follower common is con-



**fig. 1.** Emitter-follower circuit which provides correct source impedance for the crystal filter and minimizes circuit loss. Most general-purpose npn transistors may be substituted in the circuit.

\*In some Collins 75S3B receivers there is sufficient clearance under the filter shield on the top of the chassis that the crystal filter can be installed in the existing crystal-filter sockets. Although the terminals of the X455KF300 will not fit the sockets, short lengths of no. 20 (0.8mm) wire can be soldered to the filter terminals and plugged into the sockets.

ected to the grounded terminal on the rear wafer of S2; the input coupling capacitor, C1, is connected to the other switch terminal which goes to filter socket A. Install two short lengths of number 20 (0.8mm) bus wire to each of the connection points on the front wafer of switch S2. (If you don't want to include the emitter follower, connect bus wires to the rear wafer as well.)

Connect a 2200-ohm resistor across the output terminals of the crystal filter and install the filter on the mounting tab using a lockwasher and 4-40 nut. Wire in the emitter follower and solder the two bus wires to the output terminals. Total installation time should be two hours or less.

Since you have the bottom of the receiver open, this is a good time to apply some contact cleaner (such as GC Electronics *Tunerlube*) to each of the switch contacts. It's also a good idea to dab some silicone grease on the switch detent mechanisms. If your 75A4 is like most, the only lubrication the receiver has ever seen was applied at the factory, and that's pretty well dried up. A little switch care now may save an expensive replacement problem later.

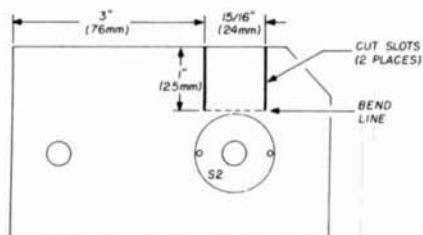


fig. 3. Collins 75A4 filter shield, showing modifications required for installing the crystal filter. Completed installation is shown in the photograph.

An alternative method is to mount the crystal filter on a small L-shaped bracket which is attached to the chassis with the screw which holds the left-hand end of the filter shield (next to the i-f gain control). In this case the filter connections are made to filter socket C. However, this method is not recommended because the connecting wires are quite long and lowered input-output isolation degrades the high skirt selectivity of which the filter is capable.

### operation

If another mechanical filter is installed in filter socket A, it must be moved to socket B or C. Operation of the 75A4 with the sharp 300-Hz filter requires some practice to gain full advantage of its high skirt selectivity. The setting of the *passband tuning* control is quite critical and for best results should be set so that CW signals peak at a pitch of about 700 Hz. When you tune in a signal with a broader filter, set the main tuning for a 700-Hz note before switching the sharper 300-Hz filter into operation. If the signal is tuned for a higher or lower note (assuming the passband tuner is set for 700 Hz), the receiver must be retuned slightly to find the signal. With a little practice, you'll find that the narrow bandwidth and high skirt selectivity of this filter do an excellent job of cutting interference or digging into the noise for weak signals.

ham radio

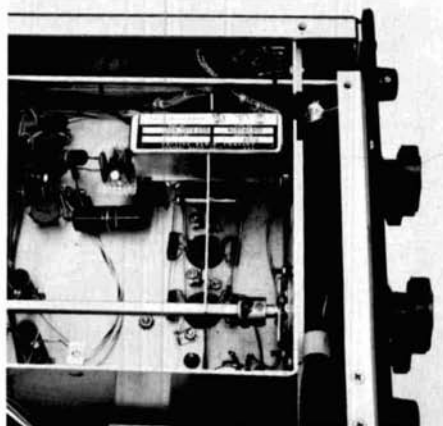


fig. 4. Crystal filter installation in the Collins 75A4 receiver. The emitter follower is on the small circuit board to the left.

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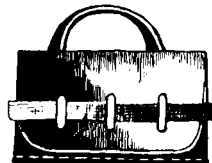
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# comments

## touch-tone decoder circuit boards

Dear HR:

Due to the rather large response to my article on Touch-Tone decoders which appeared in the December, 1974, issue of *ham radio*, I have decided to offer printed-circuit boards for sale to those individuals who might want them. I am also putting together some kits for those builders who have a hard time finding all the necessary components. All the parts and materials are top quality, commercial grade and ICs will be pre-tested to ensure performance. A set of boards is \$12.95, and a kit, including boards and toroids, is \$37.50.

John F. Connors, W6AYZ  
Electromedics  
3295 Brookdale Drive  
Santa Clara, California 95051

## ssb transceiver

Dear HR:

A small number of the transceivers built from the ssb transceiver article in the August, 1974, issue of *ham radio* suffer from apparent agc instability. The symptoms are generally motor-boating at certain signal levels.

The problem is not, in fact, due to the agc but to instability caused by i-f feedback through the unused transmitter section of the circuit. It may easily be cured by connecting a single 0.1- $\mu$ F capacitor with low rf resistance between the transmitter section power

supply line and ground (as near as possible to the SL610C amplifier). Installing this capacitor does not remove the necessity of grounding the transmitter power line during reception and vice versa.

I apologize to anyone who has been inconvenienced by this fault, but the majority of these transceivers are not affected and the problem has only recently been brought to my attention.

Brian D. Comer, G3ZVC  
Plessey Semiconductors

## quadrature-phased local oscillator

Dear HR:

I have been following the articles concerning direct-conversion receivers and find the communication between Madey and Shubert regarding the Phase II receiver in the June, 1974 *comments*

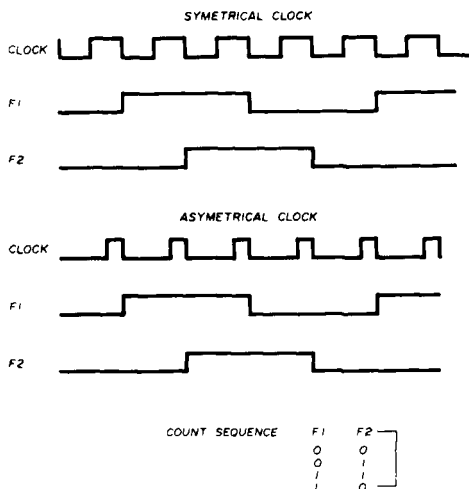


fig. 1. Waveform of the quadrature-phased local oscillator, showing independence of local-oscillator quadrature on clock-period asymmetry. Asymmetry of negative-going transitions would imply gross frequency instability.



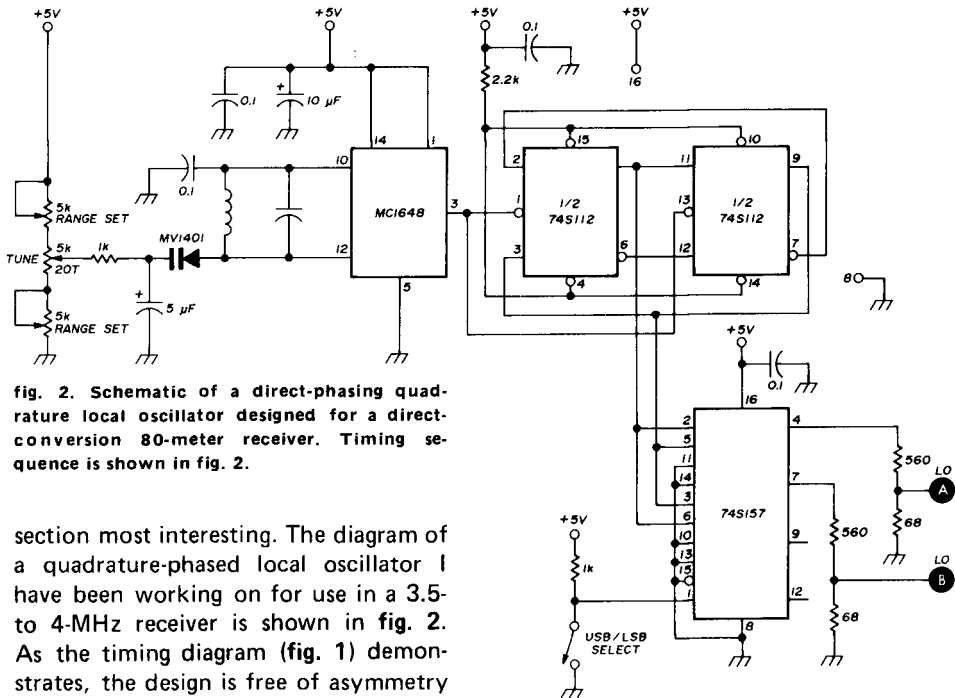


fig. 2. Schematic of a direct-phasing quadrature local oscillator designed for a direct-conversion 80-meter receiver. Timing sequence is shown in fig. 2.

section most interesting. The diagram of a quadrature-phased local oscillator I have been working on for use in a 3.5- to 4-MHz receiver is shown in fig. 2. As the timing diagram (fig. 1) demonstrates, the design is free of asymmetry errors since it is responsive to the negative-going transition of the clock waveform, and the clock may exhibit any periodicity it wishes, within device limitations. The circuit was intended for use with MC1496-type product detectors and has provision for switching the phase of the local oscillator to effect sideband reversal rather than performing the task at audio and having to accept a compromise in unwanted sideband rejection.

Douglas K. Beck, K6ZX  
Sunnyvale, California 94086

## Collins 75A4 mods

Dear HR:

Recently, when the avc failed in my Collins 75A4, the usual changing of tubes had no effect. Actually, a small amount of avc action remained — the S-meter needle rose slightly off zero with very strong signals. The trouble proved to be R86, a 39k resistor. Both R86 and R87 had suffered severe overheating — R86 had changed in value

from 39k to approximately 3k, causing overheating of R87 and eventual failure of the avc.

My 75A4 manual lists R86 as a half-watt resistor. However, a friend has a later 75A4 manual, and it shows a rating of one watt (the serial number of my receiver is in the 2500 series). If you experience avc failure in your 75A4, first check R86 and, if you're working on the receiver anyway, make sure that R86 is a one-watt resistor.

Incidentally, I cannot recommend too highly the 75A4 mixer mods described by W6ZO in *ham notebook*. I installed them over a year ago and have been extremely pleased with the results. I also changed the first rf amplifier from a 6DC6 to a 6GM6 as recommended by W2VCZ, and recommend that, too, as it increases gain and sensitivity. However, I would not plug in the 6GM6 without first installing the W6ZO mixer modifications.

Bob Locher, W9KNI  
Deerfield, Illinois 60015

## Heath HM-2102 wattmeter mods

Dear HR:

With reference to the item on the Heath HM-2102 wattmeter by VE6RF,\* the following additional information might also be of some interest. It was interesting to read how one amateur solved the problem of calibrating his Heath HM-2102 below an swr of 1.5:1. In my case the problem was solved in a slightly different manner.

In my initial calibration, using a Bird Termaline wattmeter, the minimum swr null was about 1.3:1. This was within the specified limits called for in the Heath instruction manual and, for all practical purposes, should have sufficed. However, in actual tests erroneous readings were obtained, often below the 1.3:1 reference level. An inspection of the schematic shows that C3 in series with C4 (the trimmer) will produce a capacitance of 1.99 to 5.56 pF. The total capacitance would then have to be changed to either a value lower than 1.99 pF, or higher than 5.56 pF. A 2 pF capacitor placed across C3 showed that the null could not be brought down to less than 2:1. Obviously the total capacitance of C3 and C4 had to be decreased instead of increased.

Cutting the long lead from C3 to the circuit board and inserting several values of capacitance in series with C3 showed an immediate improvement in the null. In my case a 10 pF capacitor brought the null down to a 1:1 swr. The total range of all three capacitors in series is now 1.66 to 3.57 pF. Replacing C3 with a capacitor of about 4 pF would probably have produced the same results. Since the capacitors in this circuit form an ac voltage-divider network, changes in this circuit will also affect the wattmeter reading so the wattmeter will also have to be recalibrated.

\*R. Fransen, VE6RF, "Better Balancing of the Heath HM-2102 Wattmeter," *ham radio*, January, 1975, page 56.

In my case no thought was given to changing capacitor C16 since this appears to be a bypass for frequencies outside the desired range of 50 to 160 MHz. Changes here could influence the sensitivity of the bridge and may even bypass energy at the wanted frequencies.

In addition to the above, I found two other slight modifications to be useful. The first concerns wattmeter calibration. According to the instruction manual, power calibration is performed with the wattmeter in the 25-watt range; no provision is made for calibrating in the 250 watt range. However, after calibrating the wattmeter on the low range using 20 watts of power, switching to the high range showed a meter reading of about 16 watts. An examination of the schematic shows that if R8, a 68k resistor, is replaced by a fixed resistor and potentiometer in series, a second calibration can be made on the 250-watt range which is quite accurate. In my case R8 was replaced by a 51k, 1/4-watt fixed resistor in series with a small 25k potentiometer.

The last modification was for convenience more than anything else. In order to locate the remote chassis closer to the coax feedline, the short piece of five-conductor cable supplied with the kit was replaced with similar cable about 6-feet (1.8m) long. One end of the cable was connected inside the cabinet in accordance with the instructions, but the other end was terminated in a small five-pin plug instead of being connected directly to the remote chassis. A matching five-pin socket was mounted on the chassis off to one side of coax connector A. Short leads were then run from the circuit board to the five-pin socket. To prevent rf from reaching the indicator unit through the cable, the ferrite beads supplied with the kit were mounted at the socket instead of on the circuit board. Now the indicator unit and remote chassis can be easily separated.

**B. T. Ring, K3VNR**  
Riverdale, Maryland

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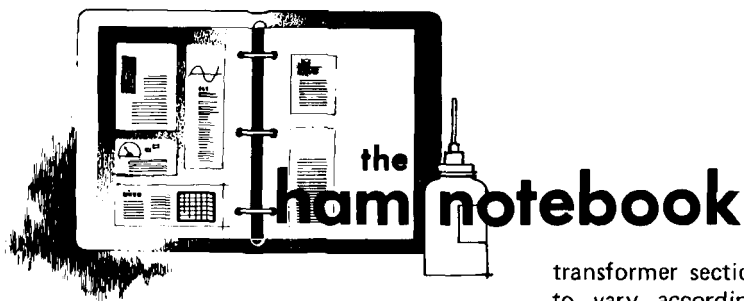
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## non-synchronous impedance transformer

In matching one impedance level to another, as in antenna work, the usual device is a quarter-wavelength transformer section whose characteristic impedance is the geometric mean of the two impedances to be matched (fig. 1). When it is necessary to match one transmission line to another, and particularly in coaxial line applications, obtaining a length of line of the proper intermediate characteristic impedance may present a major problem.

The non-synchronous transformer shown in fig. 2 offers a way out of this dilemma. It is composed of two abbreviated lengths of transmission line of the same characteristic impedance as the impedances being matched. The procurement problem is therefore greatly simplified. As indicated in fig. 2, the

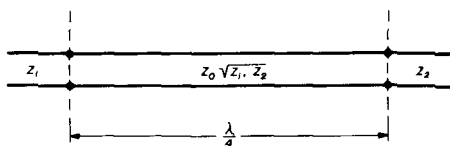
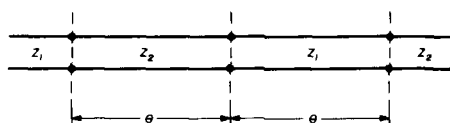


fig. 1. Characteristic impedance of the quarter-wavelength transformer is equal to the geometric mean of the impedances being matched.

transformer section length can be seen to vary according to the impedance ratio. For example, if a 2:1 impedance transformation ratio is required, each section of the transformer would be  $28^{\circ} 8'$ , making the total length about  $56\frac{1}{2}$  degrees, or in terms of wavelength,  $0.156 \lambda$ .

It must be pointed out that the non-synchronous transformer is not al-



$$\theta = \cos^{-1} \sqrt{\frac{Z_1}{Z_2} + 1 + \frac{Z_2}{Z_1}} \quad l = \frac{\theta \lambda}{360}$$

fig. 2. The non-synchronous transformer consists of two lengths of transmission line of the same characteristic impedance as the impedances being matched, with length varying according to the impedance ratio.

ways interchangeable with the quarter-wavelength version. The quarter-wavelength transformer will match an infinite number of impedance pairs, as long as their geometric mean is equal to the characteristic impedance of the transformer. The non-synchronous transformer, on the other hand, will match only the impedance pair for which it was designed. Within these limits, however, the non-synchronous transformer compares very favorably in

bandwidth as well as impedance-matching characteristics, and should find ready application in coaxial impedance-matching networks.

Henry Keen, W5TRS

## drilling aluminum

The following hint for working with aluminum, which may not be common knowledge, was given to me by ham friends in Portugal: apply a drop or two of alcohol when drilling aluminum. It not only makes the work easier but results in a much cleaner cut.

Ralph Cabanillas, Jr., W6IL

## metric conversions for screw and wire sizes

Here's a conversion chart you can use for plugging in metric values for machine screws and wire sizes. *Ham radio* articles have been including metric equivalents for dimensions of physical quantities such as area, length, mass, temperature, and volume. We have wanted to include metric equivalents for machine screws and wire but have only recently been able to obtain equivalent data for this hardware from the International Standards Organization (ISO). The ISO standard has not yet been adopted by all countries, but these

table 1. Thread conversion, American to metric.

American standard	nearest metric standard
0-80	M1.6
1-64	M1.8
2-56	M2
3-48 or 3-56	M2.5
4-40	M3
6-32	M3.5
8-32	M4
10-24 or 10-32	M5
12-24 or 12-28	M6
1/4-20	M7
3/8-16	M10
7/16-14	M12
1/2-12	M12

table 2. Wire-size conversion, American (AWG) to metric.

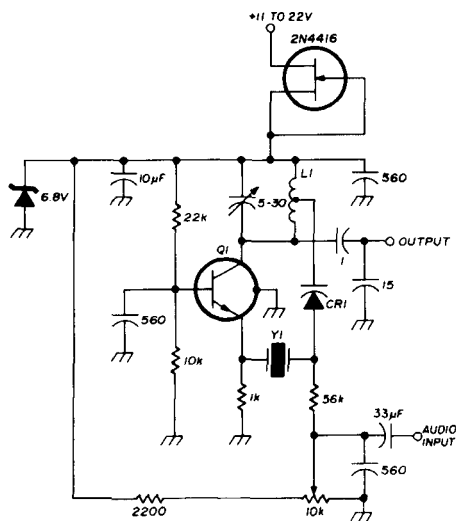
American standard (AWG)	nearest metric standard (mm)
2	6.5
4	5.2
6	4.1
8	3.3
10	2.6
12	2.1
14	1.6
16	1.3
18	1.0
20	0.8
22	0.6
24	0.5
26	0.4
28	0.3
30	0.25
32	0.2

tables will at least give overseas readers an idea of what size the author specified in the nearest metric standard.

Jim Fisk, W1DTY

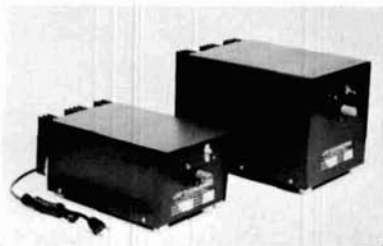
## short circuit

In DJ2LR's excellent article on crystal oscillators in the June, 1975, issue of *ham radio*, there was an error in fig. 5 (10k pot incorrectly shown). The correct schematic is presented below.



# new products

## low-voltage, high-current power supplies



High-current power supplies are an absolute requirement in commercial two-way radio shops and are now on the verge of becoming a requirement in the ham shack. Most of the new solid-state equipment being released for the amateur market is designed for 12-volt operation, either mobile or from a fixed station 12 Vdc supply. The 12-volt ac supply has been a problem in the past because well-regulated, high-current supplies tend to be complex and expensive to build while commercially available supplies are even more expensive and are frequently in short supply. VHF Engineering has recently announced two

inexpensive solid-state 12 Vdc power supply kits which are simple to build and can be used in either commercial or amateur applications. Two models are available, the PS12C for 12 amps, and the PS24C for 24 amps.

The circuit for both power supplies consists of a full-wave dc current source feeding a capacitive filter network and an IC voltage regulator. The IC regulator controls a set of pass transistors and keeps the output voltage consistent to within 2% over a load range of from zero to 20 amps (zero to 10 amps in the PS12). Large heat sinks are provided to dissipate the heat produced by the pass transistors. The 12-amp supply is rated at 10 amps continuous or 12 amps for 50% intermittent duty. The 24-amp supply is rated at 20 amps continuous or 24 amps for 50% intermittent duty. Current limiting prevents damage to the supply in the case of an accidental short circuit. The output voltage of both supplies may be adjusted over a nominal range from 12 to 15 volts. The supplies may be used as general purpose, variable voltage supplies by replacing the voltage controlling resistor with a 10k potentiometer.

The VHF Engineering high-current power supply kits are complete with all parts, computer grade capacitor, epoxy glass circuit boards, styled case, and complete instructions. Average construction time is one evening or less. The 12-amp supply kit, model PS12C, is priced at \$69.95 (\$85.95 wired and tested). The 24-amp supply kit, model PS24C, is \$99.95 (\$114.95 wired and tested). For more information, write to VHF Engineering, 320 Water Street, Binghamton, New York, 13902, or use *check-off* on page 110.

## scientific calculator



The new six-ounce HP-21 from Hewlett-Packard is the smallest and lowest priced model in HP's line, and is designed primarily for scientists, engineers and students. The HP-21 has all of the trigonometric and logarithmic functions of the HP-35. In addition, the user can calculate in either degrees or radians; convert from polar to rectangular coordinates and vice versa; format and round the display in either fixed or scientific notation; and perform register arithmetic (+, -, X, ÷) with the contents of the HP-21's single addressable memory.

The new calculator has five fewer keys (30) than other HP pocket models, but since several keys serve dual functions, the HP-21 is able to perform more functions and operations than the HP-35. Like other HP pocket calculators, the HP-21 features the company's RPN logic system with a four-memory stack that holds intermediate answers and automatically brings them back when needed in a calculation.

The HP-21 comes with an owner's handbook, soft carrying case and an ac adapter/recharger that allows the calculator to be operated on ac while its batteries are recharging. Optional accessories include a security cradle and a reserve power pack (with batteries). The HP-21 will be sold through leading col-



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Vancouver, WA 98663  
Phone 206/573-2722

lege bookstores and department stores, by direct mail and through HP's calculator sales force. For more information, use *check-off* on page 110.

## 525-MHz uhf prescaler

The new Pagel model 525 uhf prescaler divides frequency by ten to extend the range of any 50 MHz or higher counter to the vhf and uhf bands. The unit also contains a 20 dB preamp for the unscaled 1 MHz to 50 MHz range to improve frequency counter sensitivity to 5 millivolts rms or better. Sensitivity is 50 mV rms at 500 MHz, and 30 mV rms below 400 MHz. A through-line feature with an internal signal sampler can be used with transmitters up to 100 watts (requires an external 50-ohm dummy load). This feature can be used to perform simultaneous power and frequency measurements and is a great time saver.

The model 525 operates from the 117 Vac line or battery power (8 to 15 volts) and may be used for portable or mobile use. Price is \$159. For more information, write to Pagel Electronics, 6742-C Tampa Avenue, Reseda, California 91335, or use *check-off* on page 110.

## envelope detector

The *Modset* recently introduced by David R. Corbin Manufacturing is an envelope detector which can be used with an oscilloscope to provide a clear, hum-free display of the transmitted audio waveform from ssb and a-m transmitters. The *Modset* is built into a rugged, machined aluminum box, and includes input and output impedance matching and an overload protection circuit.

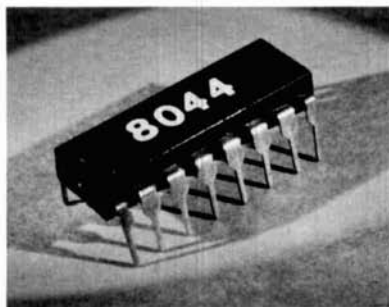
The *Modset* accepts any input signal from a few milliwatts to 25 watts peak power and operates over the frequency



range from 200 kHz to 30 MHz; to 50 MHz with slight reduction in output level. Higher power levels can be monitored by using a short whip antenna or probe instead of the 50-ohm direct coupling. Output level is 0.1 to 10 volts (relative to input power), dc reference plus recovered audio to 10 kHz. The unit is priced at \$29.50.

For more information, write to David R. Corbin Manufacturing, Post Office Box 44, North Bend, Oregon 97459, or use *check-off* on page 110.

## keyer chip adds dash memory



A companion to the 8043 keyer-on-a-chip has been announced by Curtis Electro Devices. Called the 8044, this new cmos IC offers dash memory in addition to the features found on the 8043. These are dot memory, dot, dash and space completion, instant start, key debouncing filters, iambic operation, internal sidetone, weight control and practically zero power dissipation.

An exact pin-for-pin equivalent to the 8043, the 8044 yields a top performance one-IC electronic keyer capable of running on 5 to 12 volt supplies. Usual power supply is a 9-volt transistor radio battery. The 8044 may be plugged into any keyer designed around the 8043 such as that described in the April, 1975, issue of *ham radio*.

The keyer kits are offered. The 8044-1 contains the 8044, a printed-

## LOW COST DIGITAL KITS

### NEW BIPOLAR MULTIMETER: AUTOMATIC POLARITY INDICATION



Model ES 210K

Displays Ohms, Volts or Amps in 5 ranges • Voltage from 100 Microvolts to 500 V • Resistance from 100 Milliohms to 1 Megohm • Current from 100 Nano Amps to 1 Amp • \$80.00 Case included. (Optional probe \$5.00).

### 40 MHz DIGITAL FREQUENCY COUNTER:

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ES 220K - Line frequency time base.

1 KHz resolution . . . 5 digit: \$79.50. Case extra: \$10.00

ES 221K - Crystal time base.

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### DIGITAL CLOCK:



ES 112K/124K • 12 hour or 24 hour clock: \$46.95.

Case extra: Metal \$7.50

### CRYSTAL TIME BASE:

ES 201K - Opt. addition to ES 112K, 124K or 500K  
Mounts on board. Accurate to .002% . . . \$25.00

### I.D. REMINDER:

ES 200K - Reminds operator that 9 minutes and 45 seconds have passed. Mounts on ES 112 or 124 board. Silent LED flash: \$10.95. Optional audio alarm \$4 extra.

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C-MOS Keyer Wired \$24.95  
Kit \$19.95

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		DOUBLE	48	\$15.50
108 to 144	VHF AIRCRAFT	SINGLE	20	\$10.50
		DOUBLE	40	\$12.50
135 to 139	SATELLITE	SINGLE	20	\$18.50
		DOUBLE	40	\$24.50
144 to 148	2 METER	SINGLE	20	\$9.50
		DOUBLE	40	\$12.50
146 to 174	HIGH BAND	SINGLE	20	\$18.50
		DOUBLE	40	\$24.50
220 to 225	1 3/4 METER	SINGLE	18	\$9.50
		DOUBLE	35	\$12.50
225 to 300	UHF AIRCRAFT	SINGLE	15	\$9.50
		DOUBLE	30	\$12.50
1 thru 30	HF BROADBAND	19-36	3	\$18.50

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circuit card, a socket and instruction manual. The 8044-2 kit contains the foregoing plus the parts necessary to complete a deluxe keyer exclusive of chassis, jacks, switches, speaker and knobs. This keyer will key  $\pm 300$  volts at 200 mA. The 8044 is priced at \$24.95, the 8044-1 kit at \$32.95 and the 8044-2 is \$57.95. Like the 8043, the 8044 carries a lifetime guarantee.

For further information, contact Curtis Electro Devices, Box 4090, Mountain View, California 94040, or use *check-off* on page 110.

## essential formulae for electronic and electrical engineers

This new book by Noel M. Morris provides all of the essential electrical and electronic formulas required by students, technicians and professional engineers. The rapid growth of electronics technology has made it practically impossible to memorize all the formulas which are required. This book contains all the basic equations in the fields of electronics, electrical engineering, control systems, measurements, logic, telecommunications and mathematics. Sections include electrostatics and electromagnetism, complex numbers, ac and dc circuits, transients, amplifiers and oscillators, modulation and transmission lines. The SI system of units is used throughout.

This book assumes that the reader is familiar with each of the formulas, so it does not provide any typical examples or information describing how to use them. However, for the serious worker who frequently needs this information, this valuable book provides it all in one place. 26 pages, softbound, 8 1/4 x 11 1/2 inches, \$2.95 from Halstead Press, a Division of John Wiley & Sons, 605 Third Avenue, New York, New York 10016.

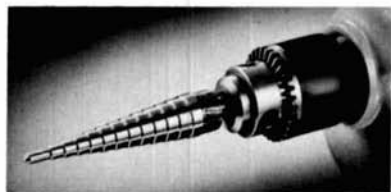
## tracking voltage regulators

Three new dual tracking voltage regulator ICs are now available from National Semiconductor. Called the LM125, LM126 and LM127 (LM325, LM326 and LM327 for commercial temperature range), the regulators are designed to provide balanced positive and negative output voltages at currents up to 100 milliamps. Input voltage can be as high as  $\pm 30$  volts, and there is a provision for external adjustable current limiting.


The LM125 provides tracking outputs of  $\pm 15$  volts making it ideal for op amp power supplies. It features output voltages balanced to within 1% and line and load regulation of 0.06%. The LM126 provides  $\pm 12$  volt outputs balanced to within 1% and features line and load regulation of 0.08%, while the LM127 has +5 and -12 volt outputs which are compatible with most mos circuits.

For more information, contact National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051, or use *check-off* on page 110.

## stepped drill bit



The Unibit,<sup>®</sup> a versatile single flute step drill that does the work of thirteen conventional twist drill bits, is now available. The first Unibit model, designed to fit any three-jawed  $\frac{1}{4}$ " (6.5mm) chuck, is intended primarily for use with hand-held electric drills. It has a starting diameter of  $\frac{1}{8}$ " (3mm)



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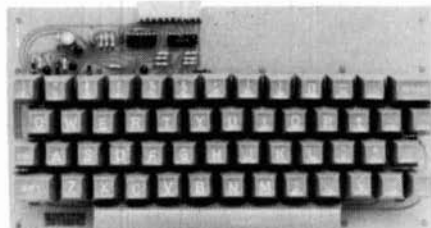
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- \* 53 Keys
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- \* Upper and Lower Case
- \* Standard ASCII Output
- \* Two Key Lockout

We are happy to announce a new addition to our keyboard and encoder line. Our new KBD-3 uses a one chip MOS encoder system to give you maximum possible features with a minimum number of parts.

This keyboard produces a standard ASCII coded output that is compatible with TTL, DTL, RTL and MOS logic systems. You have the option of wiring the kit for normal typewriter style output in both upper and lower case letter, or all upper case format. All common machine control commands such as "line feed", "return", "control", etc. are provided on the keyboard. Four uncommitted or extra keys are available for your specific use requirements. Two of these have isolated output lines to the connector for special functions such as "here is".

Keyswitches are standard, full travel style with gold plated contacts for long trouble-free service. Requires +5 Volts and -12 Volts.

**KBD-3 Keyboard and Encoder Kit \$49.50 ppd**

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and each of twelve succeeding steps removes material in 1/32" (0.8mm) increments up to 1/2" (12.5mm) diameter. Each step penetrates material up to 1/8" (3mm) thick.

The Unibit is made of industrial grade high-speed steel, heat treated and tempered to assure maximum strength for long wearing, rugged use. It exhibits superior characteristics when drilling thinner gauges of sheet metals such as steel, copper, brass and aluminum as well as most plastics and wood. Starting a hole with the Unibit is a snap because its single flute design eliminates skidding and the need for center punching. Chatter and vibration are also kept to a minimum. Its design geometry also helps prevent the Unibit from penetrating softer material too fast and "hogging-in."

Many other operations, considered difficult with conventional twist drills, can be conveniently accomplished using the Unibit. Its unique cutting edge angle automatically de-burrs a hole, eliminating a time consuming countersink tool change. The Unibit allows for sizing or aligning and reaming operations, drilling intersecting holes as well as enlarging a slot or a square into a round hole. In addition, the Unibit is available with a special non-slip key on its shank that prevents it from spinning in the chuck.

The newest Unibit drill, Model II, enables the drilling of eight round holes, sizes 9/16-inch (14.5mm) to one-inch (25.5mm), with a single bit. The Unibit II requires a starting diameter of 1/2-inch (12.5mm) or larger and removes material in 1/16-inch (1.5mm) increments in eight steps.

Designed for use with any 1/2-inch drill chuck, Unibit II works equally well with hand-held electric drills as well as drill press equipment. The Unibit II is made of industrial grade, high speed steel, heat treated and tempered to assure maximum strength for long wearing use. Its patented design features a single flute to assure smooth penetra-

tion of materials and, unlike conventional twist drills, it is easily sharpened without special tools. Unibit II is extremely versatile and allows the user to perform many operations including intersecting holes, making round holes from slots, hole de-burring and a "hole-opening" reamer.

Unibit literature, information and prices are available by contacting the Unibit Corporation, Box 331, Department 2, Wyoming, New York 14591, or by using *check-off* on page 110.

## how to use ic logic elements

Just released and completely illustrated, this new book by Jack Streater is designed to help the engineer or technician who has not previously used or designed digital logic circuits meet the challenge of digital ICs in electronics. The practical problems and limitations of connecting IC logic elements into logic systems to accomplish the required result are thoroughly covered.

The first two chapters cover binary, BCD, and decimal number systems and Boolean algebra with its applications to simple switching circuits. The next two chapters discuss gates and gate combinations, and the following chapter explains bistable elements and their uses. Then the logic families (RTL, DTL, TTL, ECL, CTL or CML, MOS and diode logics) are discussed and compared.

Another chapter is devoted to off-the-shelf logic elements — breadboarding, testing, troubleshooting and locating sources of data on integrated circuits. The final chapter includes experiments to aid in understanding the operation of logic circuits. A glossary of digital terms has been included as an appendix.

Soft cover, 160 pages, \$4.50 from HR Books, Greenville, New Hampshire 03048.

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## 12 Channel 440 MHz FM Transceiver



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### Delivers 10 Watts of Power and 12 Channel Capability

You'll like the crystal clear transmit and receive performance of this compact 440 MHz unit . . . and so will those listening.

Solid state design brings you the best in American Made circuitry. Features include Automatic Frequency Control and UHF power module. Frequency range is 420-450 MHz, with 0.5  $\mu$ v tune-up sensitivity and 3 watts audio output. No need to worry about current drain, either. And all of this for the low, low price of only

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12 Channel-25 Watts  
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2 Meter FM Transceiver



**ACT 10H/L/U**  
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# Heathkit "104"...



## ...new performance standard for SSB transceivers

A revolutionary "new generation" transceiver. It's completely solid-state and totally broadbanded to eliminate preselector tuning. And the output can be instantly switched from 100 watts to 1 watt. The true digital readout offers resolution down to 100 Hz and outstanding tuning accuracy. Receiver intermodulation distortion has been minimized and there are very few active devices ahead of the highly selective crystal filter. Adjacent channel overload is negligible, yet sensitivity is better than 1  $\mu$ V (.6  $\mu$ V typical) and front-end overload is dramatically reduced. The "104" is 12 VDC-powered for mobility and the optional HP-1144 fixed station supply fits inside the SB-604 speaker cabinet. An optional noise blanker can be installed in the "104" and an optional 400 Hz crystal filter improves CW selectivity.

- Kit SB-104, 31 lbs., mailable ..... 669.95\*
- Kit SBA-104-3, 400 Hz CW crystal filter, 1 lb., mailable ..... 36.95\*
- Kit SBA-104-1, Noise blanker, 1 lb., mailable ..... 26.95\*
- Kit SBA-104-2, Mobile mount, 6 lbs., mailable ..... 36.95\*
- Kit HP-1144, Fixed station power supply, 28 lbs., mailable ..... 89.95\*

### SB-230 — the lowest-cost conduction-cooled linear around

The SB-104's "silent partner." 1200 watts PEP or 1000 watts CW from less than 100 watts drive. It's rated at 400 watts input for slow-scan TV and RTTY. The high-efficiency Eimac 8873 triode is double-shielded to reduce stray RF and a massive heat sink replaces noisy fans and blowers. The "230" assembles in just 15 to 20 hours with no alignment.

- Kit SB-230, 40 lbs., mailable ..... 319.95\*

### SB-634 station console combines 5 convenient accessories

The "634" performs 5 important functions—a 10-minute digital ID timer with visual or audible indicators an RF wattmeter that reads 0-200-or 0-2000 watts with  $\pm 10\%$  accuracy, an SWR bridge, a hybrid phone patch that can be used manually or with VOX control, and a 24-hour digital clock that runs independently of all other functions. It's a must for every well equipped station.

- Kit SB-634, 14 lbs., mailable ..... 179.95\*

### SB-614 station monitor shows you how clean your signal is

Highly visible  $1\frac{1}{2} \times 2"$  CRT detects problems that can reduce the effectiveness of your signal—non-linearity, insufficient or excessive drive, poor carrier or sideband suppression, regeneration, parasitics and CW key clicks. It monitors SSB, CW and AM signals from 80 to 6 meters. Push-pull drive for keystone free trace; automatic sync sweep generator with 3 ranges from 10 Hz to 10 kHz. Can be used as an ordinary oscilloscope from 10 Hz to 50 kHz.

- Kit SB-614, 17 lbs., mailable ..... 139.95\*

### SB-644 remote VFO

Designed exclusively for the SB-104. It provides split transmit and receive control and you aren't frequency-limited in any way—transmit at one end of the band, receive at the other. The "644" even has two crystal positions for fixed-frequency control. The "644" has a linear dial, but the exact frequency is displayed on the "104's" digital readout. The display automatically changes when switching from transmit to receive.

- Kit SB-644, 10 lbs., mailable ..... 119.95\*

### SB-604 station speaker — response-tailored to SSB

Designed to match the SB-104 in styling and performance. The "604" uses a  $5 \times 7"$ , 3.2-ohm speaker. And there's room inside for the HP-1144 power supply. With connector cable and plug.

- Kit SB-604, 8 lbs., mailable ..... 29.95\*

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## ...top value standard for 2-M transceivers

The HW-202 puts you on "two" at a price you want to pay, with the features you need. It operates on any 2 MHz segment from 143.9 to 148.3 with independent selection of 6 transmit and 6 receive channels, and all 12 can be netted. A solid 10 watts min. transmitter output, a hot 0.5  $\mu$ V receiver sensitivity. Dual-gate MOSFET front end... IC IF... dual conversion... 10.7 MHz crystal filter... built-in hash filter/voltage regulator... crystals for 146.94 MHz... push-to-talk mike... quick-connect cable for 12 V hookup... antenna coax jack... quick-release gimbal mount... complete alignment procedures using the front panel meter... and a complete line of accessories to put you on "two" with maximum versatility and low cost.

Kit HW-202, 11 lbs., mailable ..... 179.95\*

### Crystal Certificates.

Order from Heath, mail certificates to crystal mfr., get the crystals you specify, postpaid.

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HWA-202-7, one Receive Crystal certificate ..... 5.95\*

### Tone Burst Encoder.

Put this in your "202" so you don't have to whistle while you work repeaters. 4 tone buttons can be preset to any tone between 1800 and 2500 Hz. Burst duration is adjustable. Stability is  $\pm 1\%$  from  $-30^\circ$  to  $+50^\circ$ C. Mounts behind removable front panel bezel of your "202".

HWA-202-2, 1 lb., mailable ..... 26.95\*

### AC Supply.

To work your "202" as a fixed station. Delivers 13.8 VDC @ 2.2A. with better than 1% regulation.

Circuit breaker protected. Wire it for 120 or 240 VAC. Includes 3-wire line cord and transceiver cables.

HWA-202-1, 7 lbs., mailable ..... 32.95\*

### 40-watt 2-M Amplifier.

Hauls up fringe repeaters by putting out a minimum 40 W from 10 W input. Only 7A battery drain, and so compact (3 x 4 1/4 x 5 1/2) that it fits anywhere. Internal antenna changeover relay and sensing circuitry for automatic T/R switching. Tuned input/output circuits for low spurs and coverage of any 1.5 MHz portion of 143-149 MHz.

Kit HA-202, 4 lbs., mailable ..... 59.95\*

Mobile 2-M antenna; 5/8-wave whip w. rear deck clip mount has 3.4 dB gain over 1/4-wave. Inc. 17' coax.

HWA-202-3, 2 lbs., mailable ..... 19.95\*

Fixed 2-M antenna; 5/8-wave vertical w. radials has 3.4 dB gain over 1/4-wave; for mast mt.; less coax.

HWA-202-4, 4 lbs., mailable ..... 17.95\*

New mobile 2-M colinear; 1/4 & 5/8-wave phased radiators; 5.2 dB gain; swivel trunk lip mt. 17' coax.

HWA-202-9, 3 lbs., mailable ..... 37.95\*

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HWA-202-10, 8 lbs., mailable ..... 47.95\*

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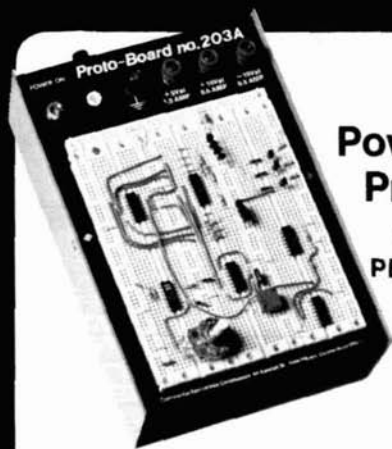






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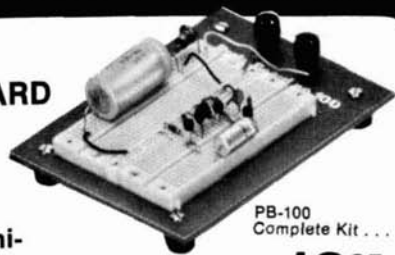


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**New Proto Boards  
PB-203 and PB-203A  
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Ready-to-use. Just plug in and start building! 2 extra floating 5-way binding posts for external signals (PB-203 only). Completely self-contained with power switch, indicator lamp and power fuse. 24 14-pin DIP capacity. All metal construction . . . no chipping or cracking as with plastic cases. Two-tone quality case makes both PB-203 and PB-203A aesthetically, as well as technically attractive.

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**A complete mini-  
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Complete Kit . . .

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The PB-100 is a low cost, big 10 IC capacity breadboard kit, complete down to the last nut, bolt and screw. Includes 2 QT-35S Sockets; 1 QT-35B Bus Strip; 2 5-way binding posts; 4 rubber feet; screws and easy assembly instructions. 4.50" (114.3mm) wide x 6.00" (152.4mm) long x 1.35" (34.3mm) high. Order your PB-100 kit! Start building and testing now!

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- 4 QT-59B Bus Strips
- 1 QT-47B Bus Strip
- Fuse • Power Switch
- Power-On Light
- 9.75"L x 6.6"W x 3.25"H
- Weight: 5 lbs.
- 5V, 1 AMP regulated power supply

# 75.

Add \$2.50 shipping/handling

#### OUTPUT SPECIFICATIONS

**Output Voltage** 5V  $\pm$  ¼V  
**Ripple & Noise** @ ½ AMP  
 10 millivolts  
**Load Regulation** Better than 1%

### PB-203A

- 3 QT-59S Sockets
- 4 QT-59B Bus Strips
- 1 QT-47B Bus Strip
- Fuse • Power Switch
- Power-On Light
- 9.75"L x 6.6"W x 3.25"H
- Weight: 5 lbs.
- 5V, 1 AMP regulated power supply (same as PB-203)
- +15V, ½ AMP regulated power supply
- -15V, ½ AMP regulated power supply

# 120.

Add \$2.50 shipping/handling

#### OUTPUT SPECIFICATIONS

**Output Voltage** 15V, internally adjustable  
**Ripple & Noise** @ ¼ AMP,  
 10 millivolts  
**Load Regulation** Better than 1%



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Self-contained, pocket size. No adjustments or calibrations needed. Puts life into digital designs. Just clip to any DIP IC up to 16 pins. **NO POWER SUPPLY NEEDED!** Simultaneously displays static and dynamic logic states of DTL, TTL,

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Trace signals or troubleshoot fast. Inject signals or wire unused circuits into existing boards. Flexible plastic web\* construction eliminates springs and pivots. Plus, the narrow throat is perfect for high density pc boards.

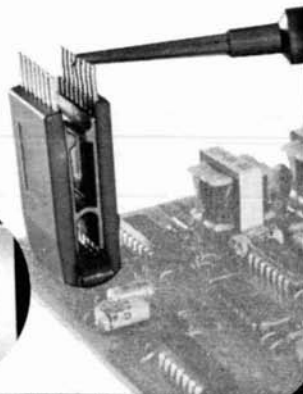
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**Scope probes, test leads lock onto unique toothed grips**



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We are pleased to announce the latest addition to the KVG high performance 9 MHz crystal filter line. The XF9-NB is a 500 Hz band width filter designed for CW reception and narrow band digital data circuits. Its characteristics almost eliminate the ringing effect present in less sophisticated narrow band filters. The XF9-NB, like all other KVG 9 MHz filters, has internal input and output transformers to facilitate matching its natural impedance to adjacent circuit stages.

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We are pleased to announce the introduction of VHF pre-amplifiers for the 50, 144 and 220 MHz bands. They consist of a two stage wide band amplifier (no tuning required) with twin outputs for feeding two independent receivers. They are especially useful for rejuvenating older converters/receivers. Additionally the twin output feature has many advantages for twin operating and similar multi-channel receiver situations. They are constructed on glass-epoxy G10 P.C. board mounted in our standard die-cast aluminum box.

	MMa 50	MMa 144	MMa 220
Freq. Range (MHz)	50-54	144-148	220-225
Nom. Gain	20dB	16dB	15dB
N.F. (typical)	2.5dB	2.8dB	3.4dB
	\$29.95	\$29.95	\$34.95

Power 12V D.C. at 20ma typical  
1 1/4" x 2 1/2" x 4 1/2" plus connectors  
Specifications apply to 50 ohm input/output system.  
Shipping \$1.00.

## VHF CONVERTERS UHF

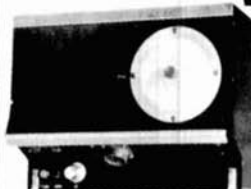
	MMc 50	MMc 144	MMc 220	MMc 432	MMc 1296
RF Freq. (MHz) +	50-54	144-148	220-224	432-436	1296-1300
IF Freq. +	28-32	28-32	28-32	28-32	28-32
N.F. (typical)	2.5dB	2.8dB	3.4dB	3.8dB	9.0dB
Nom. Gain	30dB	30dB	26dB	28dB	20dB
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R1051 or T827



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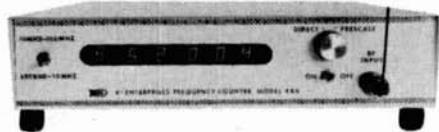
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Sensitivity	Less than 80 mV at 150 MHz
Input Z	50 ohms
Max. Input Voltage	15 V rms, 50 V dc
Time Base	Crystal Clock plus-minus 10 ppm 0°C to 40°C ambient
Readout	6 Digit 7 Segment LED
Power	120 V ac
Dimensions	2 1/4" H, 10" L, 7" D
Cabinet	Light blue

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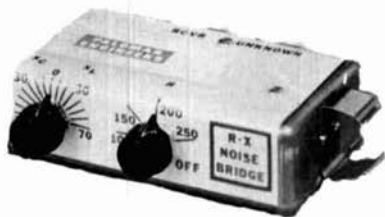
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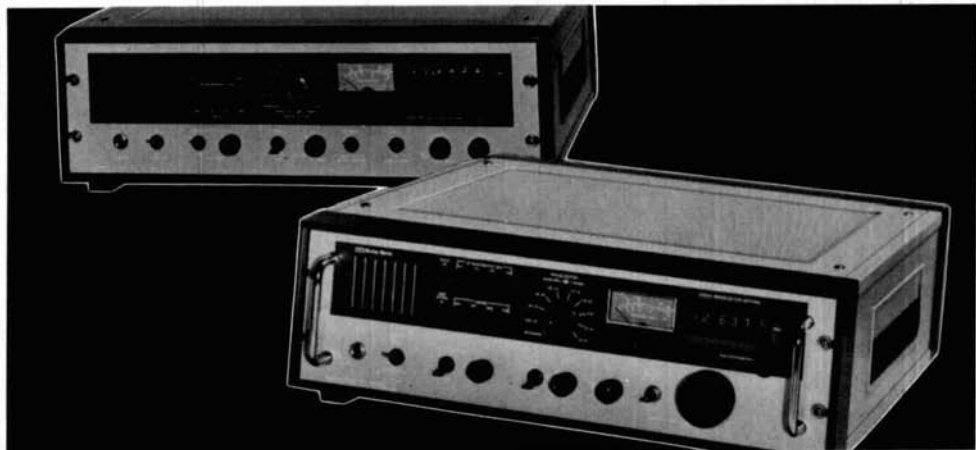
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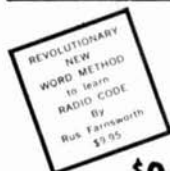
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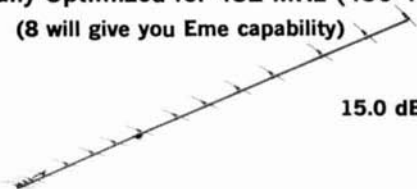
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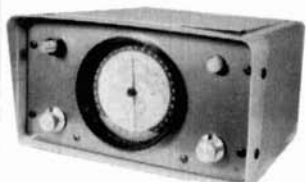
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— AT THE —

## NASHOBA VALLEY HAMFEST

SATURDAY, SEPT. 27, 1975 — WESTFORD, MASS. — 4-H FAIRGROUNDS

### PROGRAM AT FAIRGROUNDS INCLUDES:

9/26 FRI. NITE 6:00 P.M.-?

BARBECUE & CAMPING

9/27 SAT. 8:00 A.M.-5:00 P.M.

FLEA MARKET

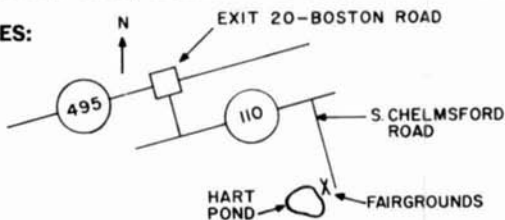
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TECH. TALKS

FOX HUNT (2 Meter)

PRIZES (All Profits Converted Into Prizes)

FOOD & REFRESHMENTS



NOTE: LOOK FOR HAMFEST SIGNS ON RT. #110.

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GENERAL ADMISSION .....	\$1.00
YL/XYL & Children under 12 .....	FREE

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675A GREAT RD.

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SEPT. 27, 1975 — AD THIS PAGE

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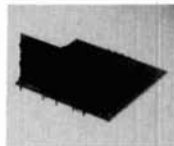


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**DIGITAL VOLTMETER**

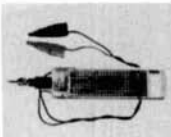


This is a 3 1/2 digit, 0-2 volt Digital Voltmeter, with a .5% full scale accuracy. It is based around the Siliconix LD110, LD111 DVM chip set. The voltmeter uses MAN7 readouts (.3" high) to provide a highly readable display. The voltmeter features the following voltages: 12, -12, 5. The unit comes complete with all components to build the unit pictured at the left, that is a complete DVM less power supply.

**\$39.95 Per Kit**

**LOGIC PROBE**

The Logic Probe is a unit which is for the most part indispensable in trouble shooting logic families: TTL, DTL, RTL, CMOS. It derives the power it needs to operate directly off of the circuit under test, drawing a scant 10 mA max. It uses a MAN3 readout to indicate any of the following states by these symbols: (H)-1 (LOW)-0 (PULSE)-P. The Probe can detect high frequency pulses to 45 MHz. It can't be used at MOS levels or circuit damage will result.



**\$9.95 Per Kit**

**DIGITAL COUNTER**

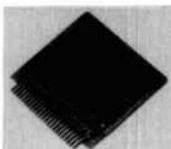


This is a 4 digit counter unit which will count up to 9999 and then provide an overflow pulse. It is based around the Mostek MK5007 digital counter chip. The unit performs the following functions: Count Input, RESET, Latch, Overflow. The counter operates up to 250 kHz. The counter is an ideal unit to be used as a frequency counter, where the only extra components needed would be a timebase, divider chain and gate. The unit requires 5V, and -12V. The unit comes complete as shown on the left less power supply.

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**5 VOLT 1 AMP T<sup>2</sup>L SUPPLY**



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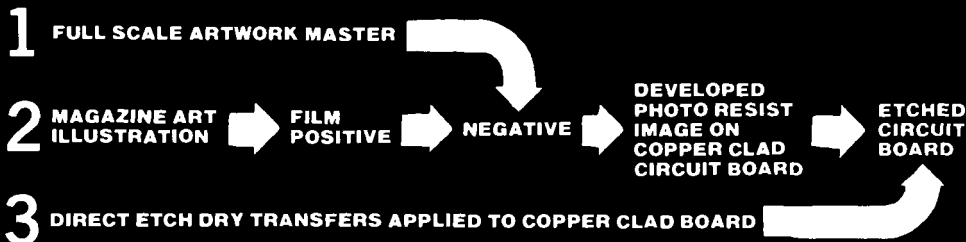
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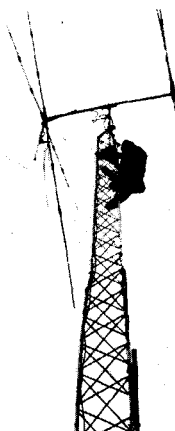
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**CINCINNATI HAMFEST**: 38th annual — Sunday, September 21, 1975 at the New Stricker's Grove on State Route 128, one mile west of Ross (Venice), Ohio. Flea market, contests, model aircraft flying, food and beverages all day. Advanced Tickets \$7.00, covers everything; \$8.00 at gate. For tickets or further information: Carl J. Dettmar, W8NCV, 8630 Cavalier Drive, Cincinnati, Ohio 45231.

**WANTED**: Ham Radio Magazine, March & November '71, February '72, May & August '73, February & October '74, January & May '75. Will pay a fair price. Edward A. Stoltzfus, P. O. Box 73, Parkersburg, PA 19365.

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**INTERNATIONAL** friendship, emergency communication public service, monthly publication "World-radio", trial subscription - two issues \$1, 2509-C Donner, Sacramento, CA 95818.

**SOCIETY OF WIRELESS PIONEERS** offers Life Membership to active and former C.W. operators on comm'l., military, gov't., etc. wireless/radio circuits. Contact: Society of Wireless Pioneers, Dept. H, P. O. Box 530, Santa Rosa, California 95402.

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**RECIPROCATING DETECTOR**, write Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

**WANT:** Non-working R-390-A receiver, also will calibrate the vfo from same for \$40.00 postpaid. Make it track within one KC. Want 390-A parts. W4AIS, 306 Thornwood Dr., Taylors, S. C. 29687.

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**RECONDITIONED TEST EQUIPMENT** for sale. Catalog \$50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

**SPRING MILL (INDIANA) HAMFEST,** Sunday, October 12, 1975 at Spring Mill State Park near Mitchell, IN. Prizes, flea market, entertainment. Write The Hoosier Hills Ham Club, P. O. Box 375, Bedford, IN 47421.

**MANUFACTURERS, Distributors!** The Memphis Hamfest will be bigger than ever. The dates are Saturday and Sunday, October 4 and 5. Best location possible — State Technical Institute, Interstate 40 at Macon Road. Security. Contact Chairman, Harry Simpson W4SCF, Box 27015, Memphis, TN 38127, phone 901 358-5707.

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**QSL'S — BROWNIE W3CJI —** 30356 Lehigh, Allentown, Pa. 18103. Samples with cut catalog 35¢.

**PENNSYLVANIA QSO PARTY,** September 13 & 14, 1975. All amateurs are invited to participate. Write to the sponsors, Nittany Amateur Radio Club, P. O. Box 60, State College, Penn. 16801 for complete rules, scoring and other details.

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**TEXAS —** The Tidelands Amateur Radio Society's Annual Hamfest is Sunday, October 5, 1975, 9 a.m. 'til ? at the Galveston County Park, League City. Advance registration \$1.50, \$2.00 at door. Free parking, swap booths and refreshments available. Main drawing for prizes at 3:00 p.m. for info send S.A.S.E. to Luke Sterling, 105 Seabreeze Drive, League City, Texas 77573.

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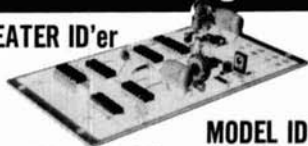
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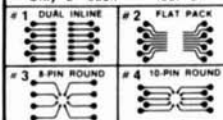
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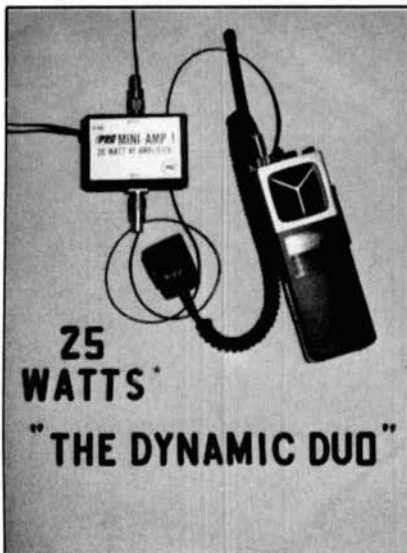
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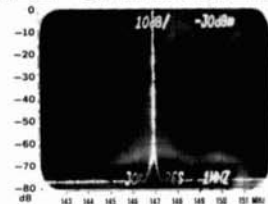
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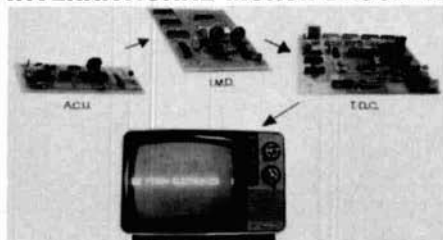
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## INDEX

Abar	325	K-Enterprises	071
Adva	265	K. E.	072
Aldelco	347	KLM	073
Antenna Mart	009	Kenwood	341
Atlas	198	Kolar	334
Barry *		Larsen	078
Budwig	233	Leland	193
Bullet	328	Levy	291
Buyers & Sellers	329	MFI	082
CFP	022	Matrix	084
Cal-Com	282	M-Tech	357
Clegg	027	Nashoba Valley Hamfest *	
Continental		National	
Specialties	348	Semiconductor	323
Comm. Spec.	330	N. E. Digital	336
Corbin	349	Northshore	
Curtis	034	RF Technology	296
Cush Craft	035	Optoelectronics	352
D-D	269	PRA Industries	316
Dames, Ted	324	Pagel	092
Datak	277	Palomar	093
Data Signal	270	Pinon	337
Davis	332	Police Call Mag.	199
Dentron	259	Poly Paks	096
Digital Tech.	350	Porta-Pak	274
Drake	039	RMS	239
Dycomm	040	RP	098
E S Ent.	208	R/T Labs	358
Ehrhorn	042	Radio Engineering	
Eimac	043	Service	353
Electronic Dist.	044	Callbook	100
Elect. Equip. Bank	288	Radio King	354
ELPROCON	301	Regency	102
Epsilon	046	SAROC	146
Fair	048	Savoy	105
Fred Franke	289	Skandia	338
Genave	168	Southwest Tech.	263
HR Report	150	Space Electronics	107
Hal	057	Specialty Comm.	
Hale	302	Systems	318
Halstead Press	308	Spectronics, FM	191
Ham Radio	150	Spectrum	108
Hamtronics	246	Summit	339
Heath	060	Swan	111
Heights	061	Teco	113
Henry	062	Topeka FM	115
Hewlett Packard	281	Tri-Line	355
Hy-Gain	064	Tri-Ex	116
ITT,		Tufts	321
Mackay Marine	184	Unibit	356
Icom	065	VHF Engineering	121
Info-Tech	351	Valu-Pak	264
International		Vanguard	346
Crystal	066	Webster	255
James	333	Weinschenker	122
Jan	067	Wilson	123
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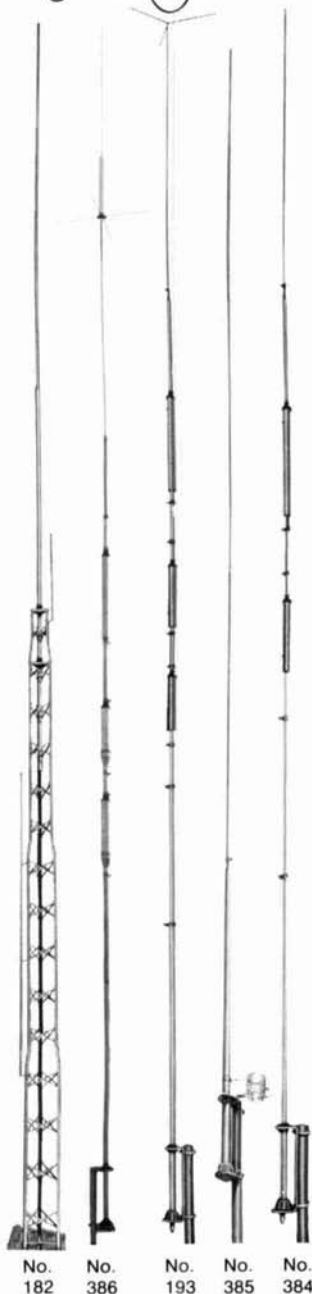
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# Advertisers Index

Abar Research	104
Adva Electronics	101
Aldelco	106
Antenna Mart	15
Atlas Radio Co.	106
Barry	109
Budwig Manufacturing Co.	106
Bullet	103
Buyers & Sellers	92
CFP Communications	102
Cal-Com Systems, Inc.	104
Clegg Division of ISC	27
Continental Specialties Corp.	80, 81
Communications Specialists	104
Cush Craft	Cover II
D-D Enterprises	103, 108
Dames, Ted	82
Datak Corp.	97
Data Signal, Inc.	65, 72
Davis Electronics	96
Dentron Radio Co.	56, 57
Digital Techniques	106
Drake Co., R. L.	83
Dycomm	105
E S Enterprises	71
Ehrhorn Technological Operations	1
Eimac, Div. of Varian Assoc.	Cover IV
Electronic Distributors	97
Electronic Equipment Bank, Inc.	88
ELPROCON	85
Epsilon Records	96
Fair Radio Sales	90
Fred Franke, Inc.	86
General Aviation	91
HR Report	108
Hal Communications Corp.	2
Hale Electronics	102
Ham Radio	106
Hamtronics, Inc.	90
Heath Company	76, 77
Heights Manufacturing Co.	
Henry Radio Stores	Cover III
Hy-Gain Electronics Corp.	111
ITT, Mackay Marine	85
Icom	5
Info-Tech	104
International Crystal Mfg. Co. Inc.	53
James Electronics	78, 79, 95
Jan Crystals	108
Janel Labs	104
K-Enterprises	84
K. E. Electronics	104
KLM Electronics	87
Trio-Kenwood Communications Inc.	112
Kolar, Inc.	94
Larsen Electronics	104
Leland Associates	90
Levy Associates	43
MFI Enterprises	94
Matrix	106
M-Tech	92
Nashoba Valley Hamfest	92
New England Digital Electronics	96
Northshore RF Technology	88
Optoelectronics	88
PRA Industries	107
Palomar Engineers	84, 103
Pinon Electronics	108
Police Call Magazine	84
Poly Paks	98
Porta-Pak	94
RMS Corporation	92
RP Electronics	107
R/T Labs, Inc.	104
Radio Amateur Engineering Service	95
Radio Amateur Callbook, Inc.	92, 100
Radio King	90
Regency Electronics, Inc.	75
SAROC	106
Savoy Electronics	86
Skandia, Inc.	109
Southwest Technical Products	74
Space Electronics Corp.	95
Specialty Communications Systems	96
Spectronics, FM	89, 94
Spectrum International	92
Summit Enterprises	96
Swan Electronics	7, 93
Teco/Tucker Electronics	69
Topeka FM Communications	97
Tri-Line Co.	107
Tri-Ex Tower Corp.	21
Tufts Radio Electronics	86
VHF Engineering, Div. of	
Brownian Elect. Corp.	47
Valu-Pak	96
Vanguard Labs	105
Webster Radio	104
Weinschenker	106
Wilson Electronics	61
Yaesu Musen USA	35, 106



# No room? Get a ###hy-gain vertical antenna!



Even if you're limited to just a few square feet of real estate, you've got room for a high performance Hy-Gain multi-band vertical. Great coverage in minimum ground space, or roof mount for optimum performance using Hy-Gain 12RMQ or 14RMQ Roof Mount/Radial Kit. All these antennas are entirely self-supporting.

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Improved for even greater wide-band performance! Three separate Hy-Q Traps with oversize coils for extremely high Q.  $\frac{1}{4}$  wave resonance on all bands. Outstanding low angle radiation pattern. Roof mount with 14RMQ. Ht. 18'. Wt. 8.6 lbs.

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#### 12AVQ 10, 15 and 20 meters

Inexpensive tri-band vertical for performance with minimum investment in space and equipment. Low radiation angle. Roof mount with 12RMQ. Ht. 13'6". Wt. 6.8 lbs.

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For prices and information, contact your local Hy-Gain distributor or write Hy-Gain.

###hy-gain

Hy-Gain Electronics Corporation; 8601 Northeast Highway Six; Lincoln, NE 68507; 402/464-9151; Telex 48-6424.  
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There are several good transceivers on the market today. But if you compare them carefully . . . study the specifications, note the important features, and finally talk to some Kenwood owners, you will have to come to the same conclusion that thousands of others have come to . . . you can't buy a better rig for the money than a Kenwood. Every unit is built with pride and designed to give top performance year after year. Join the switch to Kenwood.



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# the new look of a proven performer



## the tempo 'ONE' SSB TRANSCEIVER

*... a proven name, a proven value. Look at the specifications, look at the price tag, ask any of the thousands of Tempo ONE owners about its reliability... and the reason for its unparalleled popularity will be obvious.*

### SPECIFICATIONS

**FREQUENCY RANGE:** All amateur bands 80 through 10 meters, in five 500 khz. ranges: 3.5-4 mhz., 7-7.5 mhz., 14-14.5 mhz., 21-21.5 mhz., 28.5-29 mhz. (Crystals optionally available for ranges 28-28.5, 29-29.5, 29.5-30 mhz.)

**SOLID STATE VFO:** Very stable Colpitts circuit with transistor buffer provides linear tuning over the range 5-5.5 mhz. A passband filter at output is tuned to pass the 5-5.5 mhz. range.

**RECEIVER OFFSET TUNING (CLARIFIER):** Provides  $\pm 5$  khz. variation of receiver tuning when switched ON.

**DIAL CALIBRATION:** Vernier scale marked with one kilohertz divisions. Main tuning dial calibrated 0-500 with 50 khz. points.

**FREQUENCY STABILITY:** Less than 100 cycles after warm-up, and less than 100 cycles for plus or minus 10% line voltage change.

**MODES OF OPERATION:** SSB upper and lower sideband, CW and AM.

**INPUT POWER:** 300 watts PEP, 240 watts CW

**ANTENNA IMPEDANCE:** 50-75 ohms

**CARRIER SUPPRESSION:** -40 dB or better

**SIDE BAND SUPPRESSION:** -50 dB at 1000 CPS

**THIRD ORDER INTERMODULATION PRODUCTS:** -30 dB (PEP)

**AF BANDWIDTH:** 300-2700 cps

**RECEIVER SENSITIVITY:**  $1/2 \mu\text{v}$  input S/N 10 dB

**AGC:** Fast attack slow decay for SSB and CW.

**SELECTIVITY:** 2.3 khz. (-6 dB), 4 khz. (-60 dB)

**IMAGE REJECTION:** More than 50 dB.

**AUDIO OUTPUT:** 1 watt at 10% distortion.

**AUDIO OUTPUT IMPEDANCE:** 8 ohms and 600 ohms

**POWER SUPPLY:** Separate AC or DC required. See AC "ONE" and DC "ONE" below.

**TUBES AND SEMICONDUCTORS:** 16 tubes, 15 diodes, 7 transistors

TEMPO "ONE" TRANSCEIVER \$399.00

AC/ONE POWER SUPPLY

117/230 volt 50/60 cycle... \$99.00

DC/1-A POWER SUPPLY 12 volts DC \$120.00

Prices subject to change without notice.

The Tempo line is available  
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# **EIMAC** has powered communications via this satellite for 30 years.

The first moonbounce signal was heard nearly 30 years ago when the U.S. Signal Corps Engineering Laboratory (under the direction of W4ERI, the Project Officer) received echoes from the moon on 111.5 MHz. A pair of EIMAC 1000Ts, driven by EIMAC 450THs, were used in the transmitter. The first radio amateur EME (Earth-Moon-Earth) echoes were received by W4AO and W3GKP twenty-five years ago. Again, EIMAC was there.

The first two-way moonbounce QSO took place 15 years ago between W6HB and WIBU. EIMAC klystrons were used at both stations. From these early, controlled experiments, EME communication quickly grew as interested VHF operators turned to this new and exciting mode of communication.

Today, aided by EIMAC tubes, moonbounce QSO's are commonplace on the 144 MHz and 430 MHz bands using CW and SSB modes. On 2 meters, for example, W6PO has worked 7 countries and 28 states via moonbounce using an EIMAC 8877 in his transmitter. On 432 MHz, VE7BBG has worked 5 continents using two EIMAC 4CX250Bs.

VHF moonbounce is here! Interested? Send your QSL card for EIMAC's Amateur Service Bulletin AS-49 and get the latest information on this fascinating mode of communication. EIMAC, Division of Varian, 301 Industrial Way, San Carlos, California 94070. (415) 592-1221.

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