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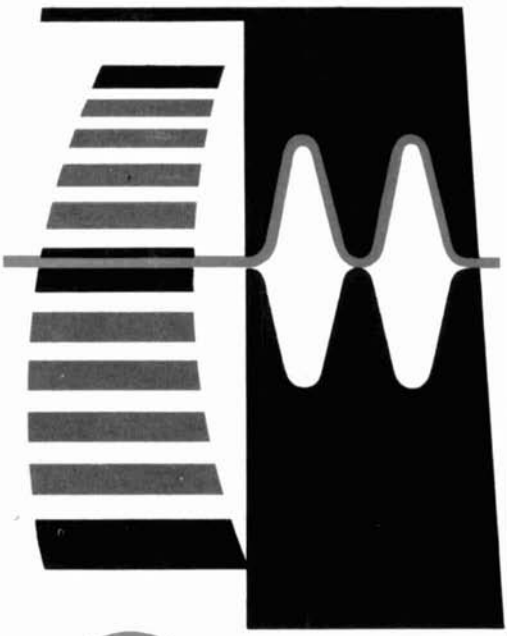
OCTOBER 1970

an swr meter



for accurate rf power measurements

this month

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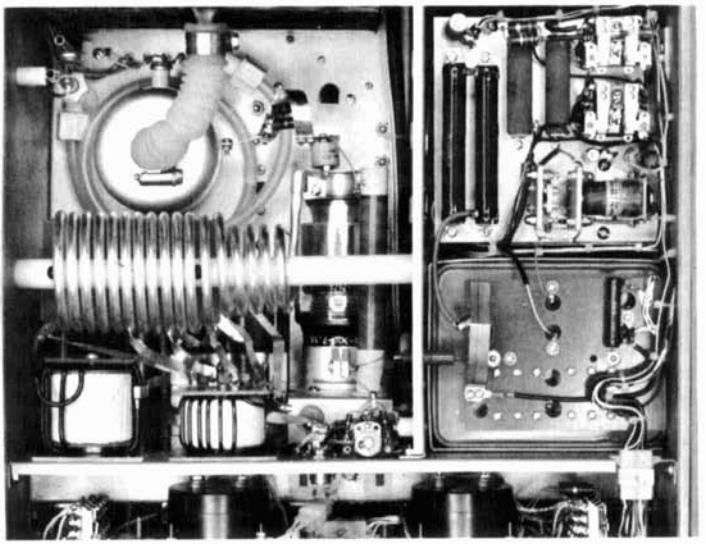

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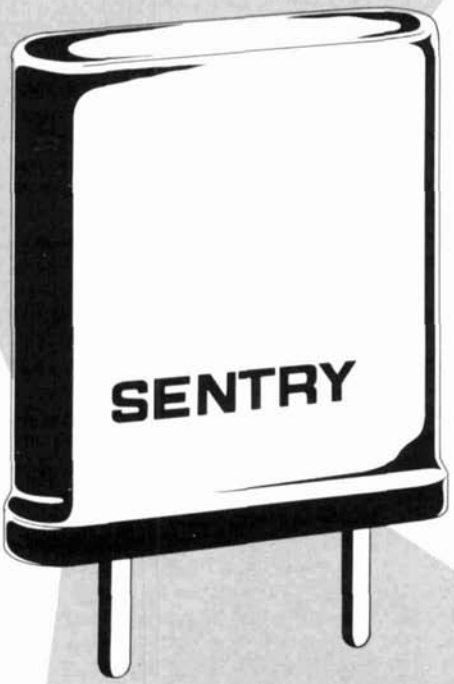

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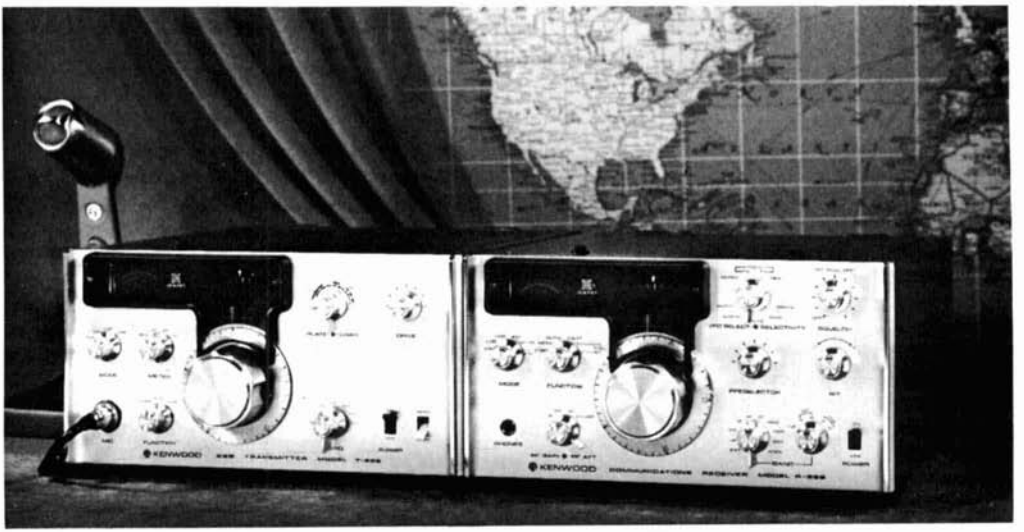

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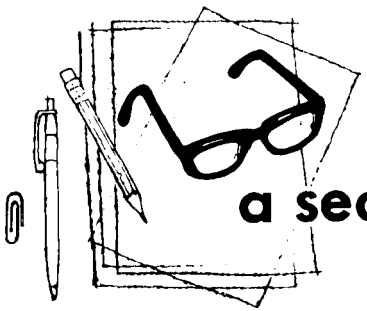

a second look

by jim fisk

High-frequency radio communications has always been at the mercy of the sun, with its sporadic cataclysmic bursts of electromagnetic radiation that convulse the ionosphere. The mighty sun will always dictate the condition of the ionosphere, but the unpredictability of solar disturbances is probably as disconcerting as the disturbances themselves. A new solar-activity monitoring system, installed this summer by Cambridge Laboratories, may end the unpredictability once and for all.

Cambridge Labs tried once before to develop a solar-activity prediction system, but it didn't work out; primarily because of the large number of errors, reporting inconsistencies and variations in instrument calibration.

The new program, however, is different. While the observation stations were under development, a parallel program was initiated to establish uniform reporting and observing techniques, as well as carefully calibrated equipment that would provide standardized information.

The basis of the system is a huge network of sensors and data-processing equipment. The network consists of fifty ground-based optical and radio observatories all over the world. Each station is equipped with ionospheric sounders, radio receivers that measure galactic noise, neutron monitors and magnetometers. (Magnetometers are used to measure the intensity of the earth's magnetic field.) The ground stations transmit their data by teletype to a large computer complex at Offutt Air Force Base in Omaha. In addition, data from orbiting satellites is fed into the system, so the computer is up to date on the radiation level in space. The computer processes the data and forecasts changes that affect high-frequency communications.

Although the program is being conducted primarily for the benefit of the Air Force, amateurs can expect some fallout in the form of improved propagation notices from WWV.

In the future, when WWV broadcasts an N7 propagation forecast, you should be able to expect pretty good, undisturbed DX conditions with some degree of certainty. There are bound to be some anomalies until they shake all the bugs out, but hopefully some of the sorcery and ambiguity of propagation forecasting will soon be a thing of the past – a thing to reminisce about, like the time 9Z1AA dropped into the solar noise just as he answered your call.

Jim Fisk, W1DTY
editor

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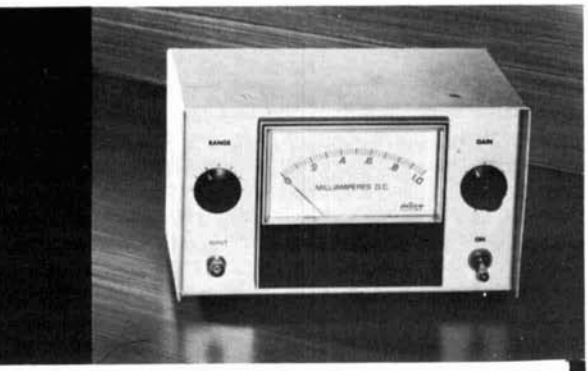


the swr meter

Not to be confused with swr bridges, this laboratory-quality instrument is essential for serious uhf work

Bob Melvin, W6VSV, 113 El Camino Real, Millbrae, California 94030

As the experimenter progresses through vhf into uhf and the microwave regions, it becomes evident that instrumentation is required to assure optimum performance of equipment and antenna systems. For the most part, the amateur suffers under the handicap of being unable to adequately measure loss or gain at high frequencies. For this reason many can only guess the actual gain of their antenna or rf preamplifier, or the actual loss in their transmission line or rf filters.

Very little has appeared in amateur publications to assist the experimenter to assign meaningful loss or gain values to the various components of his systems. For example, crosstalk in antenna relays or loss in baluns are unmeasurable with most amateur equipment. Only by knowing the performance of the various components in the complete system can one obtain the overall performance desired.

The amateur often bases measurements of gain or loss on such unreliable devices as a receiver S-meter or a through-line watt-meter. These indicators along with pilot lamps, rf ammeters, and many "swr bridges" leave much to be desired at frequencies above 100 MHz.

This article describes the construction and operation of one of the most useful measuring tools for the vhf-uhf experimenter. No calibration instruments are required—all measurements are simply derived from the indication on a 0-1 dc milliammeter. With this instrument the amateur can determine meaningful decibel loss or gain figures previously unmeasurable, including gain in antennas or preamps, loss in attenuators or transmission lines, and crosstalk in coaxial relays.

the swr meter

Drawing upon the experience of the microwave industry,[1] it is found that for many years measurements in the vhf through microwave regions have been made with a laboratory instrument termed a vswr indicator or simply swr meter. This instrument has far greater utility than its name would imply, as will be shown later.

The swr meter should not be confused with simple devices such as swr bridges, antennascopes, or other gadgets that base their calibration accuracy on the characteristics of their semiconductor diodes. The accuracy of such devices is doubtful at vhf and above, and each instrument must be individually calibrated from a known standard.

The swr meter has two major features:

1. It indicates power ratio directly.
2. It requires no calibration from an rf standard.

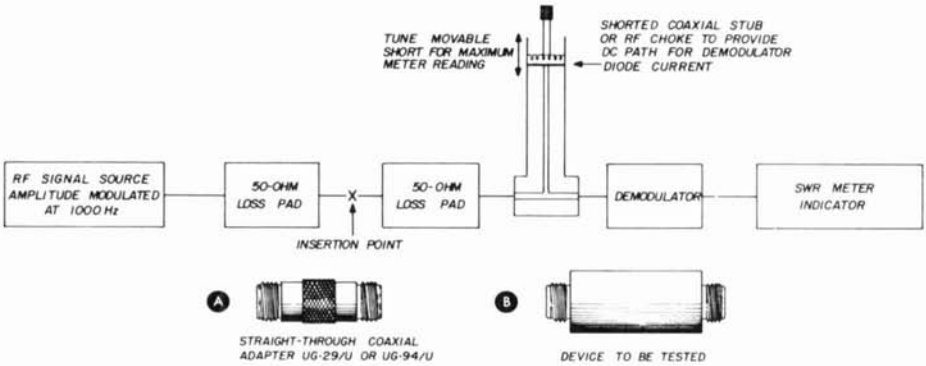


fig. 1. Instrumentation for measuring power loss. Meter is first adjusted for full-scale deflection with straight-through adapter inserted at point X; then device to be checked is inserted.

With good circuit design and careful use, swr-meter accuracy can be essentially that of the readout instrument. Power ratio may be converted to dB by applying a simple mathematical relationship or it may be taken directly from a graph.

For all loss or gain measurements a tone-modulated signal source, a demodulator, and an indicating meter are necessary. With this setup, power can be read out for transmission lines, filters, directional couplers, and other devices. Antenna gain may be measured indirectly over a suitable test range by comparing the

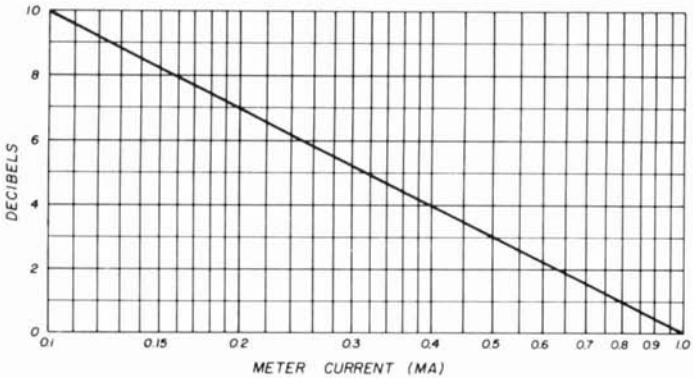


fig. 2. Conversion chart for finding dB loss from meter indication.

relative gain of the antenna under test with that of a carefully constructed reference antenna.

theory of operation

The swr meter consists of a stable high-gain amplifier, tuned to an audio frequency, with a calibrated meter readout. The swr meter is designed to display power ratios when used with an rf demodulator (or detector) operating in the square-law region. Measurements are made on the demodulated audio-signal voltage output of the detector, as it is directly proportional to the incident rf signal power amplitude. By amplifying demodulated audio rather than rectified dc, stability and sensitivity are assured.

using the swr meter

The test setup for rf loss measurements is shown in **fig. 1**. To make a reading, the instruments are connected as shown, and the swr meter gain is adjusted until the meter reads exactly full scale (1.0 mA or 0 dB). The circuit is opened at point X and the device to be tested is inserted. If the device presents a power loss at the signal frequency, the meter deflection will be less than full scale. The resultant fraction of full-scale reading represents the fraction of power flowing through the device under test. The loss can be converted to dB by

$$\text{loss in dB} = 10 \log_{10} \frac{1.0}{I} \qquad (1)$$

where

I = meter reading (mA)

This relationship has been plotted in **fig. 2**, which may be used with reasonable accuracy.

slotted-line measurements

Although this article deals primarily with loss measurements, the swr meter can be used for its originally intended purpose—to measure vswr with a slotted line.[2,3] The slotted line is a mechanically precise section of transmission line, usually 50 ohms characteristic impedance, fitted with a movable rf detector probe **(fig. 3)**. The probe samples the voltage field along the section of transmission line. The high gain of the swr meter is necessary to amplify the low-level of the sampled voltage in the line.

The combination of slotted line and swr meter not only provides greater accuracy than achievable with reflectometers or other instruments, but also indicates

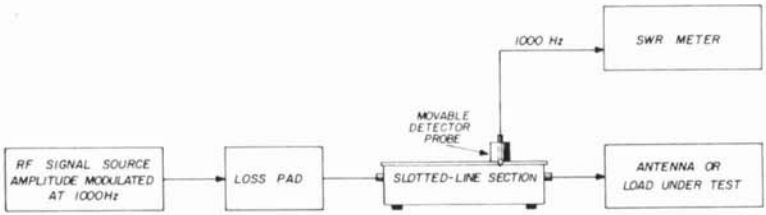
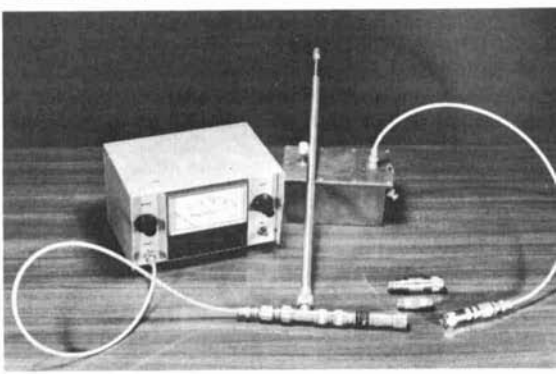


fig. 3. Setup for measuring vswr with a slotted line.

Instrumentation for a complete microwave swr measurement setup. Shown are swr meter, signal source, and coaxial accessories.



the position of the standing wave along the line. The location of the standing wave is necessary for solving transmission-line problems.

Measurements of vswr are made by first positioning the slotted-line probe carriage along the line until the point of maximum voltage is located. The swr meter gain is then adjusted to full scale (1 mA or 0 dB) at this point.

With the amplifier gain fixed, the probe carriage is then repositioned along the line to the point of minimum voltage or null. Vswr is the square root of the indicated power ratio:

$$\text{vswr} = \sqrt{1.0/I} \qquad (2)$$

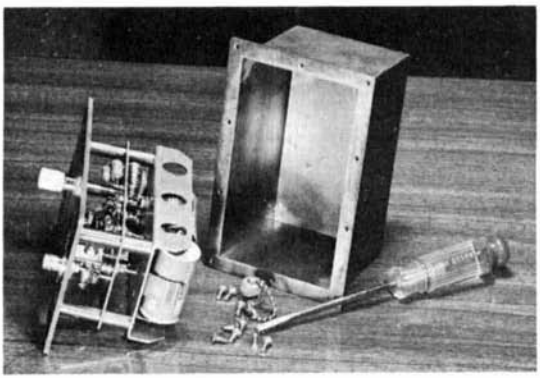
where I is the meter reading in milliamperes.

This relationship is plotted in **fig. 4**. For vswr less than 3.16 curve A is used; for vswr greater than 3.16 swr-meter gain is increased by one 10-dB step and curve B is used.

signal source

The rf-signal source may be a laboratory signal generator, although a readily constructed transistorized, crystal-controlled source will serve nicely. An output-power level of 1-10 mW is adequate for most measurements, including antenna range experiments. Special care should be used to assure low rf-harmonic content, rf-output amplitude stability, and constant modulation percentage. Minor variations of frequency do not normally cause loss of accuracy due to the relatively large bandwidth of the demodulator and device under test. The modulating tone, on the other hand, must be amplitude and frequency stable.

Crystal-controlled 432-MHz signal source. Box seams were hard soldered to reduce rf leakage. Switch is actuated by a plastic rod through a brass tube soldered to panel.



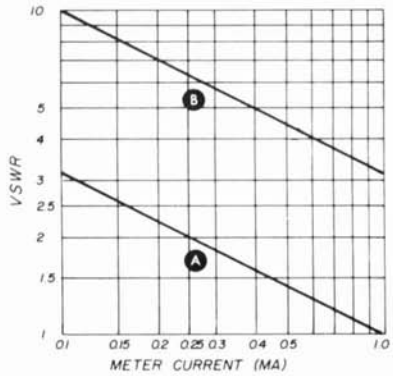


fig. 4. Calibration curve for determining vswr as a function of meter readout.

demodulator

The demodulator, or detector, recovers the audio component from the amplitude-modulated signal. A coaxially mounted semiconductor diode, thermocouple, thermistor, or barretter are all capable of serving as a demodulator. For circuit simplicity and sensitivity, we have chosen to consider the semiconductor diode only.

Diodes display very accurate square-law characteristics at very low levels of incident rf energy. In the square-law region, a demodulator produces an audio output signal voltage directly proportional to its rf input power (or input voltage squared).

Point-contact diodes such as the 1N21 series in a suitable coaxial diode mount (see **fig. 5**) are useful for rf input levels producing less than 0.14 mV rms rectified audio output. At higher input levels, the diode characteristics deviate from the square law, thus reducing the accuracy of measurements.

A significant improvement in sensitivity can be realized by employing the

more advanced hot-carrier diode as a demodulator.[4] These diodes are now available for less than $1.00 each. The hot-carrier diode, provided with a small direct-current bias, will produce an 8- to 10-dB improvement in sensitivity over the 1N21. This additional sensitivity comes in handy for antenna-range work when using a low-powered signal source.

Fig. 6 illustrates a simple coaxial mount made of common coaxial connectors and a hot-carrier diode.

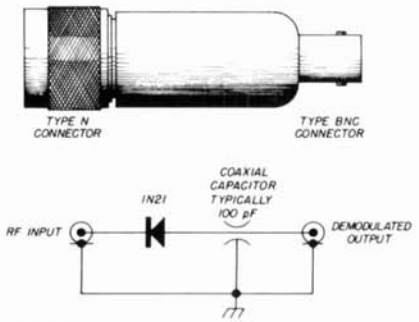


fig. 5. Microwave crystal demodulator using a 1N21 diode.

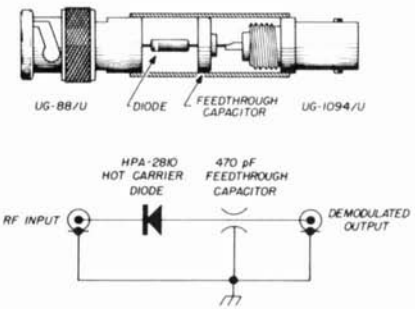


fig. 6. Hot carrier diode demodulator. Much higher sensitivity is possible using this device.

amplifier-indicator

We have observed that semiconductor diodes behave in an accurately predictable manner at very low power levels. We can take advantage of these characteristics by using a high-gain amplifier and meter readout.

The amplifier must have sufficient voltage gain and power output to provide full-scale meter deflections for signals less than 1 μV. The circuit should be gain stable and linear for all signal levels. Thermal noise and hum effects should be suppressed.

The amplifier circuit of **fig. 7** meets all conditions for gain, power output, stability and linearity. Amplifier linearity here implies that any increment of the 1000-Hz input signal will produce an exactly proportional increment in dc-meter current. Thermal noise and hum are suppressed to acceptable levels by limiting the amplifier 3-dB bandwidth to less than 50 Hz. This bandwidth is an acceptable compromise between noise rejection and ease of operation.

The input circuit consists of an impedance-matching transformer and a network to provide dc bias for the hot-carrier diode demodulator. A 1:7 turns-ratio input transformer converts the low-impedance demodulator output to the optimum input impedance of the amplifier. A miniature output transformer, rated at 600:12 ohms, was selected. The turns ratio for this unit is 7.07:1. This transformer is a good choice, since it is much less susceptible to 60- or 120-Hz magnetic hum pickup than a higher-impedance transformer would be with the same turns ratio—example: 200:10k ohms.

A forward bias of approximately 30 μA dc is necessary when using a hot-carrier diode demodulator. The bias may be disabled when using a 1N21 or 1N23,

50-ohm coaxial components. From left to right, two attenuator pads, commercial crystal holder (fig. 5), and homemade demodulator (see fig. 6).

since point-contact diodes generate a great deal of noise with dc bias current.

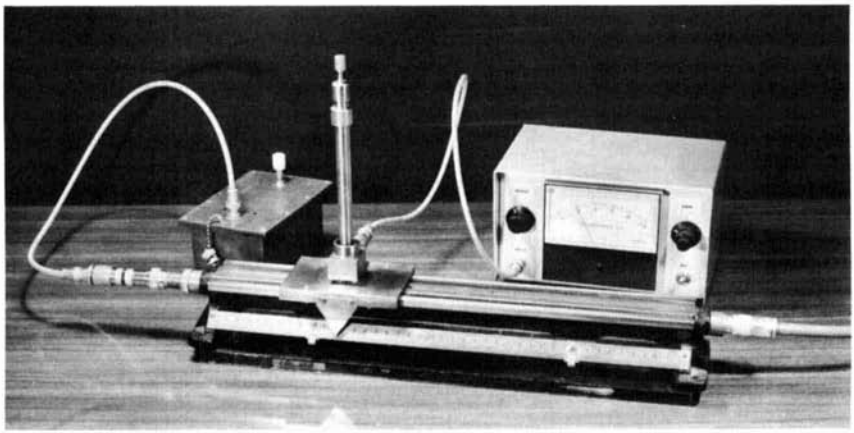
Following the step-up transformer is the first section of the range switch. This switch attenuates the gain of the amplifier in exactly 20-dB steps. Because the instrument is to be used only with square-law detectors, each attenuation step is marked as 10 dB. Attenuator resistors are of the metal film type, 1% tolerance.

A four-stage, direct-coupled, high-gain transistor preamplifier contains coarse and fine gain controls in its negative feedback loop. The second section of the range switch at the output of the preamplifier prevents overloading of any stage over the entire range of inputs to the swr meter.

A two-transistor feedback pair constitutes the second amplifier stage and drives a 1000-Hz LC filter consisting of an 88-mH telephone-loading toroid coil and two Mylar capacitors, C1 and C2. Due to the very low output impedance of this amplifier stage, capacitors C1 and C2 are effectively in parallel and resonate the coil near 1000 Hz. The values of these capacitors are proportioned as shown to provide the required passband shape factor. If it is desired to peak the amplifier response at exactly 1000 Hz, a few turns will have to be removed from the toroid. Of greater importance is the matching or tuning of the modulating frequency of the signal source to the LC filter in the amplifier.

Four transistors in a direct-coupled configuration provide additional gain, phase-inversion, and complementary symmetry output. The 1000-Hz ac amplifier output is available for external use, if desired, but is not directly used to deflect the meter. It is the dc current to the class-B complementary symmetry stage that drives the meter, thus accomplishing the ac-to-dc conversion. The large amount of feedback in this stage reduces the closed-loop voltage gain to near unity. A 0-1 dc milliammeter is a good choice for indicator, as it is rugged, inexpensive, and readily available.

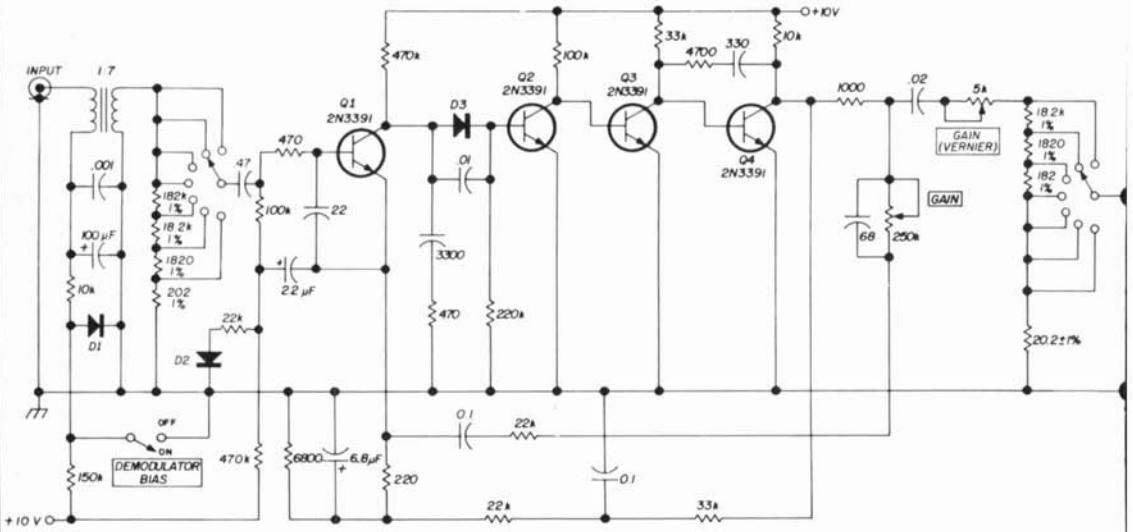
Other circuitry includes a simple voltage-regulated power supply to maintain constant voltage to the amplifier as the battery voltage declines throughout its useful life.



Using the swr meter with a slotted line.

construction

Components are mounted on perforated board for simplest construction. Care was given to avoid ground loops by having only one ground connection to the metal cabinet at the BNC input jack. A bus bar ground wire, with each ground made in the same sequence as shown in



D1, D2, D3 = SILICON DIODE, 25V OR GREATER

fig. 7. Schematic of complete swr meter for microwave measurements. Sufficient gain, output, stability, and linearity are provided for input signals less than 1 µV.

the diagram, will eliminate ground loops. The precision range resistors are mounted directly on the range switch.

instrument performance

The completed instrument meets the following specifications:

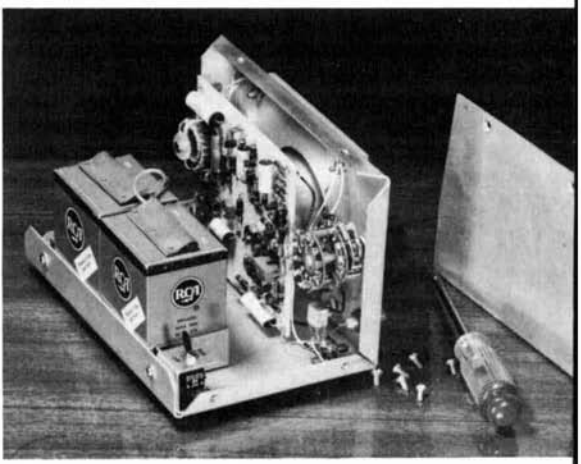
sensitivity	less than 0.14 µV rms for full-scale meter deflection at maximum gain.
noise	greater than 10 dB below full scale at maximum gain.
gain	70 dB in seven 10-dB steps using square-law demodulator.
bandwidth	45 Hz at 3-dB down.
battery drain	5 mA with no input signal, and 6 mA with input signal for full-scale meter deflection.

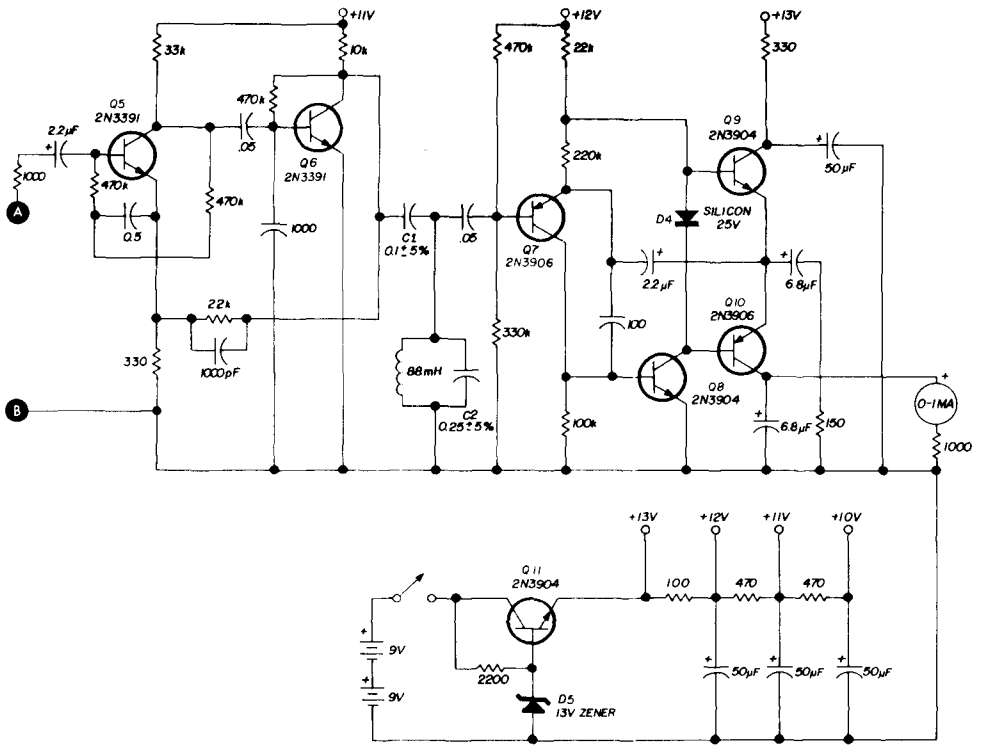
error sources

A few precautions are necessary to realize full measurement accuracy. A significant source of error is caused by operating the demodulator at too great a level. Overload can be minimized by attenuating the signal source so that the swr meter gives on-scale deflection when operating on one of the three range-switch positions of greatest amplifier gain.

Measurement errors will be caused by any deviation from 50-ohm resistive

The swr meter with cover removed. Circuit board is mounted on meter terminals. Demodulator bias on-off switch, mounted next to battery, is accessible from rear of unit.





impedance of the signal source or detector loading.* A convenient solution is to insert a loss pad rated at 10 dB or greater after the signal source and another loss pad ahead of the detector mount. (See **fig. 1**.)

Additional error can result from any change of the dc resistance in the demodulator circuit caused by connecting or disconnecting various attenuator pads during tests. A solution to this problem is to connect a shorted quarter-wave stub, rf choke, or parallel-resonant circuit from demodulator rf input to ground. Such circuits display high shunt impedance for rf across the demodulator, while providing a low shunt impedance path for the 1000-Hz audio signal.

Good practice dictates special precautions when measuring attenuation greater than 20 dB or slotted line vswr greater than 10. For these measurements, a substitution technique using a previously calibrated loss pad can be of assistance, as will be shown in Example 3.

*An impedance of 50 ohms has been accepted as standard for coax lines, matched connectors, and test equipment. If it's necessary to use another impedance, all pads, connectors, and transmission lines must conform to the selected impedance.

examples of operation

Example 1. Let us measure the loss of a length of 50-ohm coaxial cable at 432 MHz. The equipment setup of **fig. 1** is used with a 432-MHz signal source. The swr meter gain controls are carefully adjusted for full-scale meter deflection (1.00 mA or 0 dB). The junction (X) between the two loss pads is then opened, and the cable under test is inserted at this point. With the coaxial cable in the rf circuit, the meter indicates only 0.40 mA. This indication represents a transmitted power of 40 percent through the cable, or 60% loss in the cable at 432 MHz. Referring to eq. (1) we convert the meter reading to power loss in dB:

$$\text{Loss in dB} = 10 \log_{10} \frac{1.0}{0.40}$$
$$= 3.98 \text{ dB}$$

Fig. 2 may be used to simplify conver-

sion from meter reading (power loss) to dB.

Example 2. For our second example, suppose the unknown is a loss pad. When the pad is inserted in the line at (X), the meter reading is less than 0.10 mA. Without touching the coarse or fine gain controls, the range switch is switched in 10-dB steps until the meter reading falls between 0.10 and 1.00 mA. The number of 10-dB steps of gain change must be added to the reading.

In this example the meter reads 0.50 mA after the gain has been increased by one 10-dB step. The loss of our pad under test is:

$$\text{Loss in dB} = 10 + 10 \log_{10} \frac{1.0}{0.50}$$
$$= 13.0 \text{ dB}$$

Example 3. Antenna-relay crosstalk is measured by first connecting a pad of known loss at (X) and adjusting the signal-source output and amplifier gain for exactly full scale. For this example we use a pad with 20-dB loss. The pad is now removed and the relay is connected at (X). (See **fig. 8.**)

With the relay actuated in the transmit mode, the meter reads less than 0.10 mA. With the coarse and fine gain controls fixed, the gain is increased by one 10-dB step of the range switch. The meter is then found to indicate 0.25 mA. The relay crosstalk loss is:

$$\text{Loss in dB} = 20 + 10 \log_{10} \frac{1.00}{0.25} = 36.0 \text{ dB}$$

Example 4. The gain of a receiver preamplifier is measured by first connecting it into the line at (X). The swr meter is then adjusted to exactly full scale. When the premaplifier is removed and a straight adapter substituted, the meter then reads 0.125 mA. From formula or chart we calculate the preamp gain to be 9.03 dB. By this procedure, we measure the loss when the preamplifier is removed from the circuit.

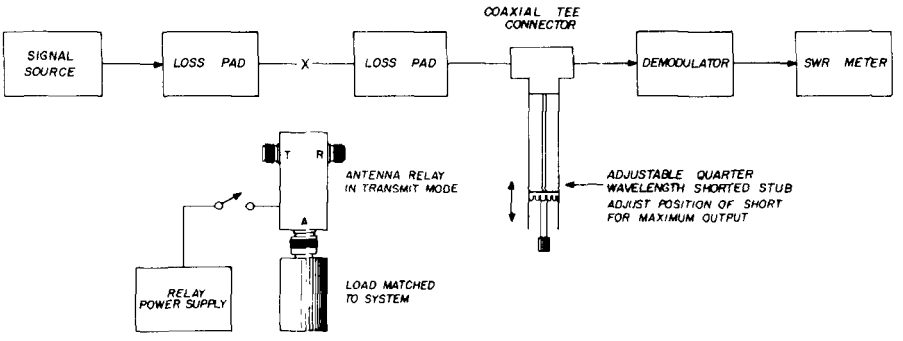


fig. 8. Measurement arrangement for determining crosstalk in an antenna change-over relay. Meter is adjusted to full scale with loss-pad inserted at point X. Relay is then substituted and crosstalk is determined by adding pad loss to meter reading in dB.

conclusion

This article covers the construction and operation of an instrument of great utility for the serious experimenter in the uhf region. With careful construction the swr meter will perform as claimed. When used according to instructions given, the instrument will take the guesswork out of rf measurements at vhf and uhf.

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ham radio

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the sideband minituner

Here's a pocket-sized direct-conversion receiver for 80 and 40 meters all for less than $25

Rick Littlefield, K1BQT/6, 209 Main Street, San Rafael, California 94901

This kitchen-tabletop project has appeal for everyone, from the beginner to the seasoned experimenter. It's perfect for cw practice, motel monitoring on trips, or for keeping an ear on your favorite net while the big rig is tied up on the DX bands. It can monitor your transmitter on ssb and cw, provide a signal source for tuning other receivers, and it can keep you in touch when power lines fail. If you are a QRP fan, it will provide you with a vfo and companion receiver for your little transmitter. Not to mention, of course, its value as a conversation piece when one of the locals drops over.

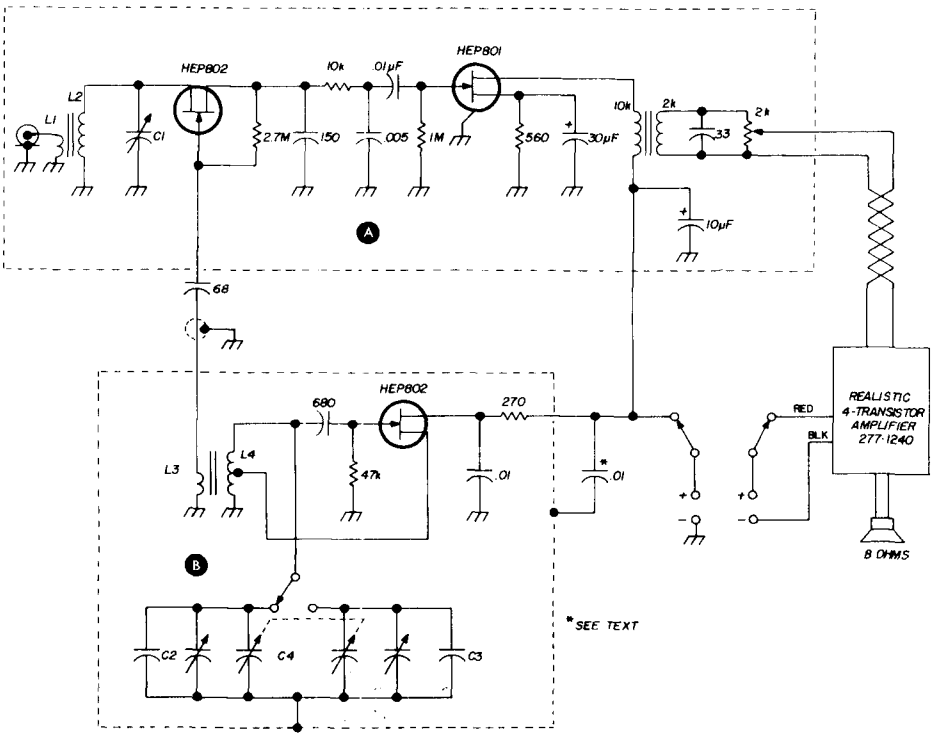
The inspiration for this project came from an article entitled "Direct Conversion—A Neglected Technique" by Wes Hayward and Dick Bingham. After working with this principle, I'm convinced that it should *not* be neglected, for there is no simpler or less-expensive approach to respectable ssb and cw reception.

design

The heart of this receiver is an extremely simple product detector circuit **(fig. 1)**. The preselected incoming signal is chopped at a rate determined by the vfo output frequency, with a resultant audio product appearing at the drain. Since the

vfo signal level at the gate is relatively high compared with the incoming signal level at the source, conduction time is short, and linearity is excellent. The output of the detector, after being fed through a low-pass filter, is amplified by a low-noise fet audio preamplifier. This single stage provides enough gain to drive one of the inexpensive imported audio modules. In this case, a Realistic 277-1240 100-mW unit was used. This unit requires an input of only 1 mW for full output, unmodified. With any reasonable antenna, the sensitivity of this circuit is far more than adequate.

Selectivity as well as sensitivity is determined within the audio range. The RC values shown provide reasonable selectivity for casual listening without sacrificing system gain. The Realistic 277-1240 audio board contains an 82k ohm feedback resistor between the output transformer secondary and the base of the transistor in the second stage. A 0.001-μF capacitor connected in series with the resistor does wonders in improv-



C1 365 pF miniature mica BC tuning capacitor

C2 470 pF small mica

C3 140 pF small mica

C4 15/16 x 1-3/8 x 1-15/16 inches. 6.3—123.1 pF and 5.7—78.2 pF (Lafayette 32E11067 or equivalent)

L1 3- or 4-turn link on L2

L2 36 turns no. 30 enameled wire on .68 diameter toroid form

L3 5-turn link on L4

L4 22 turns no. 22 enameled wire on .68 diameter toroid form, tapped 5 turns from ground end

fig. 1. Schematic of the direct-conversion minituner cw/ssb receiver. The only circuits to build are the product detector/preamplifier, A, and the vfo, B.

ing overall gain at voice frequencies. This combination causes the amplifier to be very frequency selective and decreases the interference problem between adjacent stations.

the detector will be destroyed. Thus, the oscillator module must be well-shielded from the rest of the package. I accomplished this by building a separate box for the vfo from two-sided pc board. A

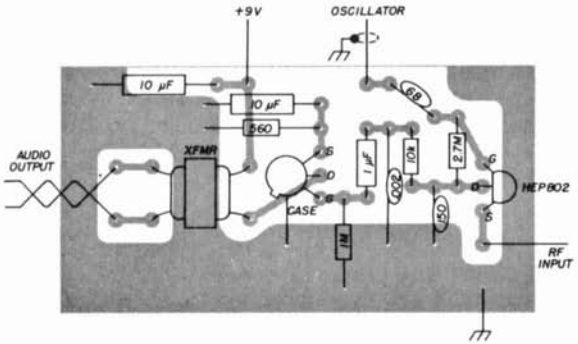


fig. 2. Parts layout for the product-detector board. Components are shown as seen from the bottom of the board. Etched board is shown on the next page.

construction

The receiver consists of three small printed-circuit modules mounted in a 2 x 3 x 5-inch minibox. Since the audio amplifier is preconstructed, a good portion of the work is already done. The other two modules are extremely easy to lay out and construct. **Fig. 2** and **3** show the board templates and component mounting.

Since the oscillator must maintain

less-elaborate shield could consist of a small minibox or an aluminum bracket. The power lead is bypassed at the vfo shield, and the vfo output lead is a length of small-diameter coaxial cable.

For the sake of stability, all frequency-critical capacitors are of the mica variety. The tuning capacitor, in this case a miniature air variable, has a ball-bearing rotor mount for smooth operation. All components on the module must be

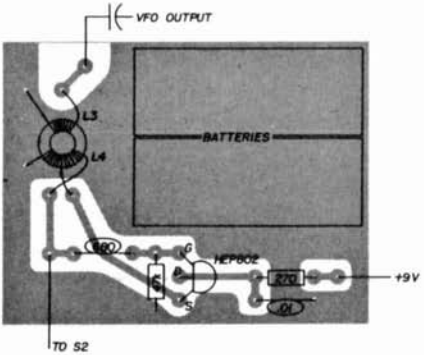


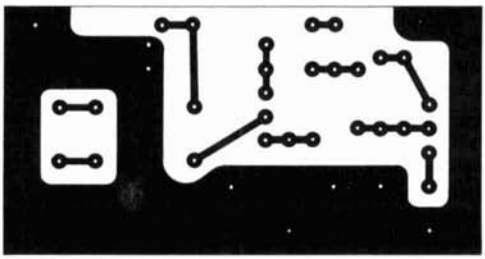
fig. 3. Parts layout for the vfo circuit board. Components are viewed as seen from the bottom of the board. Etched board is shown on the next page.

sideband isolation and stability, a few simple considerations are in order. If high-level vfo radiation reaches the rf input port of the detector via the antenna line and its tuned circuit, the linearity of

securely mounted, and all frequency-critical wire leads must be rigid. By following these few suggestions, you can expect quality reception from the finished project.

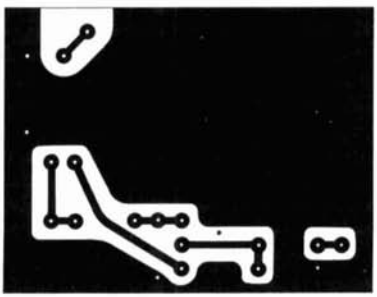
adjustment

Tuneup is a relatively simple matter because the oscillator is the only section requiring initial adjustment. Since the same value of inductance is used for both the 80- and 40-meter bands, capacitance



is the only variable determining range and band placement. The variable- and fixed-capacitor values are thus considerably greater for 80 meters than for 40 meters. For the 2-section variable capacitor specified in the parts list, I left six rotor plates on the 80-meter section and only one on the 40-meter section. This provided about 300 kHz of coverage on each band. If you use one of the inexpensive imported 6:1 vernier drives, 300 kHz is the most you will be able to cover and still maintain smooth tuning. The fixed mica capacitor values should place the vfo output somewhere within the amateur bands, where you will be able to pick up the oscillator on your station receiver.

Minor fixed-capacitance substitutions



may be necessary to achieve the precise coverage you desire. Once you have the desired placement worked out on both bands, the station receiver can be used for an accurate final calibration. The tuned-rf input circuit covers 80 and 40 meters with enough overlap so that no inductance adjustment is necessary. Variable capacitor C1 peaks the incoming signal just as the antenna trimmer or preselector control on a commercial receiver. What could be simpler?

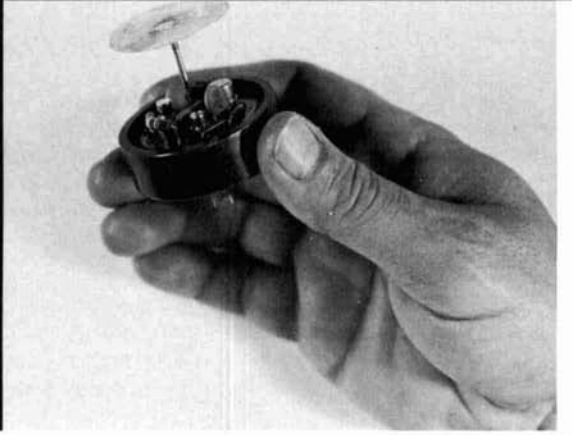
conclusion

Despite its surprisingly good performance, this unit is not the ultimate in direct-conversion design. The possible avenues of exploration are many. For example, the Realistic 277-1577 audio board provides 350-mW output for 300-μV input at 500 ohms, and is well worth trying in place of the less-sensitive 100-mW module used here. Furthermore, a dual-gate mosfet product detector deserves consideration. And, with a stable vfo, this circuit should perform as well at 144 MHz as it does at 3.5 MHz. The possible arrangements are almost endless.

Nonetheless, and regardless of its potential for further development, the sideband minituner works very well as it is. In fact, you'll find it one of the most useful minibox projects you can build.

ham radio

"I think I'd like it better over by the fence after all."



voltage-probe receiving antenna

A new two-inch-high electronic device that out-performs a 3-foot whip below 40 MHz

James Fisk, W1DTY

The voltage-probe antenna, or vpa, is a new approach to miniature high-performance broadband receiving antennas that exhibits low-noise characteristics and does not require tuning over the frequency range from 30 kHz to 50 MHz.

The vpa consists of an antenna probe and solid-state amplifying and matching circuitry designed to feed into 50-ohm coaxial line. The antenna probe itself consists of a rod two inches long, top loaded with a small disc as shown in the photo. The electronic circuitry is contained in the small cylinder below the antenna probe. Dc power, isolated from the incoming rf, is fed to the circuitry through the coaxial feedline.

how it works

The vpa senses voltage from an incoming radio wave with its antenna probe, and the electronic circuitry acts as an impedance converter by transferring the input signal voltage from the highly reactive antenna probe to a 50-ohm resistive impedance level. The vpa performs much like a cathode follower, but with very high gain. The circuitry consists of an fet low-noise input stage, a buffer-driver stage and an output stage to match the probe to a 50-ohm transmission line.

The theory behind the vpa is based on the fact that when a quarter-wave monopole antenna above a ground plane is made infinitely short, its power gain

decreases only slightly from a theoretical maximum of 2.14 dB to 1.76 dB (over an isotropic). However, as the antenna gets shorter, antenna resistance decreases while the reactance increases. This is a familiar problem to the amateur who has worked with small 75-meter mobile antennas.

As an example, at 20 kHz, a 1-meter stub over a ground plane exhibits an effective resistance on one-millionth ohm, and capacitive reactance of 10 million ohms. Since these two components are effectively in series as shown in **fig. 1**, the voltage available to the amplifier is infinitesimally small.

The electronic circuitry used with the vpa does not match impedances in the usual sense. Instead, it makes the reactive component small in comparison to the very high input impedance of the fet amplifier, swamping out the reactive component. The result is that most of the input signal appears across the amplifier input terminals.

performance

As pointed out by K6MIO,[1] the ability of an antenna to extract a radio signal from space is dependent upon the antenna's effective aperture or capture area. This capture area may be used as a basis to compute the antenna's gain as compared to an isotropic. The gain of the vpa, when placed 42 inches over a ground plane, is −10 dB, and is flat from 30 kHz to over 50 MHz. As a point of comparison, a quarter-wave whip (matched to the receiver) exhibits 2.14 dB gain. However, the whip is a high-Q device, and performance deteriorates rapidly as you deviate from its resonant frequency.

The results of a comparison test between the miniature voltage-probe antenna and a 13-foot, 4-inch whip are plotted

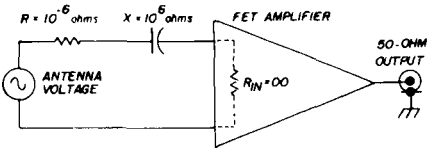
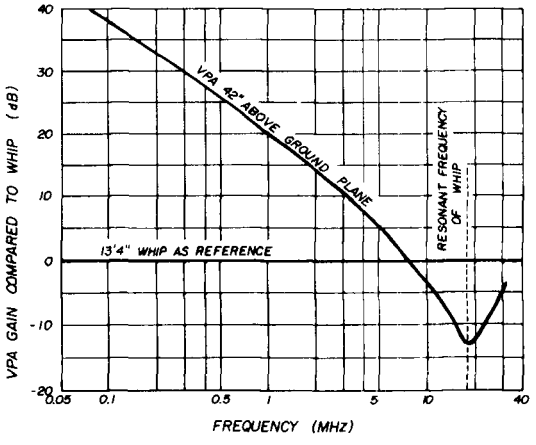


fig. 1. Equivalent circuit for a miniature 1-meter-long stub antenna at 20 kHz.

in **fig. 2**. For these tests, conducted by the Kollmorgen Corporation, both antennas were located side-by-side on a 50 x 80-foot metallic ground plane. The whip sat on a 9-inch pedestal in contact with the ground plane; the vpa was on a 42-inch post, also in contact with the ground plane. The outputs, brought out through 50-ohm coax, were compared on the same receiver; a precision variable attenuator was used to measure differences in signal level.

Performance of the vpa can be improved by elevating it further over the ground plane. This is because of signal pickup by the output coaxial cable. Although vpa gain is flat to 50 MHz, the effective gain over a whip antenna increases substantially with decreasing frequencies. The vpa shown in the photo, for example, will out-perform a 3-foot whip antenna at all frequencies below 40 MHz.

fig. 2. Performance of the voltage-probe antenna as compared to a 13' 4" whip.



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ham radio

designing with ic voltage regulators

Inherent device constraints are analyzed, and design examples are given to obtain optimum regulator performance

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Some of the load-handling capability of an IC voltage regulator may be sacrificed if a less-than-optimum system design approach is used. This article describes a design procedure that assures full realization of the regulator's load-handling capability and compliance with all its ratings. Design examples, using a typical IC voltage regulator, are included.

The cost of a monolithic IC voltage regulator is usually less than that of a voltage regulator of comparable performance constructed from discrete components. In return for this reduced cost (and increased convenience) the designer is confronted with a set of regulator operating constraints, imposed by the IC manufacturer, over which the designer has little control.

The voltage regulator IC is a complete electronic circuit block, and certain package terminal conditions must be met regardless of the regulator's relationship to the rest of the system. These are:

1. The minimum regulator input voltage
2. The maximum regulator input voltage
3. The maximum regulator output current.

Two more constraints are added when the voltage regulator becomes part of a voltage-regulated power supply system:

4. The minimum voltage drop across the regulator
5. The maximum allowable regulator power dissipation

Since the IC operating parameters and the power requirements of the load are predefined, the volt-ampere characteristic of the unregulated voltage source is the *only manipulatable system variable.* The boundaries represented by the preceding constraints can be plotted on a graph of regulator input voltage vs regulator output current, and will enclose a region that contains all the allowable combinations of unregulated input voltage and regulator output current. Obviously, the volt-ampere characteristic of the unregulated

power supply must lie within the boundaries of this permissible operating region. The mechanics of this technique are demonstrated later in the article.

device limitations

The *maximum input voltage* that may be applied to an IC voltage regulator is restricted by the IC secondary breakdown limitation and, when current flows, the maximum allowable junction temperature. The *maximum current* that may pass through a voltage regulator IC is restricted by the current-carrying capacity of the interconnections within the IC, the maximum allowable junction temperature, and the voltage applied to the regulator when the second-breakdown region is approached. Power dissipation limits will normally be exceeded before second breakdown is reached with increasing current—unless, of course, the case temperature is prevented from rising.

The *minimum input voltage* applied to an IC regulator must be adequate to maintain appropriate bias currents through the internal zener diodes. Furthermore, a minimum input-output voltage differential must be maintained to assure that the series pass regulating elements retain control over the output voltage. The greater of these two minimum input voltage restrictions must always be satisfied. The *maximum allowable power dissipation* is limited by the maximum allowable junction temperature and the thermal resistances from junction to ambient.

The numerical values and package pin connections cited in the remainder of this article apply specifically to the Motorola MC1469R connected as shown in **fig. 1**. The comments and procedures are, however, equally applicable to all other voltage regulator ICs.

typical regulator circuit

A complete voltage regulator circuit using a typical IC voltage regulator (the Motorola MC1469R) appears in **fig. 1**. The unregulated input voltage is applied to pin 3 of the MC1469R, and the IC output voltage appears at pin 1. Capacitors C1, C2, C3 provide circuit compensation, noise filtering, and assure output-voltage stability.

The 2N706 transistor, Q1, and current-sensing resistor, R_{sc}, limit (via pin 4) the maximum output current of the regulator to that which causes a voltage drop of 0.6 volt across R_{sc}. Thus, the short-circuit current, I_{sc}, is defined by R_{sc} and is determined from the expression

$$I_{sc} = \frac{0.6}{R_{sc}}$$

where I_{sc} = the approximate short-circuit current limit in amperes, and R_{sc} = the resistance in ohms of the current-sensing resistor.

The regulated and current-limited output voltage, V_o, appears at the emitter of Q1. This voltage is sensed by pin 5, and the voltage at pin 1 varies, as required, to keep the voltage at pin 5 constant. The constant voltage required at pin 5 is a function of R1 and R2, and R1 is determined from

$$R1 = 2V_o - 7$$

where V_o = the desired regulated output voltage in volts, and R1 = the resistance (in k ohms) of the voltage-setting resistor.

Pin 2 of the MC1469R is the shutdown control. A positive voltage applied to pin 2 causes the regulator output voltage to drop to zero and reduces the regulator input current to a few-hundred microamperes. Aside from its obvious use as a regulator on/off control, the shutdown control automatically limits the maximum IC chip temperature if a constant positive reference voltage is applied to pin 2. The voltage required to shut down the regulator is a function of the chip temperature:

$$V_{pin\ 2} = 1.38 - 3.4 \times 10^{-3} (T_j - 25°C)$$

where $V_{pin\ 2}$ = the approximate voltage in volts that must be applied to pin 2 to shut down the regulator at a given junction temperature, T_j, and T_j = the junction temperature in °C at which shutdown will occur. Since the shutdown voltage decreases approximately linearly

at the rate of 3.4 millivolts/°C, the shutdown voltage under a particular set of operating conditions can be determined experimentally and its value used to calculate the chip temperature rise. This technique has the advantage of not disturbing the thermal characteristics of the IC through the attachment of an external temperature-measuring device.

The continuous load current from the MC1469R must not exceed 500 mA. It will withstand a maximum input voltage from pin 3 to ground of 35 Vdc; the minimum input voltage must be 9.0 Vdc or 3.0 Vdc higher than the voltage at pin 1, whichever is greater.

The voltage at pin 1, $V_{pin\ 1}$, can be determined only after the regulated output voltage, V_o, and R_{sc} have been specified. The equation:

$$V_{pin\ 1} = V_o + I_L\ (R_{sc})$$

where I_L = the load current in amperes, is valid for all I_L from 0.0 to I_{sc}. Note that $V_{pin\ 1}$ increases linearly from V_o at I_L = 0 to (V_o + 0.6) at $I_L = I_{sc}$.

The MC1469R can dissipate 3 watts at an ambient temperature of 25°C without a separate heat sink. The actual power dissipation is calculated from the voltage drop across the IC and the current into the IC, and is closely approximated by

$$P_D \text{ actual} = (V_{pin\ 3} - V_{pin\ 1})\ I_{pin\ 3}$$

where P is in watts, V is in volts, and I is in amperes.

The voltages and currents are defined in **fig. 1**. If the MC1469R is operated with no heat sink at ambient temperatures other than 25°C, the maximum allowable power dissipation can be computed by

$$P_{Dmax} = \frac{150 - Ta}{41.6}$$

where P_{Dmax} = the maximum allowable device power dissipation in watts at an ambient temperature, T_a, in °C. The constants in the formula reflect a maximum junction temperature of 150°C and a thermal resistance from junction to ambient of 41.6°C/watt.

establishing boundary conditions

Now that the necessary facts have been ferreted out of the IC data sheet,[1] and the regulator circuit operation is understood, the boundaries on the volt-ampere characteristic of the unregulated input source become evident. The lower limit of the unregulated input voltage is restricted by the minimum input voltage requirement of the IC; the maximum current required from the unregulated power supply is equal to the regulator short-circuit current; the maximum voltage from the unregulated power supply must be less than the maximum IC input voltage limit, and must lie below the curve describing the ICs power-dissipation limit.

The general procedure for establishing these boundaries follows (again referring to **fig. 1**, and using the MC1469R parameters):

1. Specify the intended regulated output voltage, V_o. The value of R1 may be calculated at this time.

2. Specify the desired short-circuit current limit, I_{sc}. Calculate R_{sc}. I_{sc} must be less than 500 mA.

3. Calculate $V_{pin\ 1}$ from I_L = 0 to $I_L = I_{sc}$.

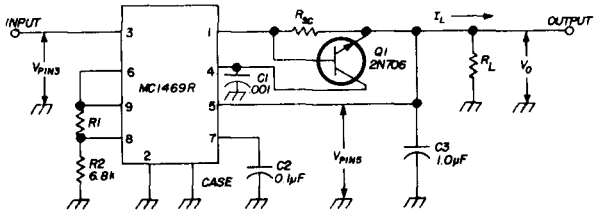


fig. 1. Complete power-supply regulator circuit designed around the Motorola MC1469R. Components Q1 and Rsc may be eliminated if current limiting is not desired.

4. Determine the minimum allowable $V_{pin\ 3}$ by adding 3.0 Vdc to the values of $V_{pin\ 1}$ calculated in step 3. If this value of $V_{pin\ 3}$ is less than 9.0 Vdc, set $V_{pin\ 3}$ equal to 9.0 Vdc.

5. Calculate the maximum allowable power dissipation, P_{Dmax}, at the anticipated temperature, T_a.

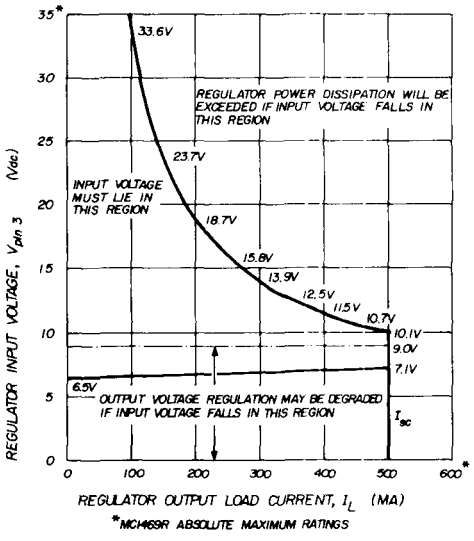


fig. 2. Restrictions on the unregulated input voltage to the 3.5 V dc regulator circuit.

6. Calculate the maximum allowable $V_{pin\ 3}$ for several points by substituting corresponding pairs of $V_{pin\ 1}$ and I_L into the following equation

$$V_{pin\ 3} = \frac{PD_{max}}{I_L} + V_{pin\ 1}$$

Calculated values of $V_{pin\ 3}$ greater than 35 Vdc, must be set equal to 35 Vdc, since $V_{pin\ 3}$ must not exceed 35 Vdc. Note that the calculated $V_{pin\ 3}$ is somewhat optimistic, since it doesn't include the power dissipation in the IC internal control circuitry.

7. Plot the data from step 4 and step 6 on a graph of I_L (from 0 to I_{sc}) as a function of $V_{pin\ 3}$ (from 0 to 35 Vdc). The volt-ampere characteristic of the unregulated power supply connected to pin 3 must lie within the region bounded by the two sets of data. If the two sets of data intersect, the short-circuit current specified in step 2 cannot be tolerated and must be reduced.

design examples

Three design examples, using the step-by-step procedure previously outlined, follow.

Example 1. Design a regulated power supply using the MC1469R delivering 3.5 Vdc at 0 to 500 mA, operating at an ambient temperature of 25°C.

1. V_o = 3.5 Vdc; R1 = $2V_o - 7 = 0$ ohms

2. I_{sc} = 500 mA; $R_{sc} = 0.6/I_{sc} = 1.2$ ohms

3. $V_{pin\ 1} = V_o + I_L R_{sc} = 3.5 + 1.2$ I_L = *

4. $V_{pin\ 3}$ (min) = $V_{pin\ 1} + 3.0$ = *

5. $$P_{Dmax} = \frac{150 - T_a}{41.6} = 3.0 \text{ watts}$$

6. $V_{pin\ 3}$ (max) = $P_{Dmax}/I_L + V_{pin\ 1}$ = *

* Values of these parameters for eleven different load currents, from 0.0 to 500 mA, are tabulated below.

I_L mA	Step 3 Vdc	Step 4 Vdc	Step 6 Vdc
0	3.50	(6.50)9.0	(∞)35.0
50	3.56	(6.56)9.0	(63.6)35.0
100	3.62	(6.62)9.0	33.6
150	3.68	(6.68)9.0	23.7
200	3.74	(6.74)9.0	18.7
250	3.80	(6.80)9.0	15.8
300	3.86	(6.86)9.0	13.9
350	3.92	(6.92)9.0	12.5
400	3.98	(6.98)9.0	11.5
450	4.04	(7.04)9.0	10.7
500	4.10	(7.10)9.0	10.1

7. The data from steps 4 and 6 are plotted in **fig. 2**. Note that $V_{pin\ 3}$ (max) is restricted to 35.0 Vdc, and that $V_{pin\ 3}$ (min) is set equal to 9.0 Vdc. The unregulated input voltage must lie between 9.0 and 10.1 Vdc at I_L = 500 mA, and between 9.0 and 35.0 Vdc when I_L = 0.

Example 2. Design a regulated power supply using the MC1469R delivering 5.0 Vdc at 0 to 500 mA, operating in an ambient temperature of 25°C.

The calculations follow the pattern of example 1. R1 is 3.0k ohms; values for $V_{pin\ 1}$ from step 3, $V_{pin\ 3}$ (min) from step 4, and $V_{pin\ 3}$ (max) from step 6 are tabulated below. Again, $V_{pin\ 3}$ (min) must be set equal to 9.0 Vdc, and $V_{pin\ 3}$ (max) is restricted to 35.0 Vdc. The data from steps 4 and 6 are plotted in **fig. 3.**

I_L mA	Step 3 Vdc	Step 4 Vdc	Step 6 Vdc
0	5.00	(8.00)9.0	(∞)35.0
50	5.06	(8.06)9.0	(65.1)35.0
100	5.12	(8.12)9.0	(35.1)35.0
150	5.18	(8.18)9.0	25.2
200	5.24	(8.24)9.0	20.2
250	5.30	(8.30)9.0	17.3
300	5.36	(8.36)9.0	15.4
350	5.42	(8.42)9.0	14.0
400	5.48	(8.48)9.0	13.0
450	5.54	(8.54)9.0	12.2
500	5.60	(8.60)9.0	11.6

Example 3. Design a regulated power supply using the MC1469R delivering 3.5 to 5.0 Vdc (variable) at 0 to 500 mA, operating at an ambient temperature of 25 °C.

R1 is replaced with a variable resistor adjustable from 0 to 3000 ohms to allow the output voltage to be set anywhere from 3.5 to 5.0 Vdc. R_{sc} remains at 1.2 ohms for current limiting at 500 mA. $V_{pin\ 3}$ (min) and $V_{pin\ 3}$ (max) from examples 1 and 2 are compared on a point-by-point basis, and the highest values of $V_{pin\ 3}$ (min) and the lowest values of $V_{pin\ 3}$ (max) become the new restrictions on $V_{pin\ 3}$, as shown in **fig. 4.**

modifying the unregulated supply

One of the key points mentioned earlier was that "... the volt-ampere characteristic of the unregulated voltage source is the *only manipulatable system variable.*" Thus the volt-ampere characteristic of the unregulated power supply must conform to the limits established by the design requirements of the power-supply regulator. If adequate control can be exercised over the selection of the power-supply components, the unregulated power supply can be designed to conform directly to the unregulated input voltage requirements of the IC voltage regulator; if not, the unregulated power supply load profile must be modified externally.

I built an unregulated dc power supply with components on hand for use with the regulator in example 3. Its output voltage was measured at various load

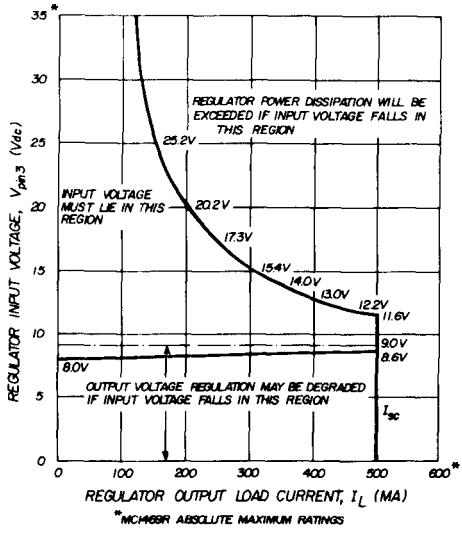


fig. 3. Restrictions on the unregulated input voltage to the 5.0 V dc regulator circuit.

currents and was varied from 17.9 Vdc at 0 mA to 13.9 Vdc at 500 mA. The volt-ampere characteristic of this supply is superimposed on **fig. 4** and identified as the "unacceptable input voltage profile." The output voltage of this supply would have exceeded the maximum allowable voltage on pin 3 of the MC1469R, under the specified design conditions, and the IC power dissipation would have been exceeded when the regulator output-current demand increased much beyond 270 mA. A substantial portion of the total output current capability of the voltage regulator IC could not have been used.

A 10-ohm resistor placed in series with

the positive lead from the unregulated power supply modified the power-supply load profile, producing the "typical input voltage profile" volt-ampere curve in **fig. 4**. Note that the voltage applied to pin 3 of the MC1469R remains in the permissible input voltage region for all values of I_L, allowing the full capability of the voltage regulator IC to be realized.

Experimental measurements on this voltage regulator system revealed an MC1469R junction temperature rise of

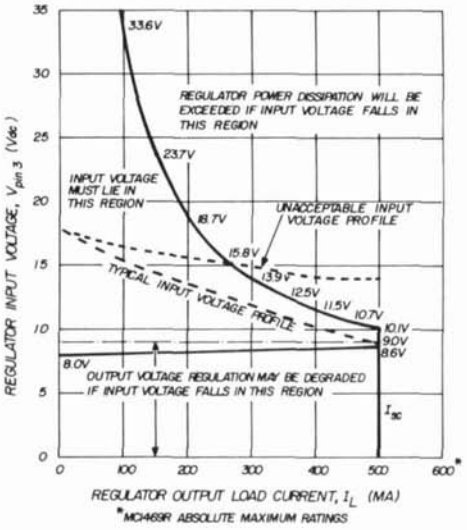


fig. 4. Input voltage restrictions and experimentally-determined unregulated power supply volt-ampere characteristics for a 3.5 to 5.0 V dc variable regulated power supply.

86 °C at V_o = 3.5 Vdc and I_L = 500 mA (2.8 watts dissipation). The measured junction temperature rise was 30 °C below the calculated value; this is attributed to (a) the conservative thermal resistance values used in the IC data sheet, and (b) the additional thermal path created by attaching the IC case to the mounting studs of the particular socket I used.

reference

1. "Motorola MC1469R Positive-Power-Supply Voltage Regulator Integrated Circuit Data Sheet," Motorola Semiconductor Products, Inc., P. O. Box 20912, Phoenix, Arizona 85036.

lunar-path nomograph

An aid for determining signal attenuation due to variance in earth-moon distance

Bill Ress, WA6NCT, Eimac Division of Varian, San Carlos, California 94070

Here's a handy operating aid that will be appreciated by the moonbounce gang. It allows accurate determination of the variance in free-space signal loss caused by the change in earth-moon path length.

The distance between earth and moon at the moon's perigee, which is the point of the moon's orbit closest to earth, is nominally 221,463 miles. At apogee, or the point of the moon's orbit farthest from earth, the nominal distance is 252,710 miles. This variation can account for a 1.28-dB change in signal level for the earth-moon path, or a total of 2.56 dB for the round trip.

The optimum time for moonbounce work, of course, is at the moon's perigee. However, since the earth-moon path distance varies, it's convenient to know the expected signal levels at times other than perigee.

data forecasts

It will be necessary to know the distance between earth and moon at the time of interest. Various tables can be consulted, but the most convenient source of this data is *Sky and Telescope,*[1] a magazine published for astronomy enthusiasts. In the Celestical Calendar section of this magazine, perigee and apogee times of the moon's orbit are given, together with earth-moon distances and the moon's effective diameter. This data is published a month in advance, since perturbations in the moon's orbit cause perigee and apogee to vary from month-to-month. Other useful information is also given. Sunspots and times of meteor showers are forecast, and articles are published on radio astronomy and satellite activity.

using the nomograph

Table 1 is a computer printout giving free-space signal attenuation in dB for

table 1. Computer printout showing free-space path attenuation for several frequencies as a function of various earth-moon distances.

distance (miles)	50 MHz (dB)	144 MHz (dB)	432 MHz (dB)	1296 MHz (dB)	2375 MHz (dB)	3600 MHz (dB)
220000	177.82	187.01	196.55	206.10	211.36	214.97
225000	178.02	187.21	196.75	206.29	211.55	215.16
230000	178.21	187.40	196.94	206.48	211.74	215.36
235000	178.40	187.58	197.13	206.67	211.93	215.54
240000	178.58	187.77	197.31	206.85	212.11	215.73
245000	178.76	187.95	197.49	207.03	212.29	215.90
250000	178.93	188.12	197.66	207.21	212.47	216.08
255000	179.11	188.29	197.84	207.38	212.64	216.25

several frequencies and earth-moon distances. The attenuation numbers can be read directly from the table for earth-moon distances between 220,000 and 255,000 miles in the 5000-mile increments. The nomograph (**fig. 1**) is used for linear interpolation to determine the free-space signal attenuation for earth-moon distances not given in the table. Note that the table and nomograph are based on an earth-moon distance of 220,000 miles.

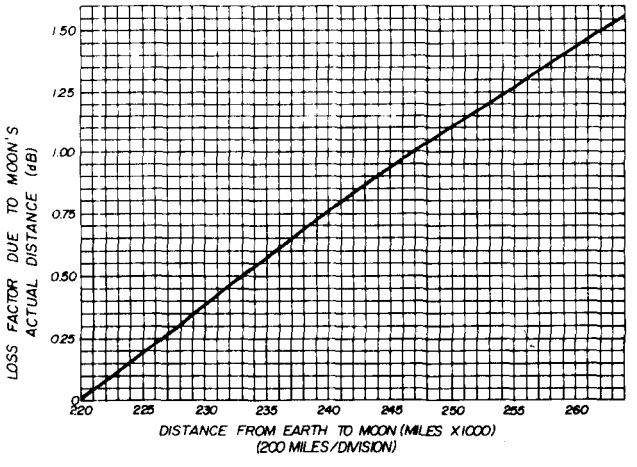


fig. 1. Nomograph for determining loss (interpolation) factor for actual distances between earth and moon.

example

Knowing the earth-moon distance, enter **fig. 1** at the distance, and move vertically to the intercept line. Then read the interpolation factor on the ordinate. From **table 1**, determine the free-space loss at 220,000 miles for your operating frequency, then add this number to the interpolation factor. Example:

Earth-moon distance = 233,000 miles

Operating frequency = 2375 MHz

From **table 1** the free-space loss (220,000 miles) = 211.36 dB

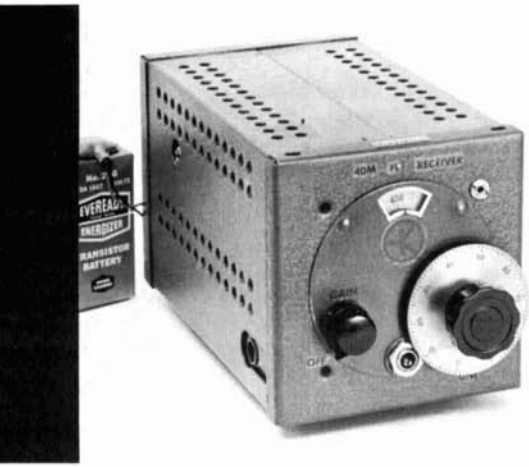
From **fig. 1** the interpolation factor (233,000 miles) = 0.50 dB

Therefore, the free-space attenuation for 233,000 miles = 211.36 + 0.50 dB = 211.86 dB.

reference

1. *Sky and Telescope,* Sky Publishing Corp., 49-50-51 Bay State Road, Cambridge, Massachusetts 02138.

ham radio



converted BC-1206 for 7 MHz

Another surplus item easily modified with transistors for low-frequency work

Bill Latta, Jr., W4FIN, 3822 North Western Parkway, Louisville, Kentucky 40212

The BC-1206 beacon receiver is another of the fine units still available on the surplus market that lends itself to modification for amateur use. It tunes from 200 to 400 kHz and has a 135-kHz i-f. The original design was for a 28 Vdc power supply.[1,2]

For some time I had been thinking about adapting a BC-1206 for use as a portable ham receiver. It looked like a natural for solid-state conversion; so I replaced the tubes with transistors, added a solid-state bfo, 40-meter crystal converter, and a manufactured audio stage. Result: an all-solid, completely portable receiver.

construction

Preliminary work consisted of checking the unmodified receiver on 28 Vdc, then on 12 Vdc after paralleling tube filaments. Reception of local and distant stations was good. It would have been possible to use the receiver on 12 volts with only a converter and bfo, but I chose the solid-state route for the challenge and because of economic reasons.

beat frequency oscillator

The bfo **(fig. 1)** is a miniaturized version for 135 kHz adapted from reference 3. It's mounted in a sawed-off TV i-f can, to which solder lugs were attached and bent outward for soldering to the inside front panel. I wired the components around the original i-f coil form after removing the wire. The subminiature rf choke was mounted inside the form by drilling a small hole through the form and pulling one choke lead through the hole. The original slug can be used to

control pitch. If no pitch control is desired, the slug can be removed.

I removed the original phone jack and substituted a ¼-inch panel bushing. The bfo assembly was mounted with the pitch control protruding through the bushing for front-panel access.

The bfo is well shielded, and a pi-network filter is included in its power lead to minimize stray radiation. I used miniature coax cable for the output lead. In the completed receiver, a "birdie" was picked up at the bfo's second and third harmonics. A phase-shift oscillator, which would have no harmonic output, should alleviate this problem and is a possible improvement. The receiver is used for cw and ssb only, so I didn't include a bfo control switch.

the converter

The 40-meter converter **(fig. 2)** is a miniaturized one-band version of another design.[4] It is housed in a steel box that fits into the space left by the i-f detector, the audio tubes and the output transformer.

I drilled a hole in the side of the crystal socket and mounted the socket horizontally to provide clearance for the housing. No special precautions are necessary in construction except to keep L1 and L2 axes at right angles to minimize coupling.

Since my interest was in the 7- to 7.1-MHz range, and receiver bandwidth is best between 200 and 300 (on the main tuning dial), a 6.8-MHz crystal was used. The rf amplifier isn't needed for sensitivity, but it helps to suppress images.

detector and audio

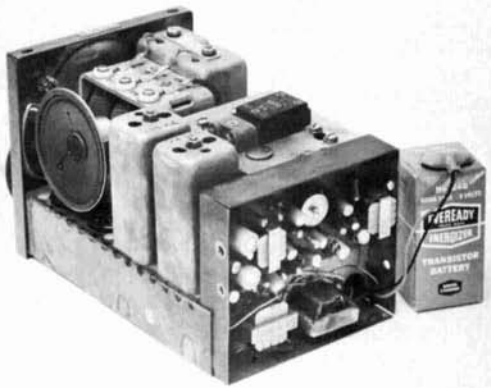
A single 1N270 could be used as a detector, with the bfo voltage injected at the i-f amplifier gate. However, I decided to use a product detector.[5] Experimentally, a pnp germanium transistor was a good substitute for the two diodes **(fig. 1)**.

I used a Round Hill model AA-100 audio amplifier* because I had one on hand. However, other audio boards, modules, or ICs will work just as well.

I mounted the audio amplifier on the rear deck of the receiver after removing all the original rear components except the small open-frame filter choke. To make the amplifier fit into the space, it was necessary to remove the output transformer, relocate one 100 μF capacitor, then saw off both ends of the board.

*Round Hill Associates, Inc., 434 Avenue of the Americas, New York, N. Y. 10011.

Rear view showing how the audio deck is mounted. Battery is an Eveready 246; six size D cells in series could be used.



Interior view of modified receiver. Converter is in box with crystal on top.

I put a thin sheet of insulation on both sides of the board and cemented more insulation to the inside back of the amplifier housing to ensure against short circuits.

and rf stages will tend to oscillate if jfets are used. Rather than neutralize these circuits, I used 3N128 mosfets, which provide good stability and adequate gain. The usual precautions must be used when

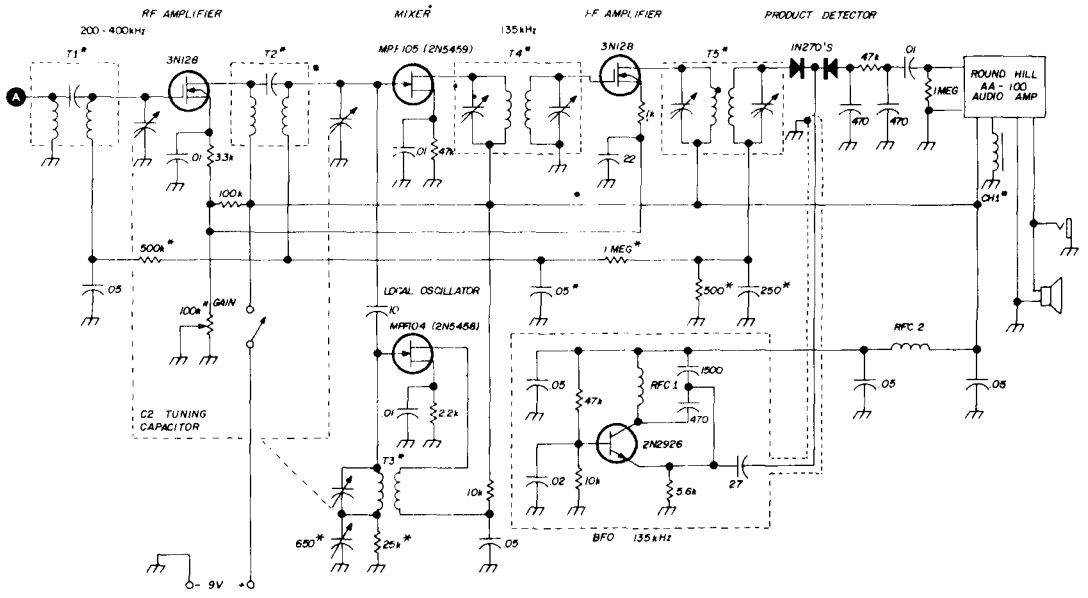


fig. 1. Schematic of converted BC-1206 beacon receiver with added bfo and audio stages. Components marked with an asterisk are original. RFC1 and RFC2 are 3.9 mH (J. W. Miller 70F393AI).

Next, I solder-mounted the output transformer below the board and reconnected the transformer. Since the board operates from positive ground, the input and output windings must be lifted from board ground and connected to the main radio chassis ground to avoid shorting the battery. These are pins 1 and 9 respectively of T1 and T3 on the AA-100 board.

The amplifier oscillated when it was connected to the common battery source, and the usual decoupling methods didn't help. The problem was cured by connecting the open-frame filter choke in series with the amplifier's negative lead. A 2¼-inch 3-ohm speaker was mounted in the space left by the original rf and converter tubes.

i-f and rf amplifiers

The receiver will work merely by replacing tubes with fets; however, the i-f

handling such devices. I used an MPF105 (2N5459) and an MPF104 (2N5458) for mixer and local oscillator.

I varied resistances for each stage for optimum performance, then soldered fixed resistors into the circuit. The agc line was left intact, although it has little effect on operation. Better agc might be had by using double-gate mosfets.

power supply

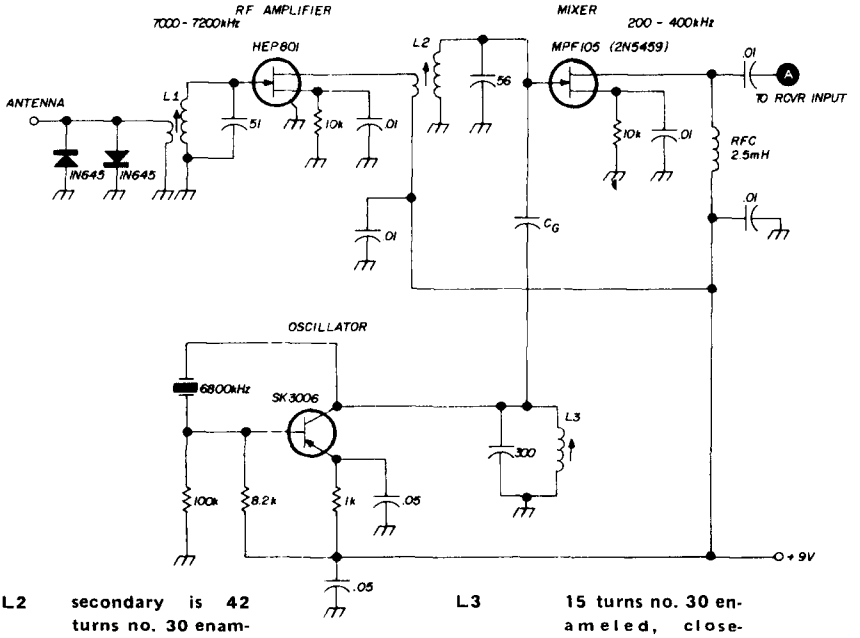
Optimum supply voltage is 9 volts, although the receiver will operate on 7½ volts with less audio. With 12 volts, additional spurious signals will appear in the output. These are caused by the crystal oscillator beating with the local oscillator harmonics. At 9 volts, idle current is about 15 mA with peak current over 35 mA.

Small transistor batteries will work, but they have poor regulation and short

life for this application. The larger transistor-radio batteries are better. Nicad or mercury batteries are also good. Six size D flashlight cells in series make an economical power pack.

good results, which satisfied an urge for a complete, miniaturized, all-battery-operated, solid-state station.

Low-power transmitters are fun, but it's more fun using a low-power receiver



L1, L2 secondary is 42 turns no. 30 enameled, closewound on ¼" slug-tuned form; primary is 7 turns no. 30 enameled, closewound over cold end of secondary.

L3 15 turns no. 30 enameled, closewound on ¼" slug-tuned form

fig. 2. Solid-state converter for 7 MHz. Components fit into space formerly occupied by tubes and output transformer. "Gimmick" is two 1" lengths of hookup wire twisted together.

the exterior

I drilled additional holes in the right side of the case for a speaker grill and added a hole in the left side for the antenna connection. I also added bumper feet to the bottom, a cutout in the rear to pass the battery connector to the outside, and mounted a battery holding strap onto the rear of the cabinet.

operation

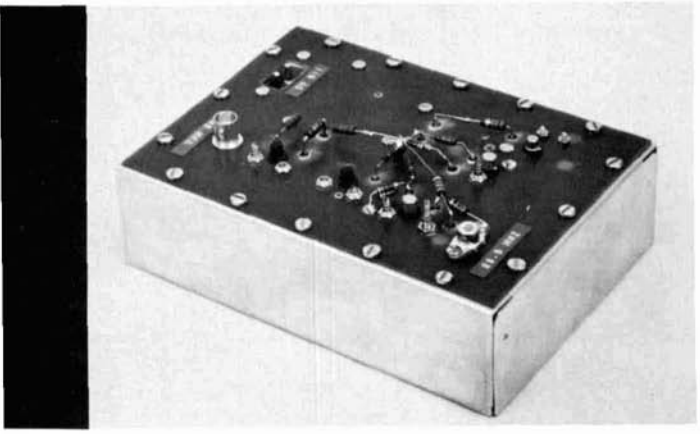
The converted BC-1206 provides sensitive, stable, and fairly selective cw and ssb reception in a small package with low power requirements. It needs only a short antenna: a wire about 15 feet long or so.

I've used this receiver with a companion low-power transistor transmitter with with the transmitter. The receiver is also a valuable adjunct to your station for emergency use.

references

1. Grayson, "Surplus Schematics Handbook," Cowan Publishing Corp., Fifth Printing, August, 1967, p. 49.
2. "Instruction Manual, Model 524 Beacon Receiver," Setchell Carlson, Inc., St. Paul, Minnesota. (Sometimes available with surplus receivers.)
3. Marriner & Meredith, "Transistorized 455-kHz BFO," *ham radio*, July, 1968, p. 12.
4. Sam Creason, "An FET Converter for 40 and 160," *73*, October, 1967, p. 26.
5. "Heterodyne and Product Detectors," The Radio Amateur's Handbook, ARRL Staff, 1969 Edition, p. 97.

ham radio



low-noise converter for 432 MHz

A circuit using inexpensive fet's that gives a good account of itself over the long hauls

James W. Brannin, K6JC, 424 Anson Avenue, Rohnert Park, California

Now that economically priced solid-state devices are available for use above 400 MHz, the cost of building uhf equipment has been considerably reduced. The converter described here uses only seven active devices, all of which cost less than $3.50. The 2N5245s net at 70¢, the 40237s are 38¢, and the diodes are about 30¢ apiece.

The bandwidth of the converter at the 3-dB points is between 431 and 433 MHz. The noise figure is 3.5 dB. If you'd like to reduce this another half dB or so, a 2N5397 fet can be used in the first rf stage instead of the 2N5245; however, the 2N5397 costs about $8.50.

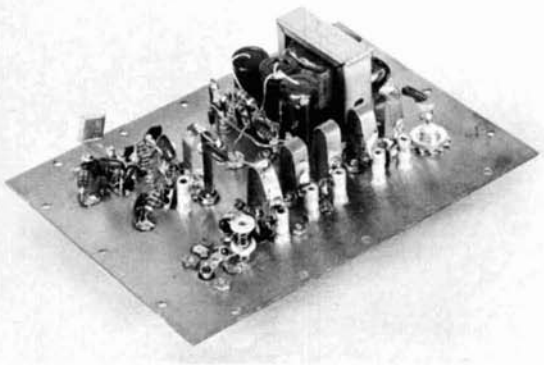
The circuit is conventional **(fig. 1)**. Two fet grounded-gate amplifiers and a common-emitter mixer are used. Oscillator output is about 8 mW. The quadrupler output is somewhat below this, but it provides sufficient injection voltage for the mixer. Both input and local oscillator signals are applied to the mixer transistor base. This arrangement offers the best conversion efficiency for this type transistor at these frequencies.

layout and construction

Component arrangement, component spacing, and wiring placement have been optimized for best performance based on several earlier versions. Shielding isn't necessary, since there appears to be enough feedback in the front end to eliminate any tendency toward instability. As a matter of fact, the shielding that was installed around each of the first three stages in the original model had to be removed to eliminate regeneration. The spacing between tuned circuits in the amplifier and mixer was optimized to provide satisfactory interstage coupling without the use of capacitors.

The chassis measures 5x7x2 inches. The circuit board is glass epoxy with copper foil on one side. These boards are available from many surplus outlets. Some are pullouts from computer modules and have discrete components mounted on them, which can be salvaged for your junk-box inventory.

Component arrangement. Rf amplifiers and mixer tuned circuits are mounted along the near edge of board; oscillator and power supply are at rear.



All wiring except that for the power supply is on top of the board. This allows power to be fed to all stages via feedthrough capacitors, which minimizes coupling problems in the wiring. The board should be drilled as closely as possible to the dimensions on the template except for holes associated with the power supply.

coil construction

The Q of the tuned circuits was increased when the hairpin loops were made of copper strip instead of wire. Coils L1, L2, L4, and L9 are made by cutting 20 gauge flashing copper in strips ¼ inch wide by 2-1/8 inches long. The mixer coil, L5, should be ¼ inch shorter to reduce its inductance so that it will resonate with the tuning capacitor piston halfway inserted. The end of the coil that is soldered to the feedthrough capacitor is trimmed to a point. When the loops are installed they should stand 1-3/8 inches above the board.

Coil L3 is made from a copper strip 2¼ inches long. The ground end should not be trimmed to a point but should be bent out 1/8 inch for soldering to the board. Otherwise its construction is the same as the other amplifier coils.

The i-f output coil, L6, consists of 18 turns of no. 24 enamelled wire close wound on any type of 3/16-inch diameter slug-tuned form. (A grid-dip oscillator should be used to check the coil.) The output link, L7, is made from three turns of no. 22 enamelled wire wound on the cold end of L6.

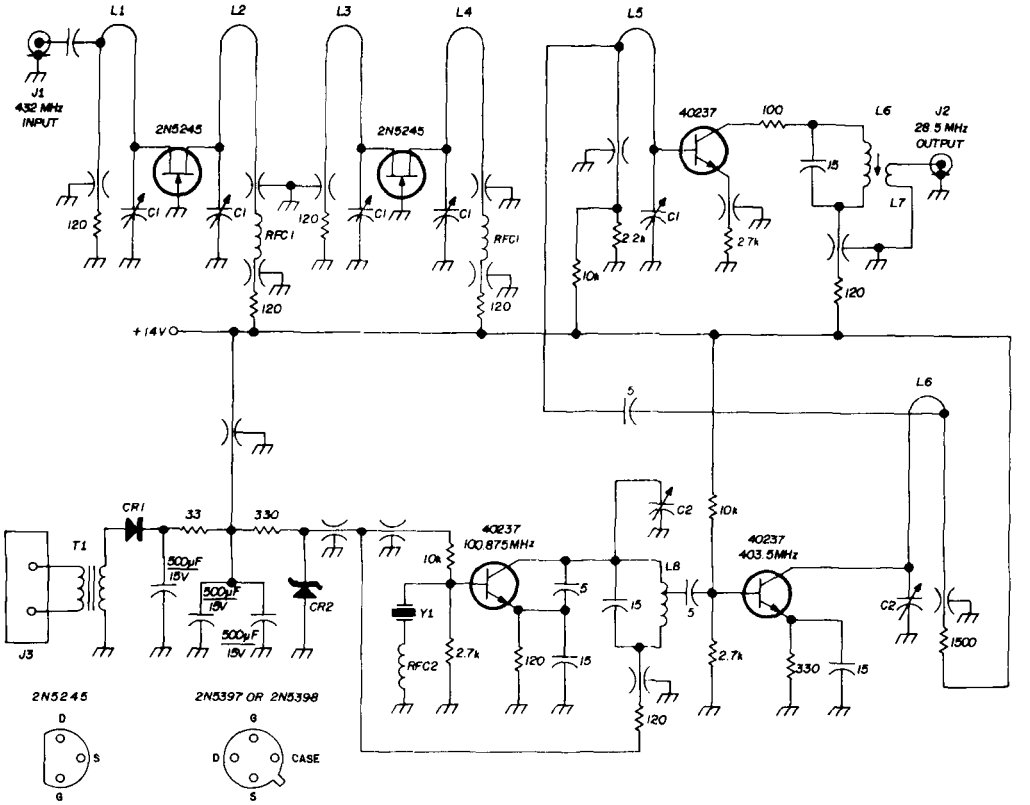
The oscillator coil, L8, consists of 4¾ turns of no. 20 enamelled wire, spacewound, ½ inch long by ¼ inch I.D. The output tap is located 1 turn from the top.

local oscillator

An rf choke is used in the crystal circuit to allow warping of the crystal frequency without appreciable loss in output. I suggest the crystal be ordered for 100.872 instead of 100.875 MHz, as the frequency will fall much closer to 100.875 if the crystal is ground for this lower frequency. The oscillator operates from the 10-V regulated supply, and the stability after a few minutes warmup is excellent. The frequency at 432 MHz was checked and exhibited a drift of about 300 Hz over a 3-hour period.

assembly

The unit should be assembled in the following sequence after the board is drilled.



C1 1-8 pF piston variable (Triko 106-01M)

C2 1½—10 pF air padder (Johnson T106S)

CR1 any diode rated at 200 V piv

CR2 10 V zener

J1 UG-1094A/U BNC receptacle

J2 phono jack

J3 standard ac receptacle to accommodate TV cheater cords

RFC1 7-3/8" length no. 24 wound on ½-watt resistor

RFC2 Same as RFC1 (may not be necessary)

T1 12.6 V filament transformer (Calectro D1-750 or equivalent)

Y1 *100.872 MHz 5th overtone crystal (see text)*

fets are *Texas Instruments 2N5245 or Siliconix 2N5397*

transistors are RCA 40237

feedthrough caps are Allen Bradley FW5N, 470 pF

standoffs are Arco DM15 1501

chassis is California A101, 5 x 7 x 2 inches

fig. 1. Schematic of the 432-MHz solid-state converter. Circuit features low-noise front end and highly stable oscillator.

1. Install all feedthrough capacitors.

2. Install the transistor sockets, using a good grade of cement.

3. Install the piston tuning capacitors and connect them to the proper terminal on the sockets.

4. Install the output slug-tuned coil.

5. Install the oscillator coil. This coil is rigidly supported by mounting it in a vertical position. Solder the bottom end to the center of the feedthrough capacitor, and connect the top end to C2 and the collector pin on the transistor socket using short, stiff leads.

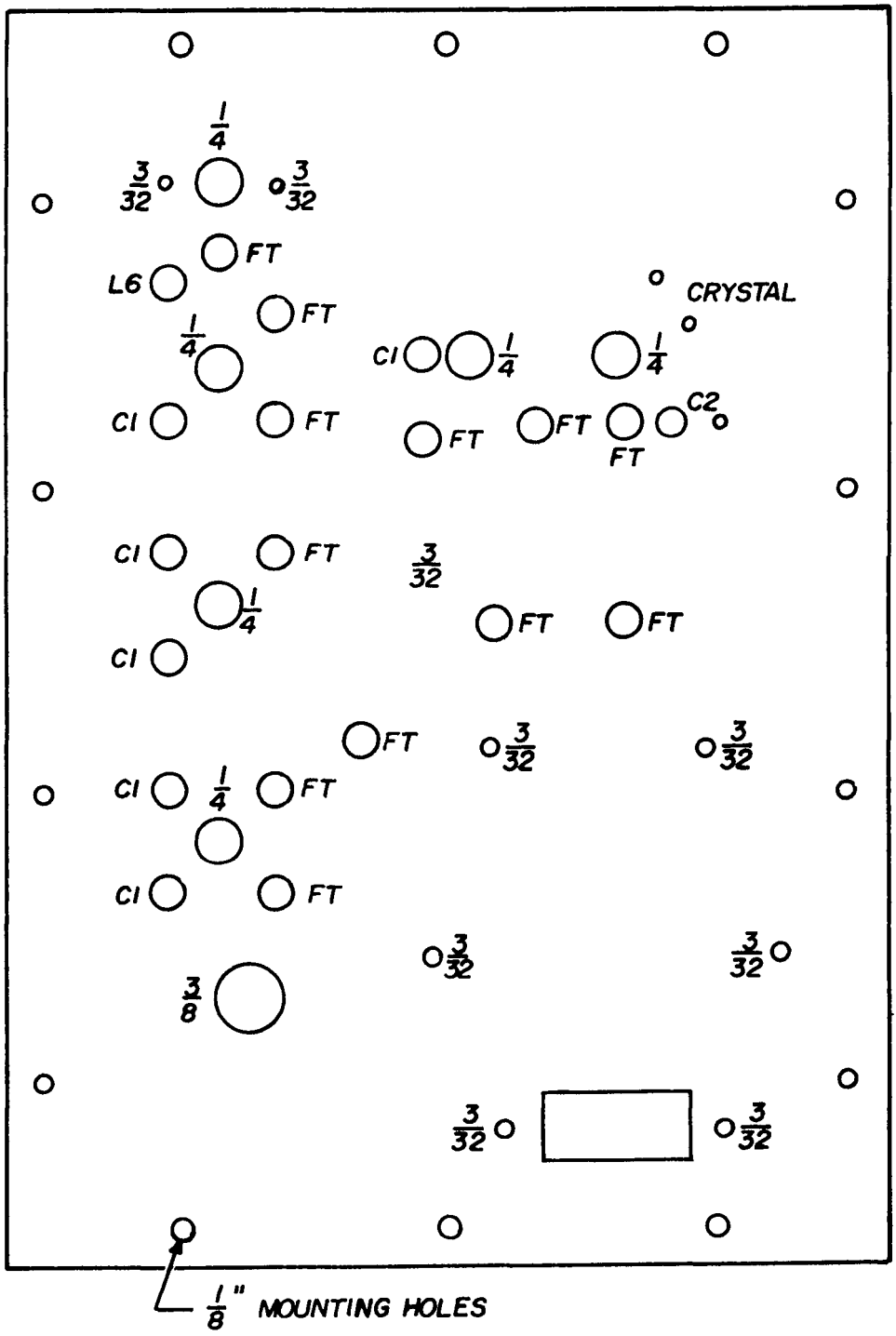


fig. 2. Full-size drill template for the 432-MHz converter. Holes for feedthrough capacitors (FT), L6 and C1 are 3/16" diameter. BNC connector holes are 3/8". Transistor sockets and J2 require 1/4" holes.

6. Install the hairpin loops, being careful to solder them to the feedthrough capacitors so that the capacitor isn't shorted with a drop of solder. The coupling capacitors on L1, L5 and L9 are soldered onto the loops near the top on the bypassed side.

7. Complete the quadrupler and oscillator wiring.

8. Finally, install the power supply, then complete the wiring on top of the chassis.

The two fets should be installed with the input tuned circuit connected to the source and the output connected to the drain so that 2N5397 or 2N5398 fets can be used if desired. When the 2N5245s are installed, the drain and source will be reversed; however this will have no effect on their operation. This is not true with some of the other fets.

tuneup and adjustment

If a commercial-type signal generator isn't available, I'd suggest that one of the vhf small-signal sources be built in accordance with my article in a previous issue of *ham radio.*[1] The converter can be aligned using the third harmonic from a 144-MHz transmitter. However, it may be difficult to obtain optimum performance unless a variable output generator of some type is used.

The first testing should begin with the oscillator and quadrupler. A gdo tuned to the oscillator frequency will allow you to determine if the crystal is operating on the proper mode. A vtvm with an rf probe can be used to peak the quadrupler output. The probe should be coupled through a 33-pF capacitor to the top of the mixer hairpin loop and the quadrupler adjusted for maximum output. It will be necessary to use one of the lower-voltage scales to detect the very small amount of rf at this point in the circuit. Once the signal from the generator or from the 144-MHz transmitter is found, all tuned circuits can be readjusted for optimum signal.

A word of caution here: When peaking the circuits, tune off the incoming signal and check the noise level as indicated on a receiver S meter. The objective is to get the greatest possible signal-to-noise ratio. Final adjustments can be made with a noise generator, which should be used if possible. A second word of caution: Use a noise generator for *very slight readjustments only.* You may get one of the stages tuned to the image frequency and the noise figure will appear to be very good, but 432-MHz stations probably won't be heard unless they're next door.

The final adjustment should be made with the converter mounted in the chassis with all of the mounting screws tightened carefully. Final adjustments can sometimes be made quite well while listening to a distant weak signal provided it isn't fading.

operating results

Several of these converters have been operating in this general area with very good results. Noise figure has been measured at close to 3.5 dB on all units. I have never failed to copy WB6PDN's two watter in Stockton with this converter connected to a 16-element colinear antenna only 24 feet high. Stockton is well over 100 miles from my location, and the path is across several mountain ranges. Stations in the San Francisco bay area as far south as San Jose, a distance of about 80 miles, are worked regularly. Only about four stations use more than a few watts on 432 MHz.

While converters in this band are not as easy to build and adjust as those for 144 and 50 MHz, they will work without too many difficulties if one is careful in construction. Try to use a hefty signal when starting the alignment and graduate later to weaker signals.

My thanks to many of the dedicated vhfers in this area who provided much helpful information in building this converter.

reference

1. James W. Brannin, K6JC, "A Stable Small-Signal Source for 432 MHz," *ham radio,* March, 1970, p. 58.

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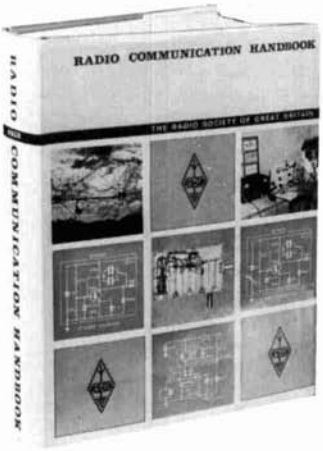

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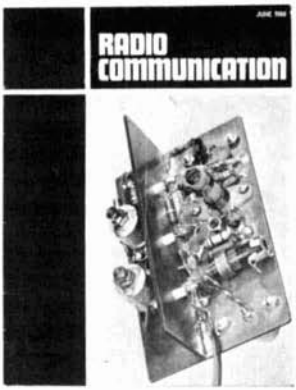

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More Details? CHECK—OFF Page 94

precise frequency tuning with ssb equipment

Hints on pinpointing operating frequency in the ssb, cw, and rtty modes

Doug Horner, WØKD, 1260 E. Avenue, Marion, Iowa 52302

Single sideband has come of age. That struggling infant, the "new" communications mode that initially attracted only a select group of amateurs, has finally been accepted. Gone are the somewhat snobbish (but enjoyable) sideband dinners and sideband forums that used to be so popular. Articles explaining single sideband are now conspicuous by their absence in the amateur literature.

Despite the wide acceptance of ssb, some of its aspects remain mysterious and confusing to many. One is how to determine the *actual* transmitted and received frequency, a capability especially needed by net-control stations and to a lesser degree by net-responding stations.

This article reviews some of the basic principles unique to ssb and offers suggestions to aid in adjusting transmitters and receivers to a desired frequency with certainty and precision.

background

Sideband started on the ham bands with home-constructed exciters. Then we added linear amplifiers, vox, bandswitching, and the oscilloscope to check linearity. Receivers became more complex. We added sideband slicers, compression amplifiers, Q multipliers, etc., until a sideband's station looked like the bargain basement in a radio store.

Then manufacturers made exciters available--receivers too. These were followed by linears. In 1957 Collins introduced a revolutionary little set that became the vanguard of the industry—a transceiver. The KWM-1 combined both transmitter and receiver in one compact package, and the radio-store look of the ham shack gave way to a neat, wife-approved station.

Sideband transceivers so dominate ham radio today that even seasoned hams at times feel as though they are operating a-m equipment in unfamiliar territory. The following paragraphs will help to

dispel some of the confusion associated with tuning ssb equipment and allow you to determine operating frequency whether using voice, cw, or rtty.

a-m signals

For a start, let's look at the grandpa signal, amplitude modulation. Basically, any radiotelephone transmitter merely translates audio frequencies to radio frequencies, and the receiver translates the radio frequencies back to audio frequencies. To accomplish this, one must use a frequency translator into which is injected two signals: that which is to be translated and another signal generated locally in an oscillator. When combined in the frequency translator, the two signals are said to be heterodyned. Sum and difference signals are produced, and the composite signal consists of the cw carrier and two mirror-image sidebands, which contain the a-m signal. A graphical representation of this is shown in **fig. 1**.

ssb

Those who take license exams must learn that, "For each modulating frequency an upper and lower frequency appears either side of the carrier by an amount equal to the frequency of the modulating tone." For speech, a band of frequencies (roughly from 300–3000 Hz) appears rather than individual side frequencies. These are called sidebands.

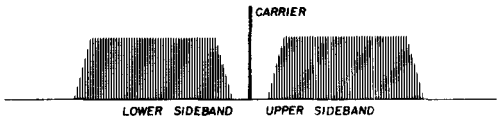

fig. 1. Representation of amplitude-modulated signal, consisting of carrier and two sidebands.

As the magazine articles told us when ssb was new, "No information is passed by the carrier. All it does is 'blow the whistle.' Therefore, we don't need the carrier for communications. Also, since it contains all the information needed for communications." This concept is depicted in **fig. 2**. The upper sideband remains, as in the a-m signal, but the carrier and lower sideband have been suppressed.

ssb tone generator

A statement similar to that made earlier about an a-m signal can be made about an ssb signal: "for or modulating frequency an upper and lower sideband appears, which is removed from the suppressed carrier by an amount equal to the frequency of the modulating tone."

The practical result is that, if you feed a pure tone of a given audio frequency into a quality ssb transmitter, a single frequency will be produced that is removed from the suppressed carrier by an amount equal to the audio frequency. Many ssb transmitters and transceivers take advantage of this phenomenon by using a tone generator to derive a cw signal.

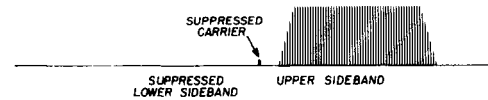

fig. 2. Single-sideband signal; one sideband and the carrier have been suppressed.

Now here's where the confusion begins. If you calibrate your receiver so the dial hairline coincides with 0 on the dial when you tune to zero beat against the calibrator signal, what you actually hear is the suppressed-carrier frequency. Theoretically, no energy is either radiated or received on that frequency. If you're operating phone on upper sideband, communication is taking place 300–3000 Hz above the dial reading. If on lower sideband, the energy is 300–3000 Hz below the dial frequency.

cw frequency spotting

The explanation above is fairly easy to understand, but let's say you own a transmitter that generates cw by passing a

tone through the balanced modulator and the sideband filter. You're the control station for a cw net, say, and must place your transmitter on a specific frequency to begin calling the net. How do you set your dial to obtain that frequency?

This isn't too difficult. If you know the frequency of the tone generator, and the upper-sideband position is used for cw, then tune your dial lower in frequency by an amount equal to the frequency of the tone oscillator (see **fig. 3**). If the audio tone is converted to "carrier" and the true carrier is suppressed, to be on frequency you must sidestep the dial tuning to place the resultant "carrier" where the true carrier would have been if it were radiated.

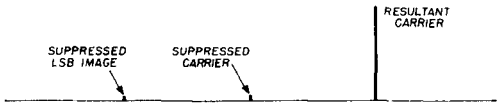

fig. 3. Frequency setting on cw with ssb transmitters using a tone generator. In the example shown, usb is used; dial setting must be set lower in frequency by an amount equal to tone oscillator frequency.

As an example, you're to call a cw net on 3565 kHz, and your sideband transmitter generates cw with a 1500-Hz tone oscillator working against the upper sideband bfo crystal. By setting your dial to 3563.5 kHz, your output frequency will be 3565 kHz;

suppressed carrier frequency = 3563.5

tone oscillator frequency = $\frac{+\ 1.500}{3565.000}$

frequency setting on rtty

Now let's suppose you're a control station for a tty net and you're feeding tones into your sideband transmitter, which it converts to frequency-shifted rf for transmission. How do you set the transmitter on frequency?

Usually, but not always, a center frequency straddled by the two tty frequencies is assigned as net frequency. It's possible your ssb exciter won't pass audio frequencies above about 2500 Hz, so you use a tone generator that operates on 1275 and 2125 Hz. This gives the more commonly used 850-Hz shift. One-half of 850 Hz is 425 Hz; 2125 minus 425 is 1700, 1275 plus 425 is 1700. Therefore, from this we may conclude 1700 Hz is the center frequency. To straddle the assigned frequency, first zero-beat your dial against the nearest 100-kHz point, then tune to 1700 Hz above the assigned frequency with the exciter and receiver in the lsb position. With 2125 and 2975 tones, the above information applies, except the center frequency is now 2550 Hz. Therefore, you should tune 2550 Hz higher for these tones.

Most sideband exciters neither have dials that can be read this accurately, nor does the output frequency ordinarily coincide this closely with the dial reading; but this is good ballpark information for much of the equipment available today. Very exacting requirements will demand the use of a counter or other accurate frequency meter to set up the individual transmitted frequencies precisely.

mark and space signals

Reference has been made to operating rtty on lower sideband. This is an arbitrary practice followed by amateurs, MARS, and some military organizations on the hf bands. What actually is transmitted can be remembered easily by stealing an acronym from a tobacco company, "LS/MFT." Supply the words, "low space makes fine teletype." The mark frequency is always the higher frequency transmitted, and space is the lower frequency. In practice the space signal sounds higher, but that's because of sideband inversion due to operating the equipment on lower sideband. When a transmitter employing a carrier is used, such as the a-m and fm equipment on the vhf bands, the tones are broadcast "right-side-up" with the space tone higher. This is known as afsk, or audio frequency-shift keying.

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the simplest audio filter

These circuits offer the ultimate in simplicity for effective cw reception

E. Dusina, W4NVK, 571 Orange Avenue West, Melbourne, Florida 32901

Many audio filters have appeared in magazine articles for both cw and ssb. The more popular of these have been centered around 44- and 88-mH toroids available for as little as 30 cents each from surplus sources.* This article describes such a filter for single-tone cw reception, but with all the nonessential frills removed. Also these filters have been tested on an audio-frequency spectrum analyzer, so their response using actual speaker loads is known quite exactly.

filter criteria

A cw filter must have one prime qualification to be considered good, namely very narrow bandwidth. Since 20 wpm represents only about 10 Hz actual information bandwidth, the filters of use to hams can be very sharp indeed. However, we can't practically use a 10 Hz filter, because transmitter plus receiver drift would require constant retuning. Also the filter would ring, producing disagreable-sounding code. The ringing could be removed by damping, but the pulses would still have rounded, sine-wave-like shapes. Therefore, the filter should be somewhat wider than the minimum bandwidth based on information theory.

Assuming ssb-grade frequency stability, the combined short-term drift of transmitter and receiver will seldom exceed 50 Hz. This bandwidth, being five times wider than the minimum necessary to pass all the information, will pass pulses with a square-wave shape. So a practical cw filter should not be narrower than about 50 Hz; and to be called good, it should not be wider than about 100 Hz.

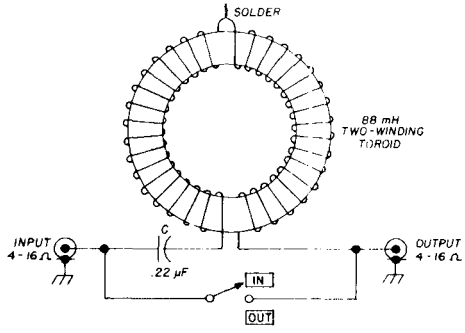
Another desirable feature for a general-purpose filter is that it operate in the speaker leads to eliminate the necessity for modifying resellable hardware.

If you're using an ssb receiver, all of which have linear product detectors, there is absolutely no signal-to-noise ad-

*See **flea market** ads in practically any issue of *ham radio.*

vantage whether the filter is in the predetection (i-f) or postdetection (audio) circuits. This isn't true for a-m receivers with their conventional detectors, however. For these, a Q multiplier in an i-f stage will give the ultimate in weak signal reception. But the audio filter is equally useful in a-m receivers for interference rejection. Why? Because the nonlinearity of the a-m detector becomes serious only on weak signals, where this nonlinearity produces noise. On weak signals the audio signal-to-noise ratio is considerably degraded from that which prevailed in the i-f amplifier before detection. This weak-signal degradation doesn't occur in an a-m receiver under normal interference conditions, since then the signals are strong enough to operate the a-m detector above the degradation point.

However, you can't have everything; and even with an ssb receiver, a very narrowband filter in the speaker leads won't prevent a strong adjacent signal from generating strong agc, thus weakening the signal you're selecting with the cw filter. This can be annoying if the strong adjacent signal is cw, because receiver gain will flip up and down in response to keying. The desired signal will sound like one subjected to severe flutter or fading conditions. The only remedy for this in ssb receivers is a filter ahead of the agc rectifier. In a-m receivers, filtering in the i-f amplifier will prevent this problem.



C (μF)	Frequency (Hz)
0.22	1200
0.5	720
1.0	520
2.0	380

fig. 1. The simplest audio filter. Bandwidth is about 70 Hz at 1.2 kHz; circuit Q is approximately 17.

circuit Q

The Q and hence the bandwidth of any practical filter is a function of the quality of components and circuit loading. Circuit Q defines the bandwidth as a percentage of the operating frequency.

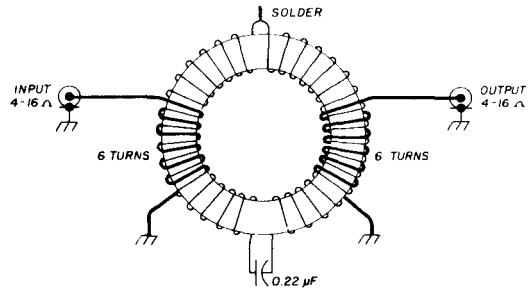


fig. 2. A filter with 40-Hz bandwidth at 1.2 kHz.

Thus a filter with a Q of 10 operating at 1 kHz would have a bandwidth of 100 Hz; and at an operating frequency of 100 Hz, the same coil with a larger tuning capacitor would still have a Q of about 10 but a bandwidth of only 10 Hz. Obviously if your desired signal had interference from a nearby signal, the lower you set the beat note, the easier it would be to separate the two signals with a given filter. With an ssb receiver, about 300 Hz is the lowest you'd care to go, because the audio circuits have very little gain below this frequency. You can therefore choose a frequency between 300 and about 1500 Hz, depending upon personal tastes.

the simplest filter

The simplest filter circuit having all the desirable features just described is the series-resonant type of **fig. 1**. The capacitor for this circuit should be 0.22 μF for a 1-kHz operating frequency, and 1.0 μF for 500 Hz. This filter has a bandwidth of about 70 Hz at 1.2 kHz and proportionally more or less at other frequencies. The

Q of the filter is thus about 17, which consists almost entirely of the coil Q. Since this is the case the Q, and hence bandwidth, won't vary much if the speaker impedance is between 4 and 16 ohms.

For those who might want a very narrow filter but don't want to operate at a beat frequency near 500 Hz, the circuit of **fig. 2** will give about 40 Hz bandwidth at 1.2 kHz.

The 88-mH toroid in these circuits is an unplotted type available from surplus, and the low-impedance windings of **fig. 2** are each 6 turns of wire wound over the existing windings. Put the input winding on one side of the core and the output winding on the opposite side for the narrowest bandwidth. However, neither the number of turns nor their placing is very critical.

selectable-frequency filter

As I mentioned at the beginning of this article, these filters are designed for bare-bones simplicity. However, if you'd like more versatility at the expense of a few more components you can make a number of tuning capacitors switch-selectable. A selection of filter frequencies will allow the cw operator to copy signals that may otherwise be lost in extremely heavy interference. A schematic of a multiple-frequency filter is shown in **fig. 3.**

insertion loss

The insertion loss of all filters of this type is about the same: approximately 20 dB. This means 1 volt out for 10 volts in. This sounds high but really isn't. The audio-volume control can be cranked up to compensate. This insertion loss results because we're using a practical toroid instead of a perfect inductor. The Q of 17 means the coil has an effective ac resistance, including wire loss and core loss (and speaker load) of about 35 ohms. The insertion loss is the ratio of coil ac resistance to load resistance, which can't be improved for that particular coil. The speaker I used was a 3.2-ohm unit, which gave the 10:1 ratio of load resistance to total resistance reflected in the 10:1 input-to-output voltage readings in my measurements. This is explained so you won't feel something is lacking to cause such an apparently large insertion loss.

The filter in **fig. 1** doesn't have dc continuity. Some ssb receivers, with no output transformer in their audio power amplifiers, require a dc path through the speaker. My Galaxy V is an example. A 4- to 16-ohm resistor across the input to the filter will solve this problem.

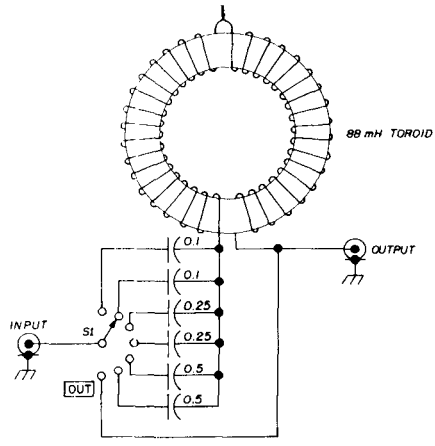


fig. 3. Frequency-selectable filter for improved cw reception. S1 is a shorting-type switch that connects the capacitors in parallel.

You've probably seen more complex filters for cw, but none will outperform these circuits *in actual use.* The loss of these filters increases 6 dB for each 40- or 70-Hz excursion from design center frequencies, and response is 40 dB down 200 or 350 Hz away.

a closing note

The simplicity of the filter will allow it to be placed almost anywhere in your rig. The toroid measures about 1 by ½ inch, and the capacitors can be physically small. The filters will perform as stated if wired into your speaker leads if you'd rather not disturb the wiring of an expensive transceiver.

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Radio-frequency chokes have certain undesirable characteristics that must be recognized and corrected if they are to operate as intended. Rf chokes have "holes" in their frequency-versus-impedance response that can cause resonance in conjunction with stray circuit capacitances.* This phenomenon can result in high circulating currents that will destroy the choke coil.

This article discusses ways of impeding the flow of rf current by using ferrite beads. These beads are made of ferrous particles imbedded in a ceramic material, much like the cores in some rf coils. The physical structure of the beads is somewhat different, however, in that they have a hole through their centers to accept a wire.

characteristics and uses

Running a wire through a ferrite bead greatly increases the inductive reactance of that length of wire. This reactance follows the familiar 6.28fL law, which shows that as the frequency increases, so does the reactance. At 50 MHz, for instance, one inch of wire through a ferrite bead may show an impedance of 50 + j45 ohms. String on more beads, and the impedance goes up. It increases in a smooth and totally predictable manner—no holes, no peaks.

Now let's see how these beads can be used in ham equipment. For decoupling dc and ac power leads, they're ideal: small, effective, free of dc (or low-frequency ac) resistance, and not susceptible to resonance from associated capacitance.

The increased impedance offered by the beads at higher frequencies suggests

*An example is the requirement for modifying the plate-feed choke in high-power tetrode amplifiers when they first became popular. This is explained in George Grammer's "Pi-Network Tank Circuits for High Power," *QST*, October, 1952 and in the 1953 edition of the *ARRL Handbook*. **editor.**

another application: that of vhf or uhf parasitic-oscillation suppression. Remember that the impedance consists of a resistive as well as a reactive component. This acts as a potent suppressor of vhf or uhf oscillations, while having very little effect on the primary signal.

This same characteristic can be a temper saver in eliminating rf pickup and rectification of amateur signals by audio equipment. One of the most frustrating jobs you can tackle is that of curing rf pickup (and rectification) in a neighbor's transistorized hi-fi audio equipment. The low impedances encountered in these sets make rf bypassing almost a hopeless task. A ferrite bead or two slipped over the base (or gate) lead of each susceptible transistor can save much hair tearing.

drawbacks

There *must* be some negative factors! For one thing, the beads saturate with too much current through the wire upon which they're strung. This means you can't use them to decouple the filament of a high-powered transmitting tube in the grounded-grid circuit. Also, they're not suitable in place of an rf choke in parallel-feeding a transistor in a powerful transmitter.

One reason why these handy little devices haven't found greater use among radio amateurs is that they are not listed in most supply catalogs.* Ferrite beads are manufactured by Stackpole Carbon Company, Electronic Components Division, St. Marys, Pennsylvania, and by Ferronics, Inc., 66 North Main St., Fairport, New York 14450. You may have difficulty in purchasing small quantities from these sources, however.

In summary, the use of ferrite beads offers a quick, easy, and painless cure for many of the problems confronting the builder of ham equipment. Use them—you'll like the way they work.

ham radio

*One exception to this is World Radio, 3415 West Broadway, Council Bluffs, Iowa 51501. WRL lists them on page 82 of their 1970 catalog as number 75A054; 12 beads in a package for $2.00.

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ideas for an electronics workbench

Like to build your own gear? Try these suggestions for an efficient and safe work area

Jim Ashe, W1EZT

What would you say is the one most important piece of equipment in your electronics workshop—oscilloscope? Vtvm? Clearly it's your workbench. A well-designed workbench can mean the difference between pleasure and drudgery if you spend long hours experimenting and building your own ham gear. If you're planning a new workshop or would like to improve your existing one, the suggestions offered in this article will help you design a work area having an efficient arrangement of facilities. Design suggestions also stress comfort and safety.

basic requirements

Key requirements for an electronics workbench are accessibility to test equipment, tools, and spare parts; adequate strength; and reasonable cost. If you work on modern equipment, as I do, you probably won't have a piece of equipment heavier than 50-75 pounds, so a massive bench is not a requirement. The trend of modern electronics equipment is such that a good workbench can be built from scratch for less than it can be purchased. Let's take a look at some design considerations.

size and height

A bench with dimensions less than 1½ x 4 feet is probably too small for maximum comfort and efficiency; if more than 2½ x 5 feet, it's really too large for modern electronics work.

The bench working surface can be either 29 inches from the floor if an adjustable office chair is used (recommended for long-time comfort), or 36 inches high for standing at the bench or sitting on a tall chair. (The Sears catalog has a good choice of such chairs.) Whatever the bench height, a slight adjustment will be necessary if you're taller than about 5½ feet. Alternately sitting and standing, over long periods of time, is restful.

The lower height is nice because everything is closer to the floor. For example, a scope on a cart[1] will free much bench space. If the cart is close to the floor, the

low c.g. is insurance against toppling a piece of expensive test equipment. On the other hand, a higher bench will allow several storage shelves underneath. To resolve this problem, I suggest you make some scaled sketches then mock up some experimental designs with cardboard cartons.

shelving

Shelves are necessary in any workshop, of course. At least one should be mounted over the working surface. Mount it

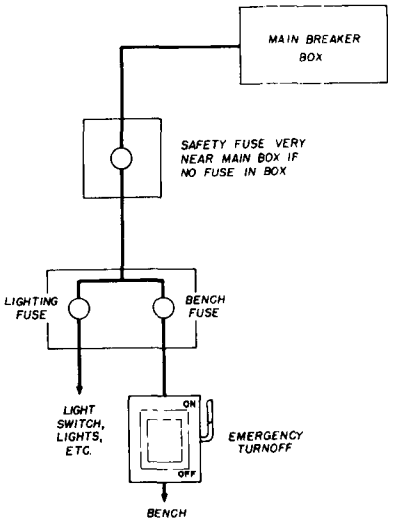

fig. 1. Simple but effective input wiring circuit. Lighting and power circuits are independent.

about 15 inches to the right of the working area if you're right-handed; opposite if you're left-handed. It should be about 12 inches above the working surface. If you do a lot of experimenting, you can't have too many shelves. I'd suggest planning your workbench installation so you can add more shelves later. You can buy metal brackets at Sears that will accept a wide variety of plain pine boards.

parts storage

An excellent source of plastic storage boxes for small parts is Allied Electronics.* These boxes are made by Vlchek. Examples are Vlchek P812 (12 compartments) and P824 (24 compartments) at about $2.00 each. Many arrangements are available for your needs. These little boxes can be nested in a modular arrangement for easy access to parts.

construction notes

Many facts taken for granted by carpenters and cabinet makers will come as a surprise if you're not familiar with woodworking techniques. For example, if your plan calls for a length of common 2 x 4 lumber, you'll discover that the item you buy is about 1-5/8 x 3-5/8 inches. Common pine or fir is good and inexpensive, but lookout for knots and warped material.

You can save yourself the trouble of cutting material to size for a little extra money. Most lumber supply dealers offer a cutting service. But watch out—if the dealer has one of those large vertical frameworks that takes anything from small board to a sheet of plywood, chances are the salesman will cut the piece by pulling a rotary saw down it. I've seen three of these arrangements, and none would cut square to either edge or surface of the work.

assembly

How do you assemble the pieces? Again, assuming you're not much of a carpenter, here are some useful hints. Use screws to join large subassemblies so they'll come apart for moving. Use nails for smaller work (shelves, bench top, etc.). An effective and strong joint can be made by running a thread of glue along the material to be joined then nailing the pieces together. The nails should come out without weakening the joint, but it's best to leave them in.

lighting

Good planning for a workbench includes lighting. Fluorescents are preferred to incandescents, as they offer more than twice the light per hundred watts of

*Allied Electronics catalog 280, p. 267.

power. If a light is poorly positioned, your vision becomes less effective and you tire rapidly.

Three to five well-positioned 40-watt fluorescents will provide good illumination for most work if the fixtures aren't too far from the bench. Used fluorescent fixtures are often available from electricians and should require very little repair. Electrical noise is a problem with some fluorescents; but in industrial and personal experience, I've never found corrective measures necessary.

power circuits

Your workbench should receive electric power from at least two circuits (see **fig. 1**). A large fuse near the main breaker box is good insurance against unforseen problems. The input line should be run into a box equipped with two more fuses; one for lights and one for power circuits. With this arrangement, the lights won't go out if your work blows a fuse. Note that the emergency switch turns off bench power but not the lights.

grounding

Grounding is important. A good ground system consists of a heavy copper wire (about no. 8) from the workbench to a copper-clad rod driven into the earth. Maximum length of the connecting wire should be not more than about 15 feet.

Avoid transformerless ac-coupled power circuits. They're dangerous and not to be trusted, because a simple accident could put some of your gear at 115 Vac with respect to ground.

antenna simulation

An antenna connection is a useful but not necessary provision at your workbench. If you can afford it, a signal generator producing a controllable microvolt signal is preferable, because it can be used for realistic sensitivity measurements. I've seen usable gear priced as low as $15.

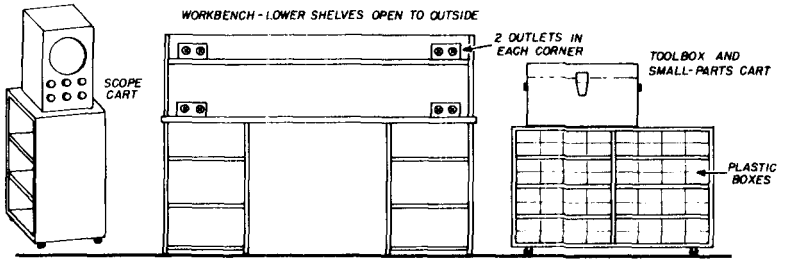

fig. 2. Suggested workbench installation.

To approximate operating conditions, a simple dipole can be erected. Make each leg about 0.1 wavelength and connect a 47-ohm resistor across the feed point. The antenna can be strung out of the way in a corner of the shop. Run the coax cable to a connector on the bench.

summary

A good bench setup is shown in **fig. 2**. A few instruments can occupy the bench working surface, and parts are easily accessible on the shelves below. Test signals are available from a small antenna, and a separate connector can be used to patch a cable to your operating position to pick up your main antenna through an swr meter or tuner. The toolbox, sitting on a small cart, is convenient. Good-quality casters should be used on all the furniture shown in the sketch.

reference

1. Jim Ashe, W1EZT, "A Cheap & Clean Scope Cart," *CQ*, April, 1970, pp. 34-36.

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More Details? CHECK—OFF Page 94

introduction to thyristors

How to use thyristors, four-layer diodes, silicon-controlled rectifiers, and triacs in electronic equipment

Paul Franson, WA7KRE, 117 Central Street, West Concord, Massachusetts

Of the three great basic classes of semiconductors — diodes, transistors and thyristors — there is no question that thyristors are least known to hams. There is good reason for that besides the fact that thyristors have become popular only fairly recently: thyristors have limited application in most ham equipment. Nevertheless, they do have many interesting uses in amateur gear and in the many other facets of electronics most hams enjoy. For this reason, all hams should know something about them. This article is an attempt to present some basic facts about these important devices and how they are used.

Thyristor is a hard word to define to someone who doesn't know what a thyristor is. Rather than belabor the point, I will ignore this problem and simply say that there are many types of thyristors, but the most popular are silicon controlled rectifiers (scr's), triacs and four-layer diodes. Other less important members of the family are five-layer diodes, gated bilateral switches, gate-controlled switches, light-activated scr's (lascr's), gate turn-off switches, and turn-on, turn-off controlled reactifiers.

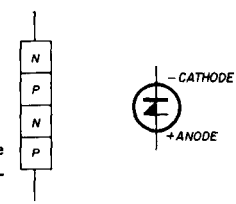


fig. 1. Four-layer diode construction and schematic representation.

four-layer diodes

The simplest type of thyristor is the four-layer diode. Its name comes from its construction. A regular diode is made of two layers of semiconductor material which form the anode and cathode. A transistor contains three: an emitter (cathode), base and collector (anode). A four-layer diode has four layers of alternating p-and n-type silicon; only the outer two layers are connected to terminals.

The symbol for a four-layer diode is derived from the numeral four, as can be seen in **fig. 1.**

The four-layer diode is indeed an odd device. It is a voltage-controlled switch, and has two "states," very high resistance

(off) and very low resistance (on). On the reverse direction, that is, when the cathode is more positive than the anode, it acts like any regular silicon diode; it conducts very little current, and as the voltage is raised, the current increases slowly until a certain voltage (the reverse breakdown voltage) is reached. Then the current increases rapidly. This high current with high voltage drop leads to high power dissipation, which will destroy the diode if the current is not limited to a low value. A four-layer diode is not used in this way; regular diodes are much cheaper!

In the forward direction (positive to anode), however, the four-layer diode acts quite unlike a regular diode. As you

fig. 2. Forward- and reverse-biased four-layer diode.

may recall, the forward voltage drop across a regular silicon diode remains approximately 0.7 V over a very wide range of currents through the diode. A four-layer diode, on the other hand, conducts virtually no current until the voltage across it rises to the breakover voltage, when it will suddenly switch to the **on** state and conduct heavily with a very low voltage drop, much like a conventional silicon diode. Thus, raising the voltage switches the four-layer diode from **off**, (no current flow, or high resistance) to **on** (high current flow, or low resistance). Because of the small voltage drop in the **on** state, very little power is dissipated in the device; a typical drop is 1.2 V at 70 mA, or 84 mW.

If current through the four-layer diode is reduced below the holding current of the diode, as by breaking the circuit, the four-layer diode switches off again. Notice that the four-layer diode is a dc device. This operation of the four-layer diode is shown graphically in **fig. 3.**

While there are many commercial uses for four-layer diodes, ham applications are limited. However, in at least some cases, four-layer diodes can simplify circuitry considerably. One example is the sawtooth or relaxation oscillator; here the four-layer diode acts like a low-voltage, dc neon lamp. **Fig. 4** shows the circuit. Since the four-layer diode does not conduct until the breakover voltage is reached, it is out of the circuit for all practical purposes while the capacitor is charging up — until it reaches the breakover, when it suddenly conducts, discharging the capacitor. The cycle then repeats, and the result is a sawtooth output voltage. The resistor and capacitor are chosen to provide the proper repetition frequency. The resistor must be fairly large and the source voltage considerably higher than the breakover voltage for best wave shape. The sawtooth oscillator can be used to generate pulses for triggering scr's or as a code or test oscillator.

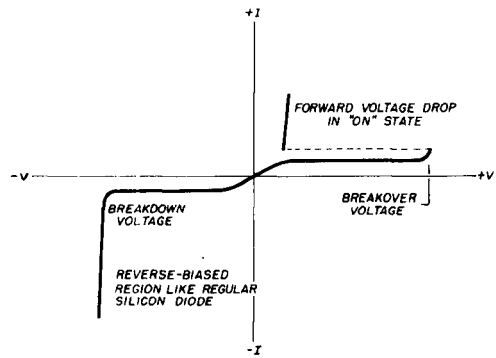


fig. 3. Volt-ampere characteristics of the four-layer diode.

Another use of the four-layer diode is as an overvoltage relay, as shown in **fig. 6.** If the source voltage rises to an excessive value, the four-layer diode will trigger, energizing the relay and disconnecting sensitive equipment. The resistor can be used to limit current if the relay coil has insufficient resistance. It will have negligible effect on the switching voltage.

sources of supply

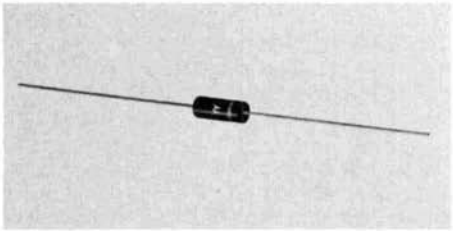
Four-layer diodes are made by a number of companies including Motorola, ITT and Crystalonics. They are fairly expensive to individuals because they are not used very widely and are tricky to make. An example of a commercial four-layer diode is the Motorola 1N5158, which has a nominal break-over voltage of 8 V, a holding current of 1 to 20 mA, and a continuous forward current of 180 mA. It costs about $3.75.

For experimenting, a low-voltage scr can be used as a four-layer diode by ignoring its gate. This is especially nice because low-voltage scr's are undesirable for most amateur uses and can be bought at very low prices. This type of two-terminal operation of scr's is not recommended by manufacturers, though. It can cause a change in characteristics or even damage the device. This will probably not bother most experimenters as long as they stick to low-voltage and low-current operation.

finding the breakdown voltage

Of course, you'll have to determine the breakover voltage when you use an scr as a four-layer diode. **Fig. 7** shows how to find this breakover voltage. Simply increase the variable voltage supply (with an eye on the voltmeter)

Package commonly used for four-layer diodes is the same as that used for conventional diodes.



until the current through the diode suddenly increases and the voltmeter reading drops. The voltage at which this happens is the breakover voltage. The current-limiting resistor should be chosen to keep the current through the four-layer diode and meter to a safe level. For a level of 50 mA, a reasonable value for

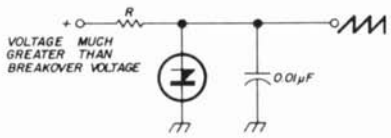


fig. 4. Sawtooth generator circuit.

most four-layer diodes, the resistance should be the maximum voltage divided by 0.05. For 50 volts, it should be 1000 ohms.

This same test circuit can be used for testing four-layer diodes, too. Reject

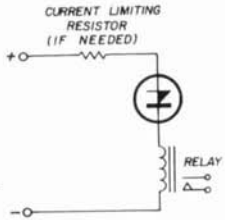


fig. 5. Overvoltage cut-out relay.

four-layer diodes can be bought from some surplus dealers, and it's always a good idea to check them before use.

Another way to turn on a four-layer diode is shown in **fig. 6**. Here a positive pulse turns the four-layer diode on and energizes the load. This arrangement is

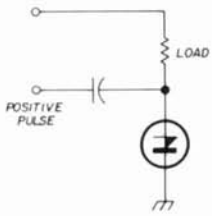


fig. 6. Alternate way to turn on a four-layer diode.

better in many switching applications than using the four-layer diode as a true voltage-controlled switch. The switching point is precisely controlled.

silicon-controlled rectifiers

The silicon-controlled rectifier, or scr, is the most popular thyristor. Unlike the four-layer diode, the scr has hundreds of

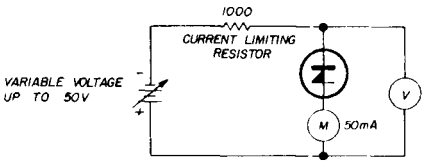


fig. 7. Determining the breakover voltage of a four-layer diode.

practical uses in consumer, industrial, military—and amateur—equipment and is widely used. Modern plastic-encapsulated scr's are inexpensive enough to be

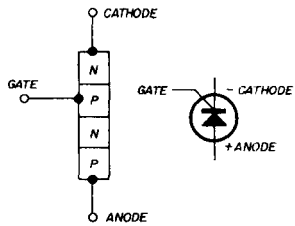


fig. 8. Construction and schematic symbol for the silicon-controlled rectifier.

used in low-cost appliances, and this, in combination with their usefulness, is revolutionizing the whole idea of control circuits.

The scr is very similar to the four-layer diode in construction. It is a sandwich of four layers of silicon containing different amounts and types of impurities. The symbol and construction are shown in **fig. 8.** The scr can be thought of as a four-layer diode with a connection to the layer next to the cathode. This connection is called the gate, and is what makes the scr so useful.

An scr acts just like a four-layer diode except that it can be turned on when in the blocking state by applying a short pulse of positive current to the gate. The scr will then suddenly switch from the blocking state to the conducting state and have a low voltage drop much like a conventional silicon rectifier. The characteristic curve of an scr is shown in **fig. 9.** Notice that is identical to the curve of the four-layer diode **(fig. 3)** except that triggering the gate "overcomes" the forward blocking voltage.

This is oversimplifying slightly, since small values of triggering current actually reduce the forward blocking voltage rather than turning the scr on. However, it's best always to use more than the minimum gate current necessary to switch the scr on and avoid this problem.

The gate trigger current is very small in relation to the amount of current the scr can control. For example, with the 8-ampere 2N4178, a triggering current of 20 mA at 1.5 V will turn the device on. The scr acts like a very sensitive relay with a very high amplification of 400 (8000/20).

In addition to its sensitivity, an scr switches very fast. A conventional inexpensive scr can easily switch on in about 1 microsecond, and off in 20 μs. This means that it can easily switch on and off during one cycle of an alternating

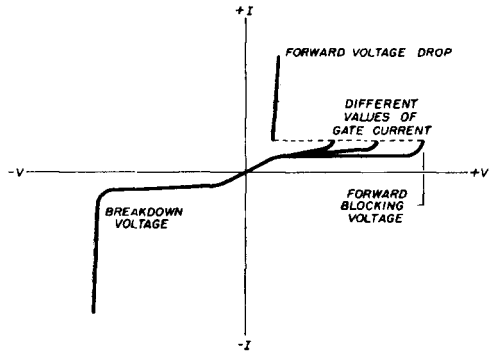
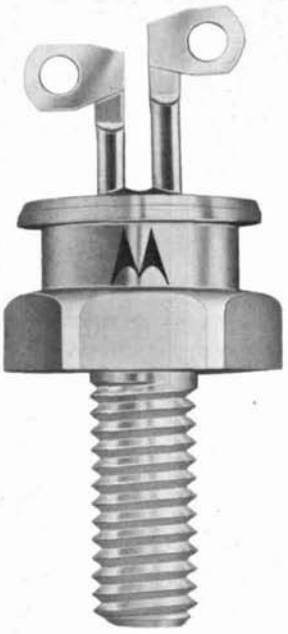


fig. 9. Volt-ampere characteristics of the silicon-controlled rectifier.

current even at 10 kHz (which has a period of 100 μs). This is a very important characteristic of the scrs, and makes it extremely useful for power control. As a comparison, conventional me-



Metal-stud package used for the 8-ampere 200V 2N4170 scr and MAC2-4 triac.

chanical relays switch in around 25,000 μs, and very fast reed relays in 1000 μs. Not too surprisingly, scr's are replacing relays in many applications where this speed is important.

Though scr's are often used to replace relays, they have a few characteristics that make them quite different. For one, you can turn an scr off only by reducing the current through it below the holding level. A pulse at the gate turns it on, but you have to break the current (or at least reduce it to a very low level) to turn it off. This is no problem when the scr is used on alternating current since the current falls to zero (and below, to negative values) during each cycle, but some means must be provided to turn off an scr used on dc or it will stay on.

Another important difference is that there is no isolation between the control circuit and the controlled circuit in an scr, as there is in mechanical relays. This may or may not be a problem.

Silicon-controlled rectifiers have many other advantages over relays, however: no contact bounce, no burned contacts, no contact arcing, extremely long life, no movement or acoustic noise and smaller size.

Some typical relay-type scr applications are shown in **figs. 10** to **13. Fig. 10** is a simple latching switch; it operates on dc. Simply applying a positive voltage to the input turns the scr, and hence the load, on. The positive voltage can be taken from the positive supply through a resistor. To turn the load off, power through the scr must be interrupted momentarily. If a conventional relay is used as a load, this makes an excellent latching relay. In any case, a small input signal can control a large load current.

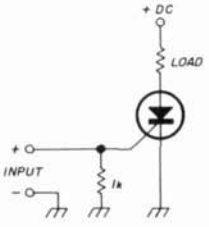


fig. 10. Simple latching switch.

Figs. 11 and **12** are simple lamp drivers (as for use with ic's). In each case, a positive pulse turns on the lamp. In **fig. 11,** since the circuit operates from dc, it has a "memory" and will remain on until power is interrupted. In **fig. 12,** the lamp does not remain on after the input is removed since the scr is operated on ac. Incidentally, note that in this circuit (but not **fig. 11**) the lamp receives power only half the time (when the anode is posi-

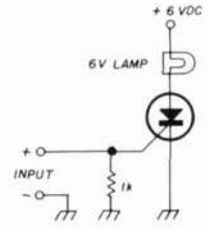


fig. 11. Lamp driver with memory.

tive) so will not light to full brilliance. Because of this, a 4.5-V lamp is suitable for use on 6 V. These last three circuits can be used on high line voltages as well as on low voltage if the proper components are used.

A full-wave ac switch is shown in **fig. 13.** It applies full supply voltage instead of half to the load. This makes it more practical for most ac applications than the simpler half-wave switches.

These relay-type scr circuits represent a fraction of many others possible. Any ham can likely think of other examples. However, another type of application far overshadows the relay uses: it is in phase control of ac power that scr's really shine.

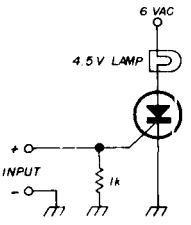


fig. 12. Lamp driver without memory.

No other device has proven so versatile in this use. The motor speed controls used in electric drills, blenders and lamp dimmers are common examples known to everyone, but scr's are also vital to modern industrial power controls.

Ac phase control is quite easy to follow if you understand peak and rms values of alternating power. **Fig. 14** is a

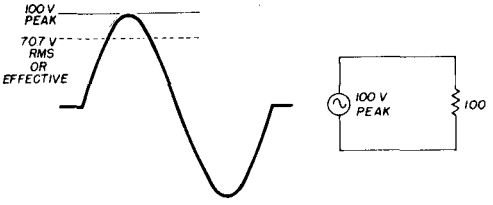


fig. 14. Peak and effective values of alternating current.

drawing of a standard sine-wave ac voltage. The peak value is 100 volts and the effective or root-mean-square (rms) value is 70.7 volts. An alternating voltage with a 70.7 V rms value has the same heating value as a 70.7 Vdc. The 117 V line is 117 V rms.

Now suppose this 70.7 V ac voltage were connected to a 100-ohm resistor. By Ohm's Law (I = E/R), 70.7/100 or 0.707 amperes would flow. As a consequence, the power dissipated would be (by P = EI), 70.7 x 0.707 or 50 watts. If we wished to dissipate less power, we could reduce the voltage to a lower value, say to half (50 V peak, 35.35 V rms); the power would be 12½ W (not 25 W, figure it out). However, reducing the voltage is not always that convenient. Adjustable autotransformers such as General Radio Variacs are fairly large, heavy and expensive.

Suppose we took a different approach. Instead of trying to reduce the peak and rms voltages with a Variac, let's leave the peak value alone and reduce the rms, since it's the important one in this application. One way to do this is to keep the

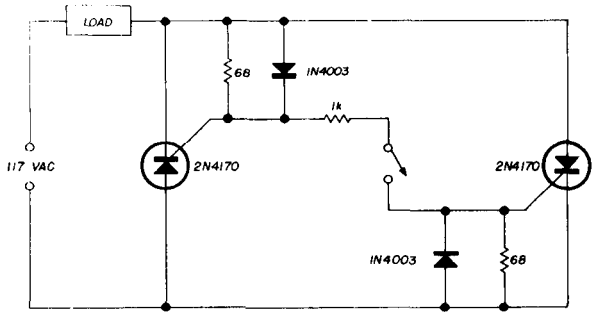


fig. 13. Scr static ac switch.

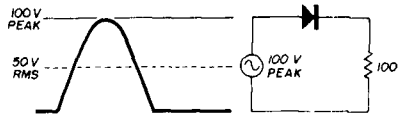


fig. 15. Rms value of rectified alternating current.

voltage from the load part of the time. A diode in series with the load would do this by blocking either the positive or negative half cycles (see **fig. 15**). Then the

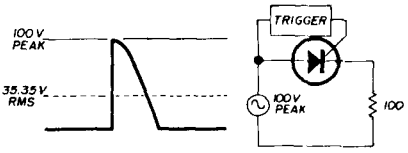


fig. 16. Rms value of alternating current with scr triggered halfway through the positive cycle.

effective value would drop to 70.7 percent of the value without the diode, or to 50 V, reducing the power to 25 W. Why 70.7 percent instead of 50 percent?

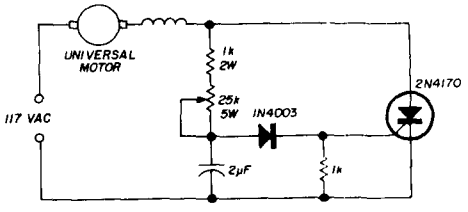


fig. 17. Simple half-wave motor speed control (not for induction motors).

Remember that you reduce the sum (root-mean-sum) to one half, then take a square root.

A diode works well, but gives limited control – full on, 50 percent of power, or off. What is needed is a device that offers better control.

The scr does just this. It can be turned on so fast that a load can be turned on for only a small part of a cycle; **fig. 16** gives an example. Here the scr is not triggered on until half way through the positive cycle. Then voltage is applied from then until the voltage drops to zero. The scr acts like a conventional rectifier for the rest of the cycle, blocking the voltage. In this case the rms voltage would drop to half, or 35.35 V, giving 12½ W dissipation.

The triggering of the scr can be adjusted to permit effective power between zero and 70.7 percent. Switching in a diode connected in parallel to the scr, but with reversed polarity, will cover 70.7 percent to full power. Other methods, which will be described shortly, can be used to obtain full variable control without switching.

practical applications

A practical scr speed control must include some method for triggering the gate on. Probably the simplest practical speed control for universal motors (ac-dc motors) is the circuit shown in **fig. 17**. It controls the average motor voltage by setting the firing point of the scr. The time required for the capacitor to charge to the gate turn-on voltage is set by the potentiometer. Once the scr is on, the capacitor voltage drops to less than the forward voltage drop of the scr for the rest of the half cycle. During the reverse half cycle, the diode blocks any current which would try to pass through the gate. The capacitor is then ready to begin charging when the next half cycle starts.

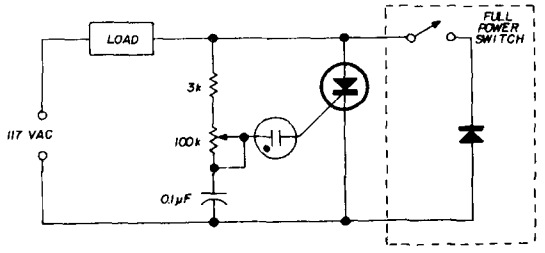


fig. 18. Half-wave phase-control circuit using a neon-lamp trigger.

A better control is shown in **fig. 18.** In this control, the neon bulb acts as a relaxation oscillator and generates pulses that trigger the scr. Adjusting the potentiometer changes the point in the cycle at which the bulb fires, varying the rms voltage applied to the load. Since this is a half-wave control, it can be used only to 70 percent of brightness or speed. Adding the diode and switch fills in from 70 percent to about 95 percent. This circuit is not suitable for control of the ac primary of a transformer because of its imbalance.

Neon bulbs are cheap triggers, but are unreliable and do not permit full range of control. They are also sensitive to radiation: heat, light and radioactivity. This can cause fast changes in speed with changing conditions. The bulbs used in commercial circuits contain a tiny amount of radioactive material that "biases" the bulb and prevents change under normal conditions. If you use a conventional bulb, such as an NE-2, at least paint it black or shield it.

An improvement in the circuit in **fig. 17** results from replacing the neon bulb with a "solid-state neon bulb," a bilateral trigger diode (BLT). A bilateral trigger diode has characteristics similar to a neon bulb, but breaks over at about 20 to 30 volts instead of 60 to 70 V. This results in better control. Incidentally, a bilateral trigger is a three-layer diode, and is not a thyristor. It is a symmetrical transistor with no connection to the base. A Motorola MPT20 BLT costs about 65 cents in a single quantity.

A unijunction transistor **(fig. 19),** four-layer diode, two transistors, or even

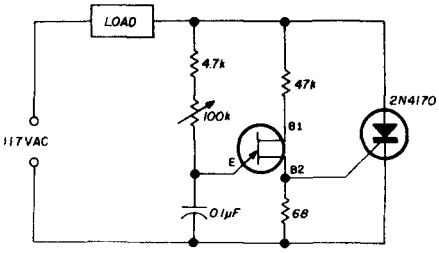


fig. 19. Half-wave speed control using a unijunction-transistor trigger.

an ic relaxation oscillator can also be used for triggering an scr.

Throwing the full-power switch is a nuisance, so full-wave control is prefer-

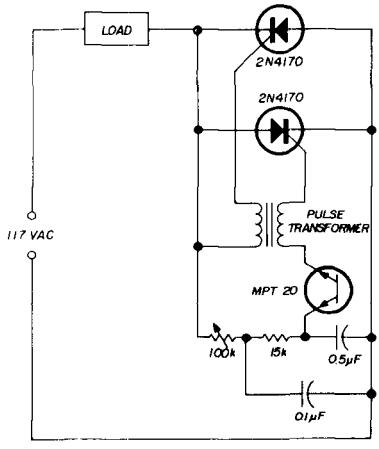


fig. 20. Full-wave speed control or "variable transformer" using two silicon-controlled rectifiers.

able in most uses. One way to obtain this is with two scr's connected back-to-back, as shown in **fig. 20.** Triggering is slightly more complex than might be wished for, though, as the scr's must be triggered out

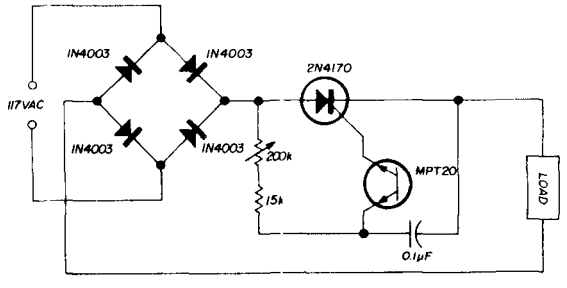


fig. 21. Full-wave control using one scr and bridge rectifier.

of phase. One scr is triggered directly (through the primary of a pulse transformer), and the other is triggered by the out-of-phase secondary winding. A simple transformer can be used for this if it can pass a short pulse, i. e., few turns, low capacitance, high-frequency core. Special triggering transformers are made by Sprague and others.

Another approach to full-wave control uses one scr and a simple triggering circuit, but requires a full-wave rectifier bridge (**fig. 21**). The bridge supplies single-polarity ac to the scr so that it is effective on both cycles. Both **figs. 20** and **21** can be used for transformer primary control, i. e., as an adjustable transformer.

A number of other scr projects that have been described in ham magazines are listed in the bibliography.

what scr to use

Many inexpensive scr's are available to the experimenter. The 2N5060 is a plastic-encapsulated 800-mA, 30-V scr that costs about 69 cents. The 2N4170 is a stud-mount, 8-A, 200-V scr for general line use. It costs about $2.10. A plastic version of the 2N4170 is the 2N4442, which costs about $1.50.

Scr's are also available from surplus dealers. Unfortunately, it requires fairly sophisticated equipment to check them properly, and nothing is more disheartening than having a project not work because of bad or marginal semiconductors.

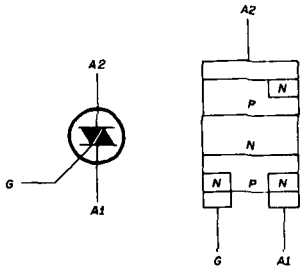


fig. 22. Schematic and construction of the triac.

the triac

The triac is a three-terminal (tri-) bidirectional thyristor for use on alternating current. **Fig. 22** shows the symbol for a triac and its internal construction. The two power terminals of a triac are called anode one (A1) and anode two (A2) rather than anode and cathode since it is not a unidirectional device. The internal operation of a triac is rather hard to understand, but it can be thought of as two back-to-back scr's with a single, more versatile gate. One of the strongest points of the triac is that it can be triggered on in any of four modes: A2+, G-; A2+, G+; A2-, G-; or A2-, G+. The construction of the triac hints at how this is possible. In each mode, different junctions "disappear" when they are biased properly to form a simpler device.

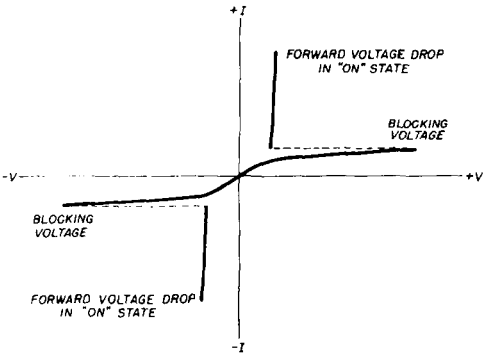


fig. 23. Volt-ampere characteristics of the triac.

The triac, unlike the scr or four-layer diode, has no reverse breakdown voltage; instead it has high blocking voltages in each direction (see **fig. 23**). If either is exceeded, the device will switch into the on state much like an scr. (Incidentally, this makes the triac protect itself from most voltage transients.) In practical use, of course, the device is triggered on by the gate in a manner very similar to an scr.

Unlike scr's, triacs cannot be used at frequencies much above 60 Hz at present.

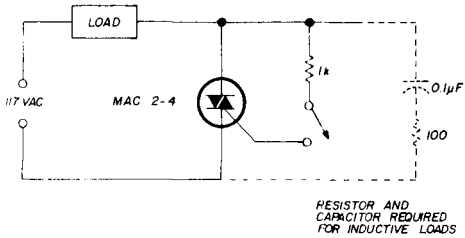


fig. 24. Static ac switch using a triac.

Scr's are available with higher voltage and current capability than triacs, and scr's cost less. On the other hand, triacs can simplify circuits considerably and are widely used because of this. A typical triac is the 200-volt, 8-ampere Motorola MAC2-4; it costs $3.45.

uses of triacs

Triacs have many uses similar to those of scr's. One is as a switch or relay for ac use, as shown in **fig. 25.** The resistor-capacitor network is necessary for inductive loads to hold down the rate-of-voltage rise, since an excessive value can trigger a thyristor on.

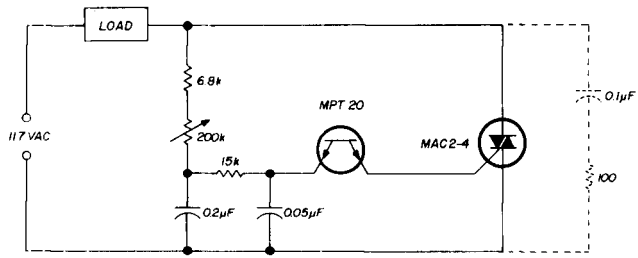


fig. 25. Full-wave phase-controlled triac speed control, lamp driver, ect.

Fig. 25 shows a simple triac lamp dimmer, or speed control for universal motors. Notice the similarity to the half-wave scr control in **fig. 18,** but also remember that this is a full-wave control.

radio-frequency interference

Radio-frequency interference (rfi), or electromagnetic interference (emi), is often a problem when thyristors are used in phase-controlled circuits. A thyristor can turn on so fast that it creates large amounts of harmonics (hash) up to vhf range. This emi can be conquered, though. Careful shielding and filtering can cure most problems. A completely different approach is called zero-point switching. A zero-point switch turns on a circuit only when the voltage is crossing zero; since no current is broken, there is no emi. To get variable control, a zero-point switching control will apply a few complete cycles of power to the load, then turn off the power for a few cycles. This results in the desired rms voltage level. Zero-point switching cannot be used with lights; it causes flickering.

conclusion

Thyristors are here to stay in electronics. Though the ham will probably never see too many in his communications equipment, he will run into many in auxilliary gear and household appliances, making an understanding of their working worthwhile.

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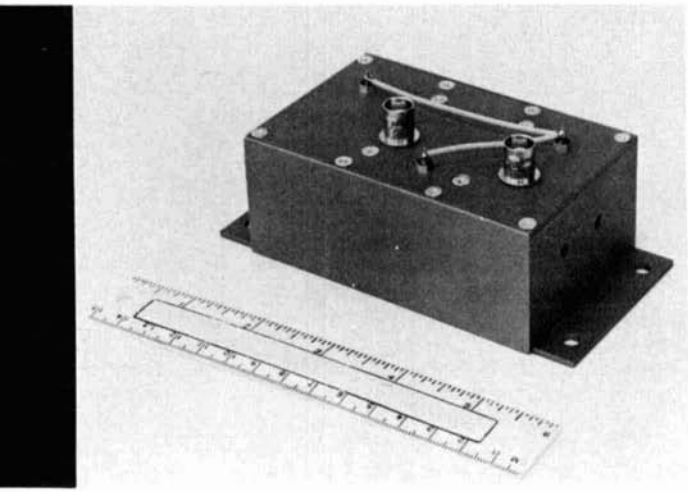


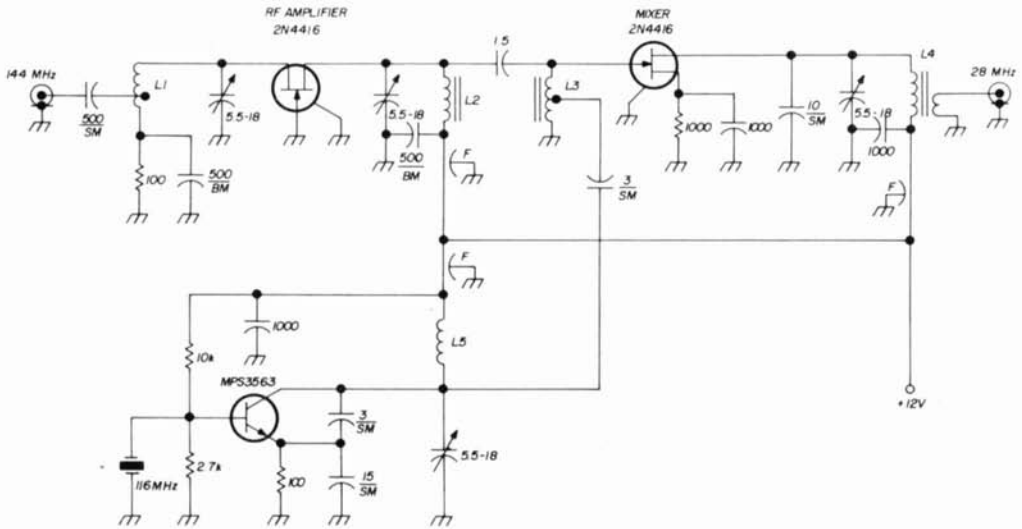
modular two-meter converter

Like to experiment with new vhf front-end designs? This packaging concept solves many modification problems

Bob Sutherland, W6UOV

New low-noise solid-state devices for two-meter receiver front ends are being announced at such a rate that it's frustrating trying to decide which direction to go. With my limited budget of time, money and ambition it became apparent that I couldn't build a complete converter for every new product announcement. I finally decided to go in the direction described in this article: the modular approach. This allows maximum circuit modification with minimum effort.

The converter described here consists of a bipolar oscillator, jfet mixer, and jfet rf stage **(fig. 1)**. The converter is built on a flexible box-chassis. After the basic circuit is completed, all sorts of low-noise front-end designs can be constructed on



L1, L3 — 8 turns of no. 22 enameled wire tapped 3 turns from cold end. Core Micrometals T30-0

L2 — 8 turns of no. 22 enameled wire. Core Micrometals T30-0

L4 — Primary 21 turns no. 28 enameled wire. Secondary 3 turns no. 28 enameled wire over cold end of the primary. Core Micrometals T37-10

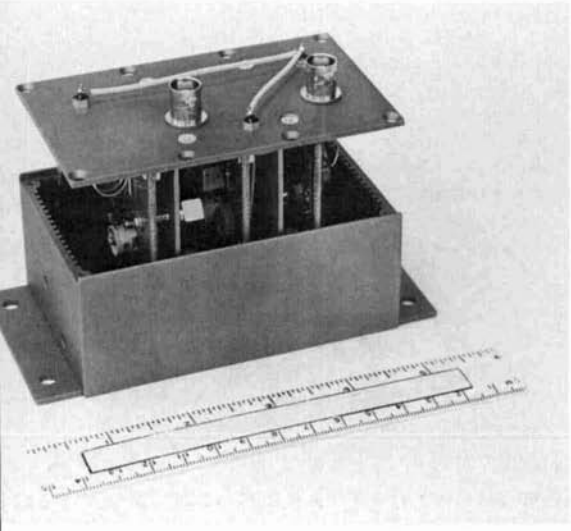
L5 — 3 turns no. 18 wire 3/8" dia. x 3/8" long

F — Gulton MF-223 miniature low-pass filter

All three 1000-pF capacitors are ceramic (Erie type 8133 or Vitramon equivalent)

Micrometals cores are available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607

fig. 1. Schematic of the modular two-meter converter. Inexpensive jfet's are used in rf amplifier and mixer; oscillator circuit will deliver 15 mW with a 12-V supply. BM indicates a button mica; SM indicates silver mica.



Completed converter partially inserted into enclosure. Aluminum shields slide into slots on the side of the box, providing good interstage isolation.

individual boards, placed into the proper enclosure, and connected by cable. The final circuit can be updated easily as new designs come along.

packaging

The circuit isn't new, but the construction technique is somewhat different from that used in the usual two-meter converter. The photos show the modular packaging scheme. The box is a Pomona Electronics model 3306 with a 3328 bottom plate. The aluminum divider for the internal shielding is model 3327. The glass-epoxy circuit boards were etched, as explained later. I think it's evident that any one of these units can be removed and replaced with a new design with little effort. Remaining circuits need not be rebuilt. Also, removed boards are still available for future use and comparison purposes.

the circuit

The local-oscillator circuit was supplied by WA6NCT as his favorite. It uses a Motorola MPS3563, which is one of the inexpensive epoxy-package transistors. In

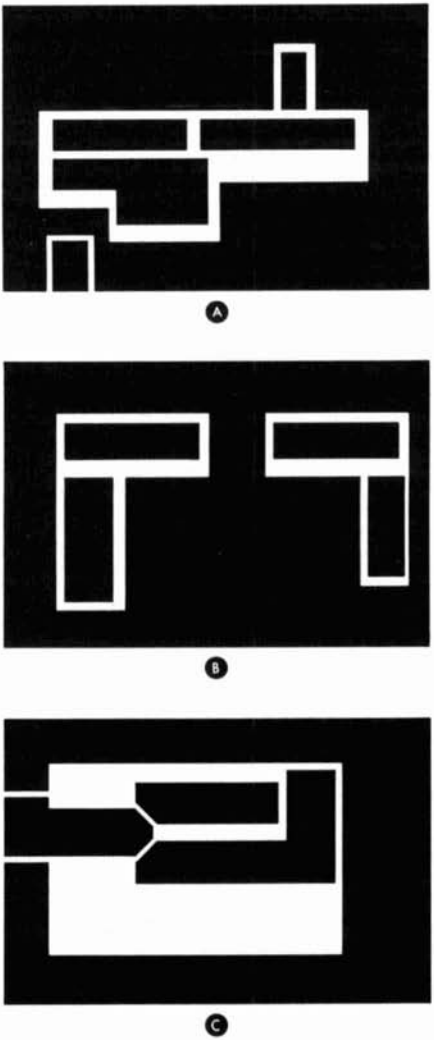
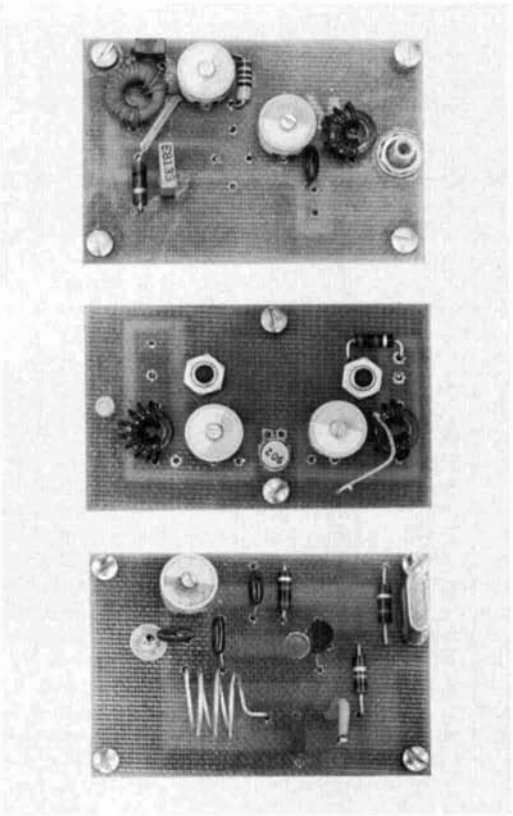


fig. 2. Full-size drawings of circuit boards. Oscillator, rf amp, and mixer are shown in A, B, and C respectively.

quantities from 1 to 99 it sells for fifty-five cents. The oscillator operates directly at 116 MHz and starts every time voltage is applied. Tests were run on the oscillator independently of the remaining converter circuits. With a 12-V power supply, the oscillator delivered 15 mW into a 50-ohm load. The second harmonic was down 27 dB, and the third harmonic was down 44 dB below the

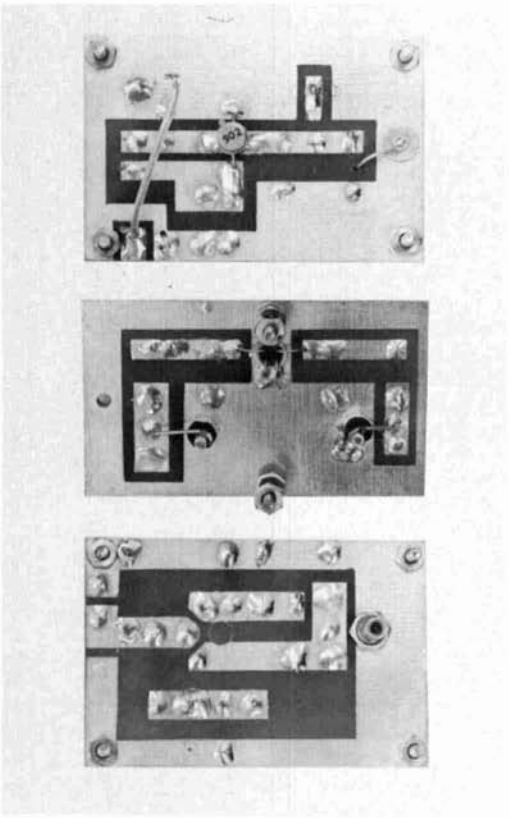


Top view of circuit boards. Top to bottom are the oscillator, rf amplifier, and mixer.

fundamental signal. All other harmonics were better than 60 dB down.

The mixer is a standard 2N4416-jfet type popular with many vhf amateurs. The gate circuit consists of a coil wound on a small toroid and tuned by a ceramic trimmer. The toroid coil has a Q of 135. The toroid was chosen to allow tight packaging of the converter. The rf fields are fairly well confined to the toroid, which helps reduce any tendency toward instability. The output, or i-f, coil is also a toroid. The L/C ratio of the i-f tuned

circuit was chosen to give a 3-dB bandwidth of 2 MHz, and the circuit was peaked for optimum response in the middle of the lower 2 MHz of the 144-MHz band. The converter covers the entire band and has a slight decrease in gain above 147 MHz. The 2N4416 mixer source resistor was chosen to establish the proper bias point.



Bottom view of circuit boards. Oscillator, rf amplifier, and mixer are shown top to bottom.

To determine the correct value of the source resistor, I measured the zero-bias drain current of the 2N4416 actually being used—in my case, it was 11.2 mA. Various values of resistance were tried until the drain current dropped to about 25 per cent of the zero-bias drain current, or 2.8 mA. The local-oscillator injection was then adjusted by the choice of a 3-pf coupling capacitor and the placement of the tap on L3 until the drain current rose to about 40 per cent of the zero-bias drain current, or 4.4 mA. The resulting bias voltage is about 0.7 of the pinch-off voltage, which allows a good compromise between high-conversion transconductance and low cross-modulation with high local-oscillator injection.

The rf amplifier is a 2N4416 in a common-gate circuit. The input and output coils are toroids very similar to the mixer input coil. The bias for this stage is provided by resistor R1. A blocking capacitor from the coax center conductor to the tap on the input coil prevents shorting the bias supply of the 2N4416 rf stage.

construction

Glass-epoxy single-sided circuit board is used for all three boards. Large areas of copper reduce the lead inductance. Narrow traces are not good practice in the vhf uhf region. The boards are coated with Kodak KPR photosensitive resist. A mechanical negative is made by placing Rubylith over the circuit board pattern and removing the red filter with an Exacto knife from areas where copper is to remain.* An ultraviolet light is used to

* Presensitized board is available from Allied Electronics, 100 North Western Avenue, Chicago, Illinois 60680. Rubylith is available from most graphic arts stores.

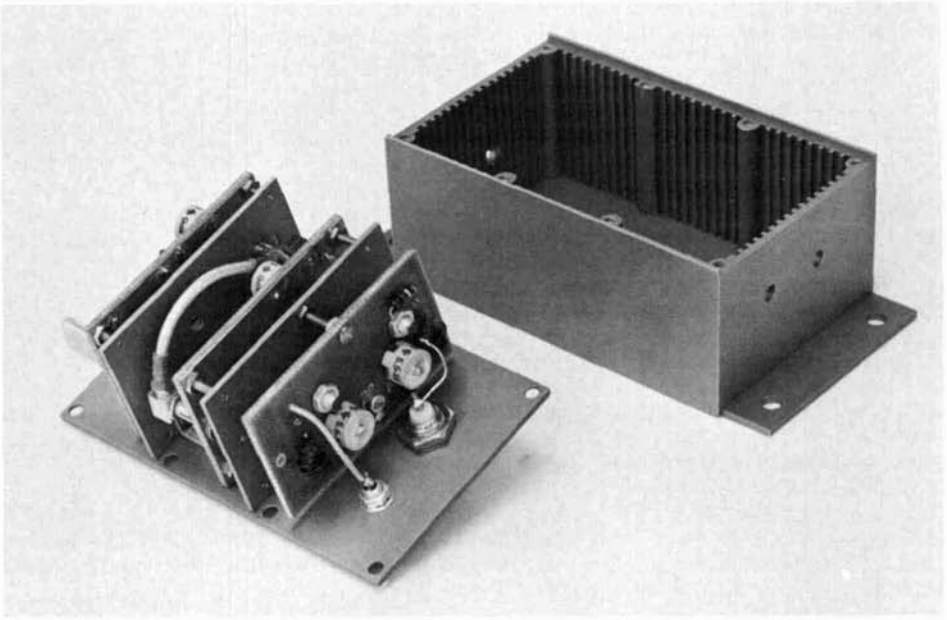
"What's this QRN signal you send everytime I come into the room?"

expose the board. Kodak developer can be used, or plain tri-chlorethylene if available. Amateurs with photographic equipment can make a negative from the scale patterns.

Another technique that works well but doesn't yield as good a job is to use ordinary Scotch electrical tape for the tuning adjustments to be made.

No sockets were used for the transistors. Also, no shielding was required between input and output of the 2N4416s. The common-gate rf stage provides complete stability.

The converter has sufficient gain to operate directly into a Collins 75A4



Interior construction of the modular two-meter converter.

resist. Mask off (with the tape) all copper not to be etched. A warm ferric chloride bath can be used for the etchant. The boards to be etched are placed face down in the solution and agitated to speed up the process. After the boards are etched, they can be sheared or cut to size.

Boards are mounted vertically on the box lid. Aluminum shields are placed between each active board. The short length of coax with rather expensive end fittings is not really necessary for good performance. The fittings were available, however, and allow for quick disconnect. A short piece of coax with each end soldered into place would be adequate. Small holes through the box walls allow receiver, as modified according to a previous article in *ham radio* by W6ZO.[1]

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improving the voice commander fm sets

Here are some simple modifications to cure receiver instability and change bandwith response of this equipment in various models

Don Chase, WØDKU, 3315 South Mount Carmel, Witchita, Kansas 67217

Many requests have come to my attention for help with the General Electric Voice Commander. Many hams aren't happy with these sets because of receiver instability. This article offers a means for resolving the receiver instability problem and provides information for converting narrowband receivers to wideband operation. A couple of minor but useful transmitter modifications are also described.

The Voice Commander was manufactured in three models: Voice Commander I, II, and III. Model I used subminiature tubes in the transmitter, but the receiver is essentially the same as in the other models. Components and physical layout for the receivers were changed only slightly throughout the entire model series. Models II and III have nearly identical receivers.

An rf amplifier was added to the receiver of the Model III. This circuit is on a separate chassis hidden under the transmitter board. Also included is a ptt relay for an external microphone. In this article, all references are to the Model III; however, they apply to Model II except for the part about the receiver rf amplifier.

The Voice Commanders were manufactured in two production splits. Split 1 covered 132-150 MHz; split 2 covered 150-174 MHz. Most high-split units will tune to 146-147 MHz with no trouble. Information is included here on appro-

priate padding to accomplish this tuning range.

receiver rf amplifier

The receiver rf amplifier is model 4EA19A10 (low split), or 4EA19A11 (high split). The original unit used G.E. part no. 19C300037-2 transistor. It was replaced in revision A with part no. 19A115413-1 (2N2996). The higher gain of this transistor produced oscillation in some receivers. This led to revision B, in which the collector was moved to a tap on the output coil, and a 10k ¼-watt resistor was added across the coil.

If your receiver is revision A, the 10k resistor is sufficient to tame it. To pad from high to low split, which is normally not necessary, add a 3-pF capacitor across input and output coils.

curing receiver instability

The basic complaint of receiver instability can be corrected by following the steps outlined below, in which dc voltage distribution is rearranged to eliminate a tendency toward regeneration and oscillation. These changes were incorporated by G.E. into later versions of the Voice Commander. A manual for the Voice Commander III is available from G.E.*

modifications

The first step is to identify the chassis. Inside the square can are three small chassis with a lid on each. Remove the lids. The chassis are identified as follows, although the numbers are sometimes hard to see.

1. 4EL13A10 (low i-f gain and discriminator board).
2. 4EF29A10 (narrowband) or 4EF29B10 (wideband) high i-f gain second-oscillator/mixer and low i-f filter board.
3. 4EF14A10 (low split) or 4EF14A11 (high split) front-end board.

Begin with the low i-f gain and discriminator board. At each end of the board is a black lead running to the high i-f gain and low i-f filter board. Unsolder the black lead at hole 14 (near the discriminator transformer) and let it hang loose for now. Move the other black lead from hole 13 to the top of R3 (2.2k ¼W) next to hole 13. You're now temporarily finished with the discriminator board.

Remove the high i-f gain and low i-f filter board (center chassis) and turn it over to the solder side. You'll see a wire in sleeving connected from a point in the center of the board (hole 4) to one end. The end connection is at hole 9; remember its location and unsolder the end of the wire from this hole. Move the end of the wire to the opposite end of the board. The black wire hanging there is in hole 14. (You disconnected the other end from the discriminator board.) Remove this black wire and discard. Connect the wire previously removed from hole 9 to hole 14. Install a 2k ¼-watt resistor between hole 4 and hole 9. Use sleeving and dress the leads carefully.

Now turn the board over and locate R2, a 6200-ohm ¼-watt resistor next to hole 13. Install a 0.047 μF capacitor from the top of R2 to hole 13. Unless you have very small components, I recommend that you order the capacitor from a G.E. service center. The part number is 5492638-P6.

Unsolder the black wire from hole 13 and let it hang. This wire connects to the 4EF14 front-end board.

receiver wideband conversion

If your Voice Commander is a narrowband unit and you wish to convert it for wideband use, you'll need a 47k ¼-watt resistor, a miniature 1k pF capacitor (G.E. part no. 5491500-P7), a miniature 1200 pF capacitor (part no. 5491500-P8), and a miniature 12 pF capacitor (part no. 5495334-P42).

Looking at the top of the high i-f gain and low i-f filter board, locate Q2, which is near the center of the long side and

*General Electric Co., Box 4197, A & SP, Lynchburg, Virginia 24503. Enclose check or money order for $1.00.

next to one of the four slug-tuned coils. (Q2 is a TO-18-size transistor.) Locate the two small holes for the 47k resistor between Q2 and the slug-tuned coil. The 47k ¼-watt resistor will fit into this space, although it's a tight squeeze. In the area bounded by the four coils are seven capacitors. Four of these are 110 pF. Leave these alone. Replace the 3300-pF, 2.7-pF, and 4700-pF capacitors with 1000-pF, 12-pF, and 1200-pF capacitors respectively.

front-end board

If your unit is one of the high-split sets and you wish to convert it to low-split operation, remove front-end board 4EF14A11. Locate three air-wound coils, and pad each coil with a 4-pF capacitor. Turn the board over, and you'll see a short, black wire hanging from J2. Remove and discard this wire. Install a 5½-inch-long length of black no. 24 wire in J2.

The first-oscillator crystal is interchangeable between Voice Commanders I, II, III, the Progress Line portable, the transistorized portable (TPL), and Voice Director receivers—in case you want to borrow one to check it out.

"Before you send in that article on converting this rig to solid stage don't you think we should try it?"

reassembly and alignment

At this time, replace the three chassis into the square can. Use care, especially with the center board with the added 2k resistor on the bottom. Dress the black wire hanging from J2 on the front-end board through the same slot containing the coax cable. Run the black wire along the edge to the audio-squelch board. (This is a square board with a round hole in the center.) This board will be identified as 4EA18A10 (narrowband) or 4EA18A11 (wideband). Only the purist will worry about the difference here.

Connect the black wire from the front-end board to hole 8, the location on the audio-squelch board already having a black wire going to the low i-f discriminator board. Do not disconnect the wire already attached to hole 8.

The receiver is now ready for alignment. The low i-f is 290 kHz; the high i-f is 8.7 MHz. Test point 1 is the limiter metering, and test point 2 is the discriminator secondary metering. Be careful of the four slug-tuned coils in the low i-f filter, as a strand of rubber is usually placed inside as a friction device and it has a strange feel on the tuning tool.

transmitter

The Voice Commander II and III transmitters are simple and straightforward. On some models, the crystal plugs in; on others it's soldered in. A tuning chart is mounted inside the back cover of all units. The only coils needing alteration are those in the driver and final, and a simple squeeze will suffice.

The audio system of the Voice Commander transmitter is pretty hot. If you wish to speak close to the microphone, reduce the sensitivity by shunting a 390-470-ohm resistor across the microphone cartridge.

With the modifications described in this article installed in your Voice Commander you will have a unit that is a pleasure to use.

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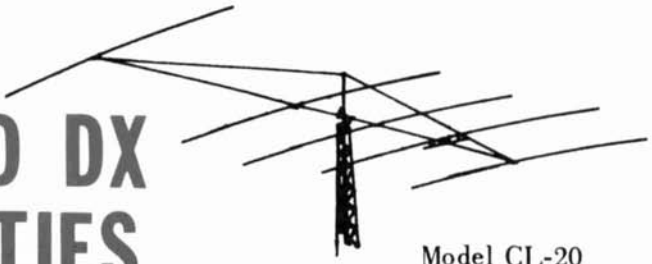

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- FEED POINT IMPEDANCE: 52 ohms.
- NUMBER OF ELEMENTS: 5. Aluminum tubing; 6063-T832.
- MAXIMUM ELEMENT LENGTH: 38 ft. 1½ in.
- BOOM LENGTH: 46 ft.
- RECOMMENDED MAST SIZE: 3 in. OD.
- TURNING RADIUS: 28 ft.
- WIND SURFACE: 18.7 sq. ft.
- WIND LOAD (EIA Std. 80 MPH): 364.45 lbs.
- ASSEMBLED WEIGHT: Approx. 139 lbs.
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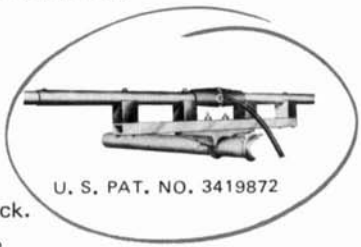

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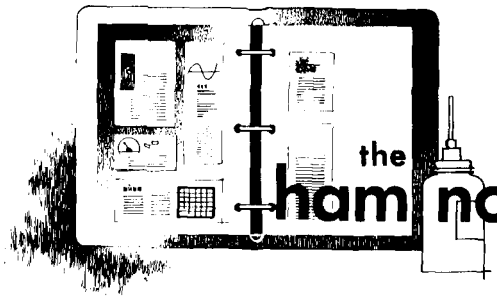


the ham notebook

improved transceiver selectivity

The advantages of operating with transceivers are well established. However, most transceivers on the market lack adequate selectivity for cw reception. I've seen many circuits for narrowing receiver audio bandwidth, but they are either too complicated or entail too many modifications, which reduce the transceiver's trade-in value.

I use a parallel-resonant circuit between the audio-driver and power-amplifier tubes in my transceiver to improve selectivity. Don't be misled by the simplicity of the circuit (**fig. 1**), as it works very well. The toroid coil, which is available from surplus outlets, and capacitor C form a tuned circuit at the desired audio-tone frequency. A value of C that will give the desired audio frequency may be chosen from **table 1**.

Only two connections need be made at the transceiver—nothing to disconnect or modify. Simply install the tuned circuit between the audio power-amplifier tube grid and ground through a switch. The assembly may be remotely located or mounted at the operating position. The tuned circuit and switch may be mounted in a minibox, with a shielded cable to the transceiver. Thus no holes or other alterations are needed that will degrade the transceiver.

As with all passive networks, this filter causes some loss in audio power, especially as C is increased beyond 0.5 μF. This means you'll have to crank up the volume control a bit higher than normal. This shouldn't pose a problem, because most transceivers have volume to spare.

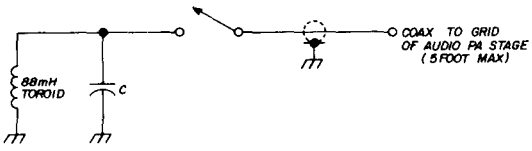


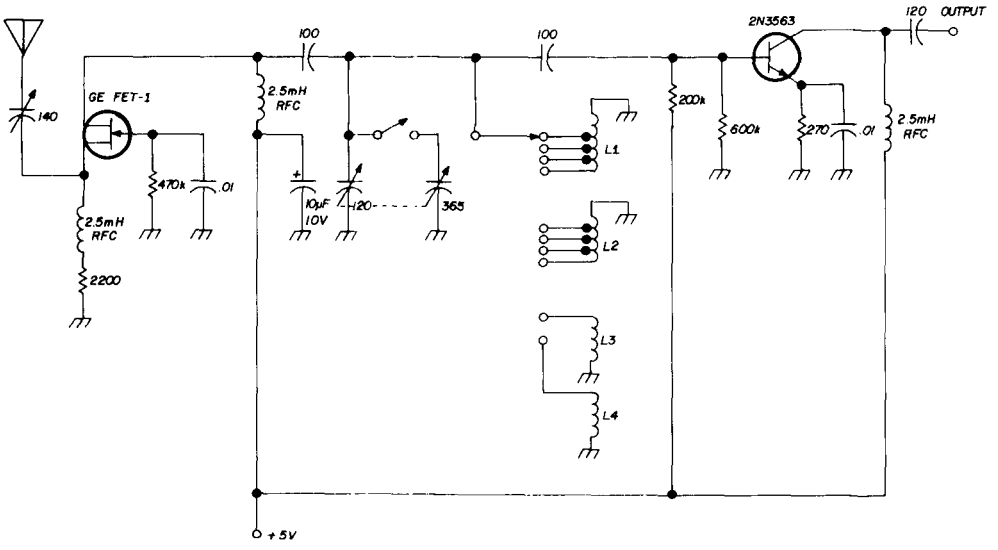
fig. 1. Simple filter for CW selectivity.

table 1. Capacitor values for desired tone

tone (Hz)	value of C (μF)
1700	0.1
1000	0.33
750	0.5
550	1.0

With this simple filter you'll find that interference from other signals and man-made noise will almost disappear. Cw signals a few hundred Hz apart can be separated easily, and the main tuning dial becomes very sensitive.

J. Donato, VE3BWD



L1 31 turns no. 18 airwound, 5/8" diameter, 1-7/8" long, (B&W 3007) tapped at 2, 11 and 27 turns (tunes 4—40 MHz)

L2 59 turns no. 18 airwound, 1" diameter, 1-7/8" long, (B&W 3016) tapped at 7, 28 and 38 turns (tunes 1.75—18 MHz)

L3,L4 80 turns no. 26 closewound on ½" slug-tuned ceramic form, brass slug (L3 tunes 1.05—2.2 MHz, L4 tunes 0.5—1.25 MHz)

fig. 2. Preselector for use with general-coverage receivers.

general-coverage preselector

The circuit in **fig. 2** was designed for receivers tuning between 0.5—30 MHz. Active devices are an fet in a common-gate, source-input circuit and an npn silicon transistor in a standard common-emitter circuit. The transistors are inexpensive. The fet, a GE FET-1, costs $2.25; the 2N3563 transistor is available from Poly Paks at four for a dollar.

The preselector has fairly uniform gain. Measured at the receiver, preselector gain is 20 dB between 2—30 MHz, with a rising characteristic toward the low end of the broadcast band, where the gain of most receivers seems to be down.

The low-impedance source input of the fet matches low-impedance antennas. The fet is used mainly as an impedance-matching device and has little gain when used alone. High output impedance of the fet and high input impedance of the npn transistor results in low tank-circuit loading; thus tank-circuit Q remains high. With a 5-volt power supply, total current drain is less than 2 mA.

Another fet could have been used instead of the npn transistor; however, the 2N3563'S gain characteristic, together with its low price, made it a desirable choice.

The broadcast band is divided into two segments. A two-gang capacitor, with provisions for paralleling, is used. This gives some flexibility, but it isn't entirely necessary for satisfactory operation. The variable capacitor in the antenna circuit is used to vary input coupling on the lower-frequency bands, since overloading causes cross modulation.

The transistor sockets and related circuit components are mounted on a 2 x 4-inch piece of perf board. This board, plus the larger parts, are mounted on a 4 x 7-inch piece of wood.

With my DX-150, which has spotty sensitivity and some image problems, the preselector improves reception on the low end of the bc band and on 160 meters. With a 25-foot-length of wire for an antenna, the preselector-receiver combination performs very well.

George Hirshfield, W5OZF

printed-circuit labels

Often it's desirable to permanently label components, terminals, and the printed-circuit board itself. These items may be labelled with copper by using dry-transfer letters. The letters resist the metal etchant in the same manner as tape, etch-resist pencils, ink, or paint placed on the copper-clad board.

Dry transfer labels for electronic equipment are made by Datak Corporation, Passaic, N. J. Many amateurs use them to label panels or chassis. The transfers resemble decals, but are more convenient to use. The lables are transferred by lightly rubbing over the characters with a ball-point pen. The sheet of characters is gently lifted to assure a complete transfer. This technique isn't convenient for use with boards using photo-resist chemicals, however.

Earnest A. Franke, WA4WDK

harmonic generator

The circuit shown in **fig. 3** will produce 50-μV harmonics through 1296 MHz with an input of 0.15–1 V from a 100- or 1000-kHz crystal oscillator. With a germanium diode instead of a tunnel diode, harmonics can be heard up to about 147 MHz.

ture, the voltage developed across the resistor alters the base current, through dc feedback, to stabilize the collector current. I am not using an emitter resistor, however, and have had no trouble. A larger resistor, up to about 470 ohms, can be used. This will affect the output of the circuit. The emitter resistor should be bypassed to prevent gain loss due to degenerative feedback.

A complete circuit is shown in **fig. 4** for those who don't have a 100- or 1000-kHz oscillator.

Chuck Spurgeon, W5GDQ

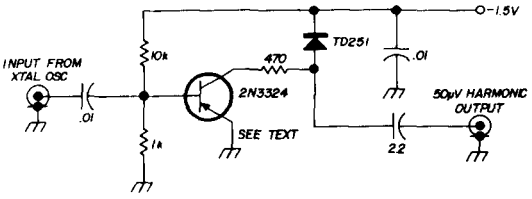


fig. 3. Basic harmonic generator using a tunnel diode.

hardware for uhf use

When building vhf and uhf components such as resonant cavities and stripline amplifiers, the need occasionally arises for nylon screws and nuts. Many of us don't have a supply of such items and look for substitutes.

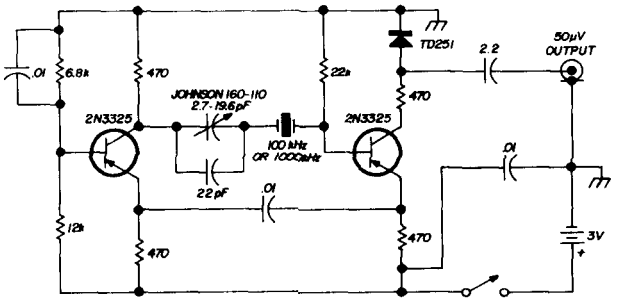


fig. 4. Complete harmonic generator circuit including reference oscillator.

A 2- to 5-ohm bias resistor can be inserted between emitter and ground to prevent possible thermal runaway. As the collector current increases with tempera-

A source of raw material is the flexible plastic handles used on ordinary cotton swabs known (appropriately) as *Q TIPS*. The handles measure 0.10 inch in diam-

eter—just the right size for a 4-40 die. The *Q-TIP* handles will thread nicely for use as screws. All that remains to be done is to saw a slot in one end to accept a screwdriver. The cotton swabs are available for a few cents in any drug store.

Insulating nuts or washers can be made from sheet plastic. Drill and tap a 4-40 hole in the sheet, then punch out the material around the hole with a paper punch. The disc out of the punch becomes the nut or washer.

Ted Swift, W6CMQ

six-meter mobile antenna

It's easy to assemble an effective six-meter mobile antenna from hardware-store material. An additional advantage is that no holes need be made in the car if the antenna is only temporary.

My antenna was made of two telescoping pieces of do-it-yourself aluminum tubing and an inexpensive plastic ice chest. The plastic foam of the ice chest is the nearest thing to air, and it must be reinforced at critical points. This is important for mobile operation at high speeds.

I mounted the ice chest on a cartop carrier and ran a horizontal dipole through it, fore and aft. Each of two larger sections of the tubing entered the plastic ice chest and were joined in the center by a dowel. The coax feed was run from this point through a hole in the bottom of the ice chest. I inserted the small-diameter tubing in the ends of the larger sections and adjusted the antenna for minimum standing-wave ratio.

The antenna was highly effective on a cross-country trip. I obtained good signal reports, worked some good DX, and the antenna was durable at high speeds; however, the reinforcement is essential for this.

If a carrier is made from the suction cups and straps available at auto-supply stores, the entire antenna is less expensive than any commercial version and is apparently a better radiator as well. I noticed little evidence of directivity.

Guy Black, W4PSJ

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The heart of the FM-6 is a 100-kHz crystal oscillator, adjustable to WWV, that produces a precise gate to permit the unknown signal to pass to a digital

counter and display. To increase accuracy and prevent ambiguous readings, a special dual synchronizer circuit is used to synchronize the gate with the signal to be measured.

The readout consists of two long-life Nixie[R] tubes that display both kilohertz and megahertz together with the appropriate decimal point. As an example, if the frequency is between 7248 and 7249 kHz, the dial will read 7.2 on the MHz scale, and 49. on the kHz scale. On higher frequencies, the highest digit is deleted. (ie. 14.3 MHz would read 4.3). The readout is constant as long as a carrier is on the air. Once every second a sample of the transmitter signal is made, and the frequency reading is "updated." This process takes only a few microseconds and the reading is stable and constant between measurements. Measurement accuracy is within 100 to 200 Hz, and the readout accuracy is 1 kHz.

The unit is all solid-state and uses TTL-MSI (medium scale integration) logic. A high-voltage power supply for the tubes, and a regulated supply for the logic circuits is self-contained in the small metal enclosure (3 1/8" high, 5 1/2" wide and 7 1/4" deep). The easy-to-assemble kit is supplied with all parts, cabinet, circuit board, coax connectors and detailed assembly instructions; $139.50. A factory assembled unit is $169.50. For more information, write to Micro-Z Electronic Systems, Box 2426, Rolling Hills, California, 90274, or use **Check-off** on page 94.

rotary qsl file

In the new products release in the July, 1970 issue, it was indicated that each rotary QSL holder comes complete with *600* clear plastic pockets. This was in error—each holder comes with *160* plastic pockets. The model CB-8-H rotary QSL file is $8 post-paid from M-B Products & Sales, 1917 Lowell Avenue, Chicago, Illinois 60639. For more information use **Check-off** on page 94.

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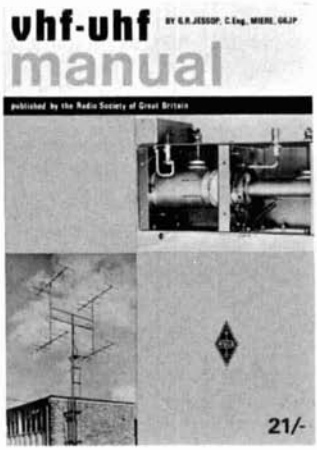

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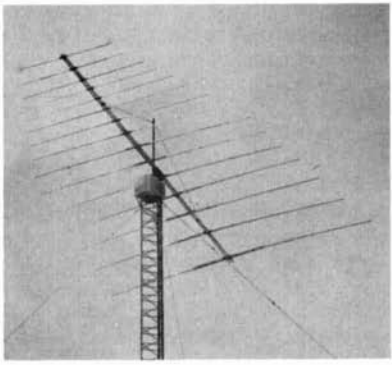
low-cost rf detectors

Radiation Devices Company has announced a new line of low-cost coaxial rf detectors for rf demodulation and voltage measurement over the frequency range from 1 to 1000 MHz. Units are available without terminating resistors, or with disc terminations of 50 or 75 ohms. Point-contact or hot-carrier diodes may be specified, with positive or negative output polarity. Frequency response is ±0.5 dB to 500 MHz, and ±1 dB to 1000 MHz. Maximum output voltage is 3 volts rms (point-contact diode) or 25 volts rms (hot-carrier diode). Power dissipation is 1 watt at 25°C. Mounted in BNC-type plug or jack with panel mounting option. Prices range from $12 to $15; for more information write to Radiation Devices Company, Post Office Box 8450, Baltimore, Maryland 21234.

log-periodic antenna



Hy-Gain Electronics Corporation has announced the availability of an all new rotatable log-periodic antenna that provides continuous coverage from 6.2 through 30 MHz. This antenna has been specifically developed for limited-space applications and is one-half the size of comparable antennas covering the same frequency range. The wideband coverage of this antenna makes it ideal for MARS, maritime, and government high-frequency communications applications.

The vswr over the operating range is

less than 2:1. Gain is 10 to 12 dB over an isotropic; front-to-back ratio is 10 dB average. Power handling capability is 1 kW average, or 2 kW peak. Input impedance is 50 ohms. The boom length is 36 feet, and the longest element is 40 feet. Weight is 250 pounds.

This new log-periodic array, the LP-1017, is priced at $1400. A complete system, the 5017, includes the antenna, Hy-Gain R-3501 rotator and remote-control indicator, and a roof-mounted 20-foot support structure; the 5017 is priced at $2850. For more information, contact the Hy-Gain Electronics Corporation. RR3, Lincoln, Nebraska 68505 or use **Check-off** on page 94.

digitone

Digitone Telecommunications Associates offers a number of interesting products for the vhf-fm amateur operator. Digitone decoders, logic processors, and other associated devices have been developed to fill the need for highly reliable, inexpensive solid-state tone-control equipment. The decoding devices are highly versatile in that different combinations may be selected to achieve varying degrees of complexity. Control outputs may be derived directly from the decoder (recognizing single tones), from a binary-decimal converter (recognizing tone pairs), or from the decimal code processor which recognizes and responds to sequential three-digit tone-pair codes.

Products currently available from Digitone include the TDM-202 tone decoder module, the BDC-203 binary-decimal converter, decimal code processors, DPS-201 decoder power supply, COR-221 carrier-operated relay, ACU-222 autopatch control unit, STE-101 single-tone encoder, and TTE-102 tel-touch encoder.

For more information on the complete line of Digitone products, and a copy of their latest application notes, write to Digitone, Post Office Box 116, Portsmouth, Ohio 45662, or use **Check-off** on page 94.

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	(1)	2" Boom to 1½" Mast T-Mount	Net **$22.45**
DL-3	(2)	3" Hub V-Supports	
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QM-3	(2)	1½" Hub Spiders	
	(1)	1½" Boom to 1½" Mast T-Mount	Net **$14.65**
QM-4	(2)	2" Hub Spiders	
	(1)	2" Boom to 1½" Mast T-Mount	Net **$22.45**
QM-5	(2)	3" Hub Spiders	
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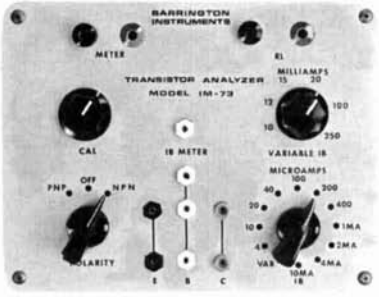

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More Details? CHECK—OFF Page 94

flea market

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QSL'S — BROWNIE W3CJI — 3111-B Lehigh, Allentown, Pa. 18103. Samples 10¢. Cut catalogue 25¢.

ORIGINAL EZ-IN DOUBLE HOLDERS display 20 cards in plastic, 3 for $1.00, 10 for $3.00 prepaid. Guaranteed. Patented. Free sample to dealers. Tepabco, John K4NMT, Box 198R, Gallatin, Tennessee 37066.

TAMPA HAMFEST — Hillsborough Amateur Radio Society, Inc., announces its Annual Tampa HAMFEST to be held Sunday, October 11, 1970 at Lowry Park, Sligh Ave. and North Blvd., in Tampa, Fla. Plenty of Free Parking. Lots of Prizes.

COLLINS-KWM-2 #13000, PM2, CC52, $750; 30L1, $325; 75S2B w/noise-blanker, $300; all mint cond. 32V2, HT41, HT37, DX100B, HA6 w/ps (new) Antennae, Misc., K7HRW, 685 Emerson Way, Sparks, Nevada 89431.

RG8U or RG11U — Low loss foam coax 10¢ foot, PL259 - SO239 - 40¢ each, 15/$5, Jacketed ½-inch aluminum 50 ohm Foamflex 20¢ foot, New factory sealed Ham-M Rotor $95. Everything new! F.O.B. Monte Southward, R. I, Upper Sandusky, Ohio 43351.

NOVICE CRYSTALS: 40-15M $1.38, 80M $1.83. Free flyer. Nat Stinnette Electronics, Umatilla, Florida 32784.

TEKTRONICS SCOPES 513D, DC to 18 MHz, good cond. **Asking** $275, area 201 542-8084 or 625 Pinebrook Road, Eatontown, N. J. Also 511 $175 or less w/trade. After 5:00 p.m.

BUY, TRADE, SELL — Used Receivers. Steven Kullmer, Evergreen Hatchery, Dysart, Iowa 52224.

1916 QST'S wanted. Especially May and June. Any unreasonable price paid! Ted Dames, W2KUW, 308 Hickory Street, Arlington, N. J. 07032.

KITS WIRED, Heath and others. Written guarantee given before assembly; 12% of retail price. Stanfill, WOMZU, Hills, Minnesota 56138.

CIRCUITS for 32 electronic projects, R.F., audio and gadgetry, complete plans $1.00. P.M. Electronics, Inc., Box 46204, Seattle, Wash. 98146. Dealer inquiries invited.

NORTHERN CALIFORNIA HAMS: Best deals — new and reconditioned equipment. Write or stop for free estimate. The Wireless Shop, 1305 Tennessee, Vallejo, California 94590.

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HEATHKIT SB-401, SB-301, SB-600, Two 4-1000A's, $500. Good working condition. Once-in-a-lifetime deal. Contact Fred, 860 N. 23rd St., Springfield, Oregon 97477.

POLICE — FIRE — AIRCRAFT — MARINE Calls on your broadcast radio with TUNAVERTER S! Tunable — Crystal! Brochure. Salch Company, Woodsboro HMC, Texas 78393.

PC BOARD. 3/32 inch, 2 oz. Copper one side, paper base. Specify size desired. 1.5¢ per square inch plus postage. HAL Devices, Box 365H, Urbana, Illinois 61801.

COLLEGE: SB401 with Mic and Crystal Pack, 20 hrs. $225.00. RME 6900 with match spkr. $175.00. OM 1 Scope $30.00. BC669-D Transceiver w/Power Supply $50.00. WA9TJK, Greg Drover, 24499 State Road, #23, So. Bend, Indiana 46614, Phone — Area 219, 288-8653.

I AM COMPILING information to publish a Hamfest Directory for 1971. Any club can have their hamfest listed free by having an officer of the club send all information to me before December 1, 1970. Art Collatz, K9JZM, 2127 Market St., Blue Island, Illinois 60406.

SAVE. On all makes of new and used equipment. Write or call Bob Grimes. 89 Aspen Road, Swampscott, Massachusetts, 617-598-2530 for the gear u want at the prices u want to pay.

VHF-UHF RF AMPLIFIER: AM-915A/TRC-24, RF Multiplier/Amplifier. 4X150A multiplier, 4X150G amplifier. Good for 144-432 MHz multiplier/amplifier combination. Can run up to 500 watts input. Need only B+ and filament power to operate. Good condition with tubes $45. Fair condition without tubes $25. Send check or money order to Richard Solomon, 19 Pierce Road, Watertown, Massachusetts 02172.

GREENE DRAGON FLY . . antenna for 20-40-75 meters . . one feed line . . SWR one to one . . and guaranteed-self construction drawings $5.00. Greene, Box 423, Wakefield, R.I. 02880.

DON'T BUY QSL CARDS from anyone until you see my free samples. Fast service. Economical prices. Little Print Shop, Box 9848, Austin, Texas 78757.

FOR SALE — HY GAIN TH4 $50.00. Henry Ingwersen, Topsfield, MA 01983.

DRAKE R4B — brand new — save $100. Factory-sealed, shipped prepaid. K9KDI, 419 S. Euclid Ave., Oak Park, Ill. 60302.

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DUAL GATE MOSFET CONVERTERS FOR TWO METERS

Low noise figure (2). Excellent cross modulation and image rejection (116 MHz xtal oscillator). IF 28-30 MHz. 12 VDC/20 mA. Silverplated, glass-epoxy p.c. board. All inductors shielded. Fully assembled and aligned. Braun Model DGTC 22, **$35.00**

Highly compact converter (3″x2″x1″); can be mounted in existing receiver or transceiver cabinet. Electrical characteristics as above, except any IF between 14 and 32 MHz can be selected by simple plug-in of the appropriate oscillator crystal. (116 MHz crystal furnished with converter). Oscillator-emitter follower output for use with transceiver. Schilling Model HS 1000 Jx, **$39.50**

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More Details? CHECK—OFF Page 94

TOROIDS! Lowest price anywhere. 40/$10.00 POSTPAID, Center tapped 88 or 44mhy. (5/$2.00). Lorenz 60 speed page printer, with built in reperf and TD (ASR) $125. Teletype model 32KSR, reconditioned, perfect page printer (60 or 100 speed) $200. Reperferator tape 11/16" $10./case/40. Stamp for list. Van W2DLT, 302H Passaic Avenue, Stirling, N. J. 07980.

WORLD QSL BUREAU — see ad page 92.

1" MAGNETIC TAPE on metal reels (boxed) 2500'/$7.50, 5000'/$10.00 Printed Circuit Connectors standard dual 22-pin (new) .35/ea. 4/$1.00 Miniature Balanced Modulator on circuit board with trimpot, Transformers, components, etc. $2.50. SASE for other bargains. Hatfield, K8VDU, Drawer 27100, Columbus, Ohio 43227.

THE FOLLOWING EQUIPMENT was stolen: 1 — SM-1 Microphone, P.T. #12814, Ser. #2740; 1 — 516F2 Power Supply, P.T. #12809, Ser. #23194; 1 — 32S3 Transmitter, P.T. #12805, Ser. #101254; 1 — 75S-3C Receiver, P.T. #12811, Ser. #13753; 1 — 312B-4 Speaker Console, P.T. #14560, Ser. #60133; 1 — 30L-1 Linear Amplifier, P.T. #12815, Ser. #28517; 1 — Complete Interconnecting Cable Set. Any information pertaining to the above Radio Equipment is respectfully requested by: Fred Mc Murray, Communications Officer, City of Baton Rouge, P.O. Box 1471, Baton Rouge, LA 70821. 504-344-1723.

TELETYPE PICTURES for sale. Volume 2, 16 pages containing 50 pictures $2.00. Volume 3 coming $1.50. Also audio and perforated tapes. W9DGV-d 2210-30th St., Rock Island, Ill. 61201.

HAMMARLUND HX-50A xmtr, Johnson Ranger II. All good condx. WB4AXQ, 305 Caroldale, Middletown, Ky 40243.

TELEGRAPH KEYS WANTED: Wire, wireless, Spark or CW. Related books. Ted Dames, W2KUW, 308 Hickory St., Arlington, N. J. 07032.

TECH MANUALS — R-390/URR, R-390A/URR, BC-639A, ARR-7, OS-8C/U, TS-186D/UP, $6.50 each. Hundreds more. S. Consalvo, 4905 Roanne Drive, Washington, DC 20021.

PARKS 2M CONV., exec. cond., 7 MHz i.f., $50; BC-455 RCVR, w/pwr. supply, $25. John Ethridge, 113 White St., Martin, Tennessee 38237.

TOROIDS 44 and 88 mhy. Unpotted, 5 for $1.50 ppd. W. Weinschenker, Box 353, Irwin, Pa. 15642.

TELETYPE #28 LRXB4 reperforator-transmitter "as is" $100; checked out $175. Includes two 3-speed gearshifts. Alltronics-Howard Co., Box 19, Boston, Mass. 02101. 617-742-0048.

SALE — Motorola MC724P IC's — 75¢ each. Stancor P-6134 6.3V CT @ 1.2A — 85¢ each. Please include postage. W3KVQ/2, 2308 Branch Pike, Cinnaminson, N. J. 08077.

WANTED: PS-150-120 AC. C. E. 600-L (cheap) with manual. Eico keyer. Henry linear. C. E. MM-2. 2 ea. Eimac SK-600/SK-606. 8122's. 8163's. Collins 351R1/R2 rack-panels for S-Line (need 2 each). 30S1. TR4 (late). T4X/T4XB, AC4. James W. Craig, W1FBG, 29 Sherburne Avenue, Portsmouth, N. H. 03801, (603) 436-9062.

QSLS. SECOND TO NONE. Same day service. Samples 25¢. Ray, K7HLR, Box 331, Clearfield, Utah 84015.

HAMFEST — Monroe County (Michigan) Radio Communications Assn. October 11, at 10:00 a.m. to 4:00 p.m. (Doors open at 8:00 a.m. at Monroe Mich. Fairgrounds. Prizes and contests. Tickets: $1.25 in advance. $1.50 at the door. Contact Rick Bronson, WA8YDZ, 2085 Hollywood Drive, Monroe, Mich. 48161. Talk in 3.930 SSB, 50.4 AM, 52.525 and 146.94 FM.

DRAKE 2C, still in sealed-carton, only $200, shipped prepaid. K9KDI, 419 S. Euclid Ave., Oak Park, Ill. 60302.

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Freehold, New Jersey — Irving Strauber, W2ERV/W4MVC, has announced the formation of Irving Strauber Associates. This organization will act as manufacturers representatives in the electronics and communications field.

Three separate divisions have been set up. One will service OEM accounts, another electronics distributors, while the third will concentrate on industrial business.

Mr. Strauber states that his firm has already acquired a number of lines from some of the best known manufacturers in the communications field. Other names will be added in the future to further round out their product line.

The address of this new business is Irving Strauber Associates, 14 Bernice Drive, Freehold, N. J. 07728. Telephone 201-431-2367.

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More Details? CHECK—OFF Page 94

FOR SALE: Factory-sealed: 30L1, $445; 312B4, $175; 516F2, $135; 32S3, 516F2, 75S3 (6EH7 RF amp), 312B4, $1000; 75S1, 32S1, 516F2, 312B4, $695. 30L1, $300. Swan 500C, 117XC, VX2, $450. HT32B, $225. HW32A, HP23A, $140. KW Match Box, meter, $125. Thunderbolt Linear, $250. Galaxy 300, PSA 300, $185. SP600JX17, factory-reconditioned, $250. Messenger III, AC supply, $100. Filter F455-Y60 (6 kc, for 75S1, 75S2, 75S3), new, $25. Variac 220V/31 amps, $50. Transformers: 115/12.8 @ 20A, $7; 115/2880 VCT @ 500 ma, $13; 115/1300 @ 3.0 amps, $35. Cubex 4-el tri-band quad, $100. Hy-Gain LP-1007 Log Periodic (13-30 mcs, 5 KW peak), $350. Telrex rotator, A1312RIS, Indicator Console, 100 ft. Telrex control cable (PVC jacket), $350. 312B5, $250. 62S1, $500. NCL2000, $350. SR160, PS150-12 DC p.s., $195. T4 Reciter (factory-sealed carton), $350. HA-460 Lafayette transceiver, $60. HW22A, HP13, $145. Lamda VR supplies (rack-mounting), $25, write for details. Power supplies, 115 VAC/2000VDC with rack panels, UTC components, $25 (write for specifics). RCA 8121, $5. Henry 2K-D, $450. Heath "Chippewa" KL1, KS1, $250. Capacitors, 2 ea 4 mfd/10KV, $25 ea. Choke, 20 hy, 1.0 amp, $25. 4CX1000, sealed carton, $100. 4-400, sealed cartons, $22.50. Transformer, 220/3KV (no C. T.) @ 10 amps, $75. James W. Craig, W1FBG, 29 Sherburne Avenue, Portsmouth, N. H. 03801, (603) 436-9062.

LISTING SERVICE — Gear to sell? Need rig? Sellers $1.00 lists information year. Buyers — free. SASE brings details. W8TXX Listing Service, Box 1111, Benton Harbor, MI 49022.

THE ANNUAL HAMFEST AT LAKE TEXOMA LODGE on Lake Texoma, near Kingston, Oklahoma, will be held November 13, 14 and 15, 1970. All the programs indoors and there will be entertainment for all. Technical discussions and swapland shop. Ray Bryan, W5IQ, Box 246, Kingston, Okla. 73439.

SWAN 250, 117XC AC supply and TV2B (new). SB 500 Transverter. Clegg-Venus XCVR and 416AC Supply. SASE for details. Scotty, 14534 Vaughan, Detroit, Mich. 48223.

SIX NEW BOXED COLLINS mech. filters for sale 1.5 KC plug in (455 Q6) with spec sheets $25 each. URM 26A Sig Gen. 4-405 Mc. $350. URM 25E Sig Gen. 10 Kc to 50Mc. $350. Both good with accessories. Fifteen new (sealed in cans) 7035/4X150D tubes $12 each. Check or COD to N. F. Moss, K61WG/KL7, PO Box 2191, **Fairbanks, Alaska 99701.** Will buy or trade for any legal aircraft radio gear such as Narco King ARC Collins or Bendix.

TEST EQUIPMENT — Signal Generators: Meas. 80, 2-400 MHz — $250; URM26A, 3-405 MHz — $225; Meas. 65B, 15kHz — 50 MHz — $350; HP608A, 10-500 MHz — $425. Counters: Berkeley 5500, Univ. EPUT — 100 kHz — $165; HP524B, 10 MHz — $495; HP525A, 10-100MHz plug-in — $115; HP526B, Time Interval plug-in — $95. All guaranteed. Many more, send SASE for list. Grattan Gray, P. O. Box 941, Monroe, MI 48161.

REVISED REQUIREMENTS for the Okinawa Award, as follows: QSLs required: 25 — KR6 and KR8 applicants; 10 — BV, CR9, DU, HL/HM, JA/KA, KG6, VS6, W/K applicants; Rest of the World send 5. KR6 and KR8 applicants must submit cards. All others, send only a log book extract with signed confirmation that required QSL information had been received and verified by two licensed amateur radio operators, or by an official of a recognized radio club or society. Send all applications and $1.00 (U.S.) or 10 IRC's, to QSL and Awards Manager, Okinawa Amateur Radio Club, P. O. Box 465, APO, San Francisco, CA 96331.

PACKER'S DISTRIBUTING will specialize in sales and service of Amateur and Citizens Band Equipment, Industrial Communication and Home Entertainment systems. Opening date for the Green Bay, Wisconsin store will be announced within the next thirty days. Packer's Distributing, 6918 Maple Street, Omaha, Nebraska 68104.

DRAKE R4A, T4 with AC supply, best offer. Heath HW-17 factory reconditioned and modified to HW-17A, $98.00. K4CWW, 217 Milton Drive, Carrboro, N. C. 27510.

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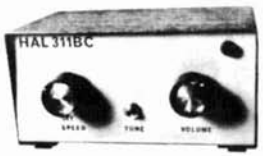

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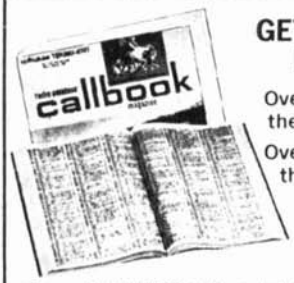

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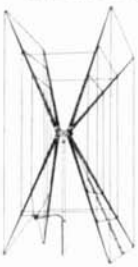

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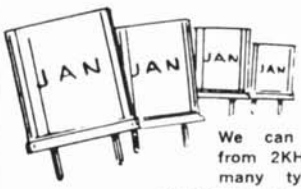

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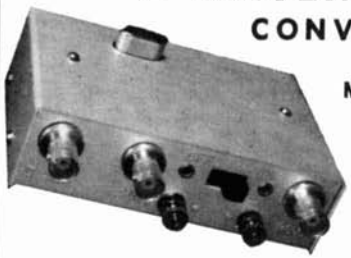

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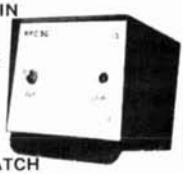

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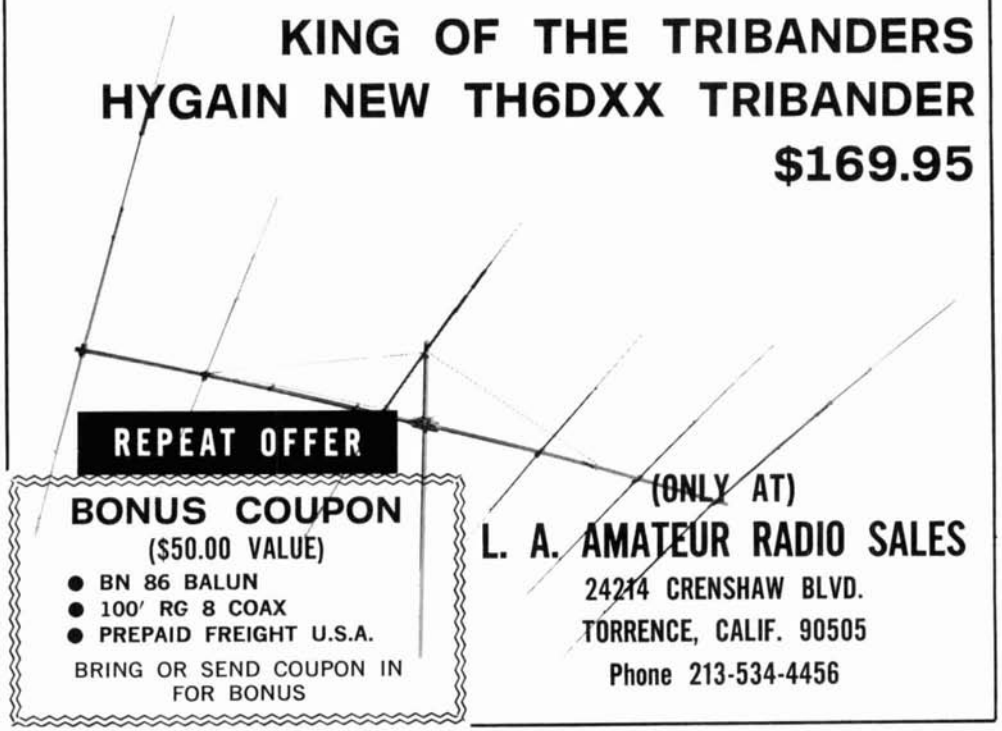

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Snide
Some ~~Side~~ Remarks about Raytrack

There are some people who marvel that a short wave receiver can tune in stations thousands of miles away. You and I know that this is normal and natural. There are some people who believe that only a linear whose name matches that of their transceiver will perform appropriately. You and I know their thinking to be wrong. But perhaps this confining view is just as well -- for I doubt if Dan Eisenmann, for example, could make his Raytrack Horizon VI Amplifier the beautiful linear it is if greater customer pressure existed.

This six meter linear does not have a Raytrack transceiver to drive it with, it does not have a spurious input filter, it does not have automatic tuning, it does not have ALPL (Automatic Legal Power Limiting), and it wasn't designed to turn itself off in a microsecond if the antenna load wasn't connected to it. Worse, it does not have the latest zero drive tubes parallel connected to enable it to function at the mere thought of excitation. Dan wanted these features and more but we dealers did succeed in explaining that some of the six meter boys could tune an amplifier and read their meters correctly and that there were a few "technicians" who had been known to understand VSWR, and further if this new amplifier were made completely "idiot proof" that he did not have enough money to finance the deluge of orders that would result. Then we showed him he would have to borrow at the bank, and with interest the way it is today the bank would be taking in more than Raytrack. And, damn it, the boys in the shop would unionize (all three of them) and that too would mean more expense. Then if that wasn't enough the IRS would suddenly take notice and offer to carry their side of the wheelbarrow to the bank. And Dan, if that kept up for long, the next thing you'd realize is that our cousins in J A land would put their noses into the air and sniff a good thing, too. (Where would you be then, Mr. Frankenstein Eisenmann?)

And so reason prevailed. Raytrack did the proper thing, they concentrated on making an honest 2 kw six meter linear with real transmitting tubes that could be fed from anybody's Swan, Drake or Heath exciter and with simple connections -- only three of 'em -- so clearly labeled that even Johnny Newham could hook it up right the first time.

And they soldered every joint and put a lockwasher where a lockwasher was supposed to be and finished their unit by testing it on the air and into a dummy load with proper instruments -- and lo fellows, look what we got -- and don't say that the price is high 'cause it ain't!

Study the photo and the specs and if you have something to listen with, tune me in, that is presuming that my demonstrator has not been sold (the last time it lasted 1 1/2 hour --s' help me.)

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Incredible.

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These days, when you think of Japanese-built products, think of Nikon, or Sony, or Toyota. And Yaesu. Our transceivers are state-of-the-art engineered and carefully hand-assembled. They're so solid, stable and reliable we guarantee them for one year. Yaesu is quite likely the best transceiver made anywhere in the world today.

The complete Yaesu story is a long one. So we've compiled a comprehensive information packet that gives you the complete picture. Including things like comparative detail photos, a schematic, and a comparison chart that shows you the FTdx 560's superiority over rigs you're more familiar with. Once you've looked over the FTdx 560 literature we think you'll agree that the amateur operator's impossible dream has become an incredible fact.

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The 500CX installs conveniently under the dash of most cars, and the power supply goes under the hood. Add the Swan Model 35 high Q single band mobile antenna, or your choice of either the Swan Model 45 or 55 band switching mobile antenna, and you can enjoy mobile operation to the fullest. Home station performance with a mobile rig? Nothing comes closer than a Swan transceiver.

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