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**ELECTRONIC**  
**EXPERIMENTER'S**  
**HANDBOOK**

SPRING EDITION

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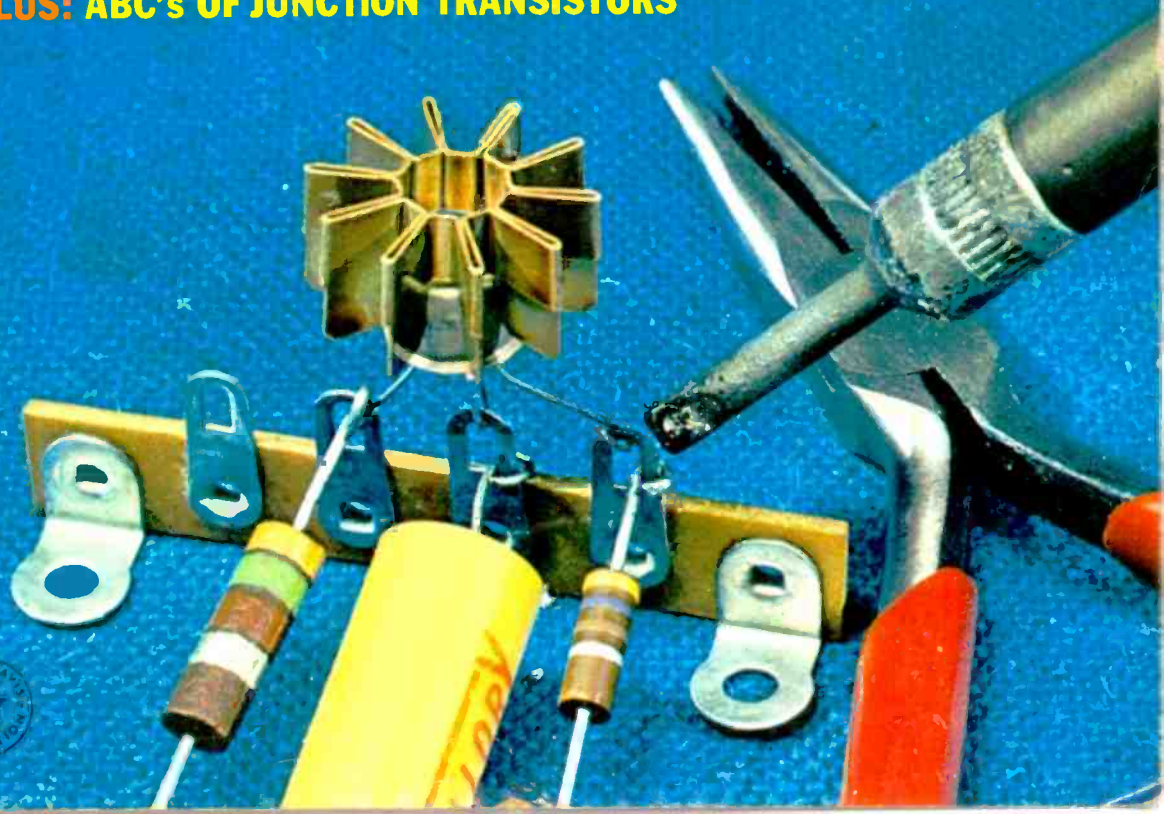
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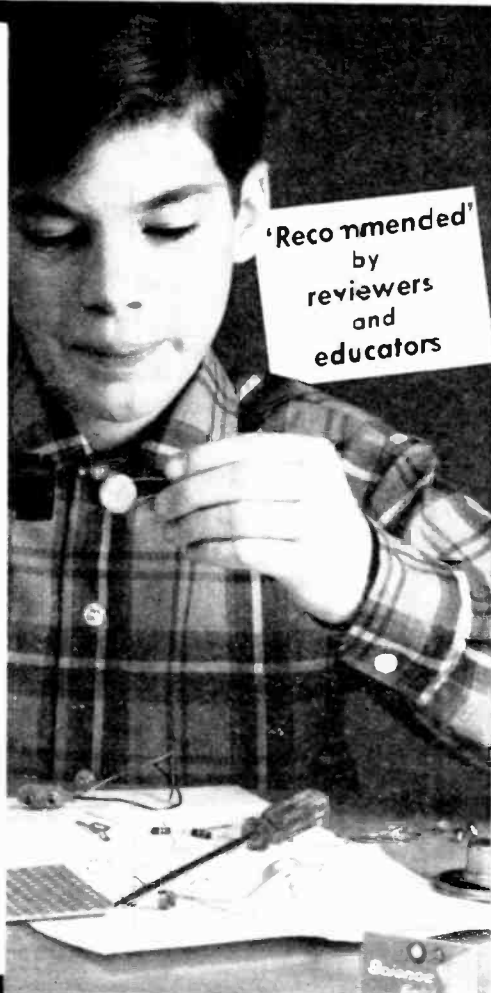
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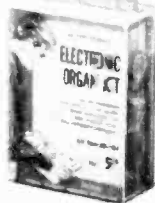
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# SPRING EDITION 1968 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

When this issue of the ELECTRONIC EXPERIMENTER'S HANDBOOK appears on the local newsstands, many hobbyists will be recalling that this is the twentieth anniversary year of the discovery of the point-contact transistor. Few inventions have had as far-reaching impact as the transistor—upon every person in every nation around the globe. Even a partial list of the contributions of the transistor to our everyday life would consume pages. Be it automobile, food blender, lighting fixture, color TV, satellite, or computer, the transistor and its offspring in the family of solid-state components participate in our everyday life.

Naturally, most of the projects described in this edition of EEH use solid-state devices—junction transistors, silicon-controlled rectifiers, field-effect transistors, integrated circuits, etc. Some projects are simple, some complex, but all have been tested and double-checked for performance before publication.

And, in speaking of transistors, I have noted that many experimenters tend to shy away from a workable understanding of how to test transistorized circuits. Chapter 3 is devoted to a new and different approach to this subject—read it over a couple of times and see if your knowledge of transistors doesn't increase by leaps and bounds.

OLIVER P. FERRELL



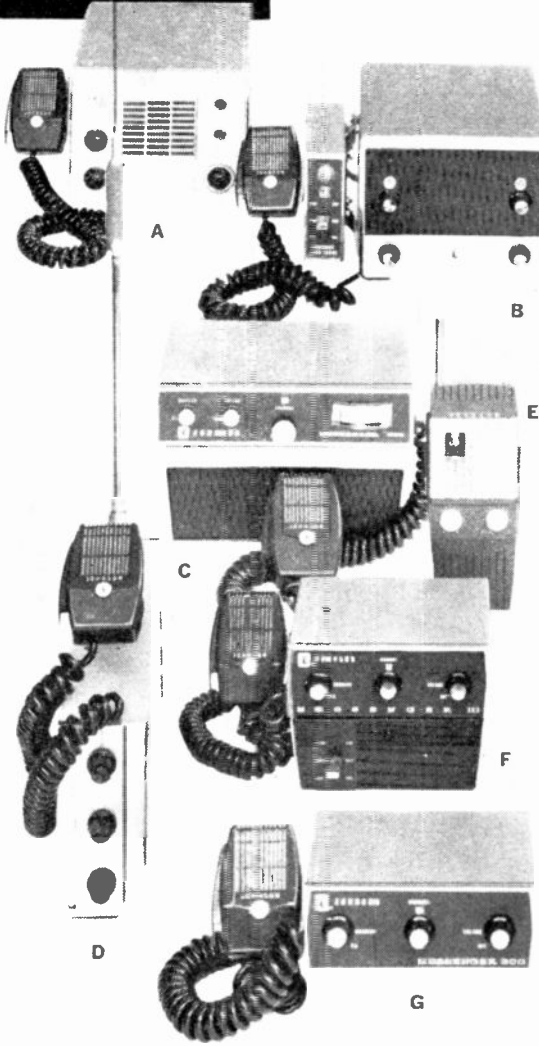
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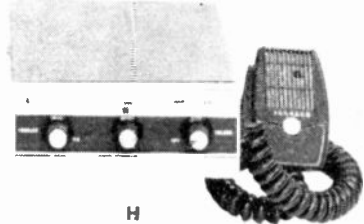
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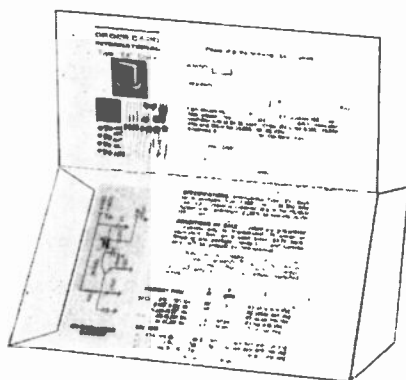
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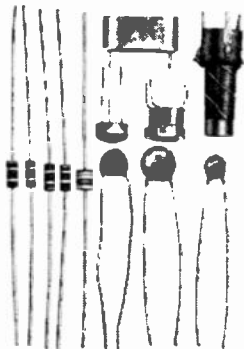
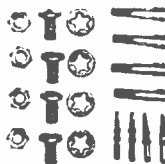
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# CHAPTER 1

## USEFUL PROJECTS

Selecting the "ideal" projects to appear in this chapter of the Spring Edition of the **ELECTRONIC EXPERIMENTER'S HANDBOOK** was not a particularly easy task. There was a wealth of interesting and valuable projects to choose from and certainly no outward sign that hobby electronics is losing its appeal. We have tried to "mix" the projects, providing something for fun and games, something for the motorist, something for the photographer, etc.

As the result of many requests, we have included plans for a very low-cost metal locator. You can build this unit in a couple of evenings and be positive that it will work. It won't spot treasures three or four feet under the surface, but it will locate rings, coins, and lost jewelry under two to five inches of sand or loose gravel.

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# REMOTE COMMANDER

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RADIO CONTROL SYSTEM  
TURN ON AND OFF  
YOUR RADIOS, TV'S,  
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UP TO 500 FEET AWAY

By **ELDEN C. MAYNARD, K6SAI**



**T**HE "REMOTE COMMANDER" radio control (R/C) system can save you time and energy inside and near your home. It lets you take care of little jobs, like turning TV sets, radios and lights on and off from remote locations. Outside your home, the system is a real convenience; it can be rigged to a garage door opening and closing setup that can be controlled with the touch of a button—you don't have to get out of your car in even the stormiest weather.

The system is made up of a transmitter that is compact and light enough in weight to be carried in your shirt pocket and an equally compact receiver. In operation, the receiver remains in a fixed location near the device being controlled, while the transmitter can be moved to any location within range of the receiver. No physical link between the two units is required, so you are not limited to a few "strategic" locations—any location you happen to be at is strategic when you have the transmitter with you.

The "Remote Commander" R/C system was originally conceived as the controlling device for the "Pulse Command Responder" (see page 47 of this issue). If used with the responder, it is connected as shown in Fig. 1. However, the responder is not required for operation of the system. The "Remote Commander" can be used with an inexpensive power relay to control a single device.

Of course, being a radio control system, the "Remote Commander" can also be used for controlling model airplanes, boats and racing cars.

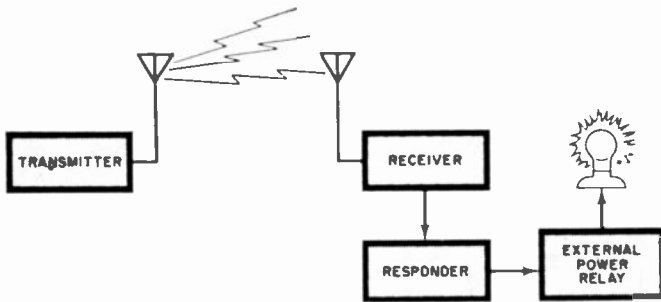


Fig. 1. "The Remote Commander" can be used as an R/C remote control device for the "Pulse Command Responder" (page 47) if the setup is as shown above.

**How The System Works.** The two devices that make up the major elements of the system are reproductions of actual manufacturer circuits. (The schematic shown in Fig. 2 is a Mark II "Mule" tone transmitter, and Fig. 3 is a Model "4" superregenerative tone receiver, both made by Controilaire Division of World Engines, Incorporated.)

The transmitter circuits (Fig. 2) develop a 26.995-MHz carrier and an 800-Hz modulating tone, generated by crystal controlled oscillator  $Q1$  and blocking oscillator  $Q4$ , respectively. The modulating tone is amplified through  $Q3$  before it is passed on to  $Q2$  where it modulates the r.f. carrier. After amplification through  $Q2$ , the resulting tone-modulated signal is coupled through  $C1$  to the antenna and finally radiated into space.

The receiver's antenna (see Fig. 3) picks up this signal and passes it to superregenerative detector  $Q1$ . Transistor  $Q1$  operates as an interrupted oscillator that generates a quenching voltage and maintains the  $Q$  of tuned circuit  $L1-C4$  at maximum (on the border line just before  $Q1$  goes into oscillation).

The r.f. carrier is shorted to ground through  $C6$ , and the modulating tone is transformer-coupled *via*  $T1$  to audio amplifiers  $Q2$ ,  $Q3$ , and  $Q4$ . When  $Q4$  conducts,  $K1$  energizes.

The input sensitivity of the receiver is 4 microvolts or better and is directly attributable to the use of a superregenerative detector.

When  $K1$  energizes, the load being controlled either receives or is denied power,

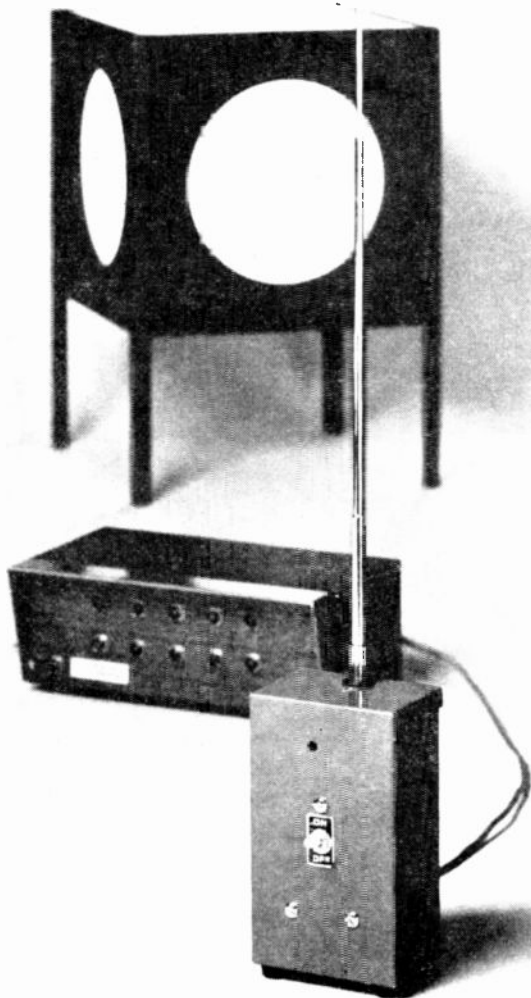


Fig. 2. Transmitter is crystal-controlled to conform with the FCC specifications regarding carrier frequency stability. Output consists of a 26.995-MHz carrier signal, modulated with an 800-Hz tone.

### TRANSMITTER PARTS LIST

- B1—9-volt battery  
 C1—100-pF ceramic capacitor  
 C2, C3, C5—0.02- $\mu$ F ceramic capacitor  
 C4—0.05- $\mu$ F ceramic capacitor  
 C6—62-pF ceramic capacitor  
 L1—R.J. coil assembly (See Text)  
 L2—12- $\mu$ H radio frequency choke  
 Q1, Q2—2N706 transistor  
 Q3—2N2924 transistor  
 Q4—2N229 transistor  
 R1—1500-ohm  
 R2, R4—100-ohm  
 R3—10,000-ohm  
 R5—47,000-ohm  
 R6—15,000-ohm  
 R7—27,000-ohm  
 R8—4700-ohm  
 S1—S.p.s.t. normally-open momentary action push-button switch  
 T1—10,000- to 1000-ohm impedance matching transformer  
 XTAL—26.995-MHz crystal (available from Texas Crystals, 1000 Crystal Dr., Fort Myers, Fla.)  
 I—Printed circuit board\*  
 A—Antenna (similar to Lafayette Radio Electronics No. 99 II 300S)  
 Misc.—Metal box, battery clip,  $\frac{1}{2}$ " rubber grommet, hookup wire, solder, hardware, metal strip, insulator, etc.
- \*See Receiver Parts List.

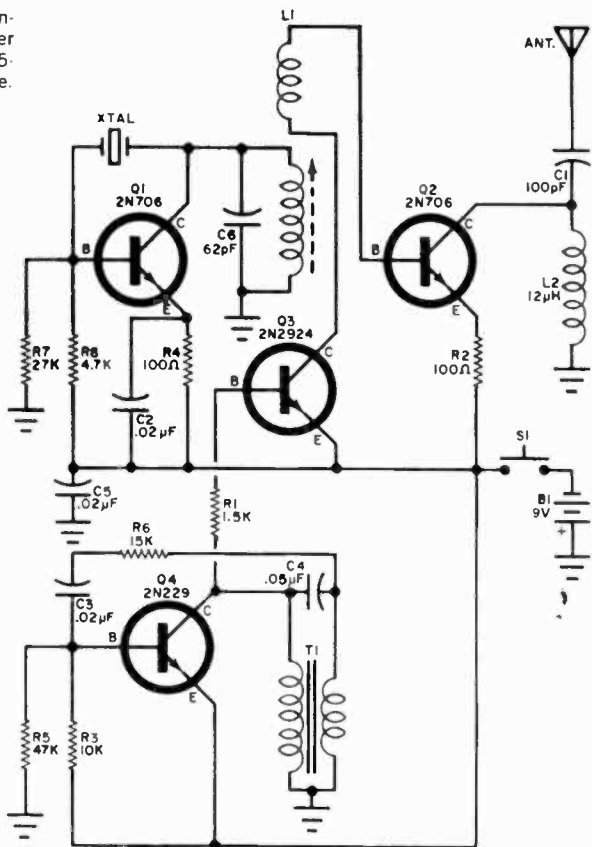
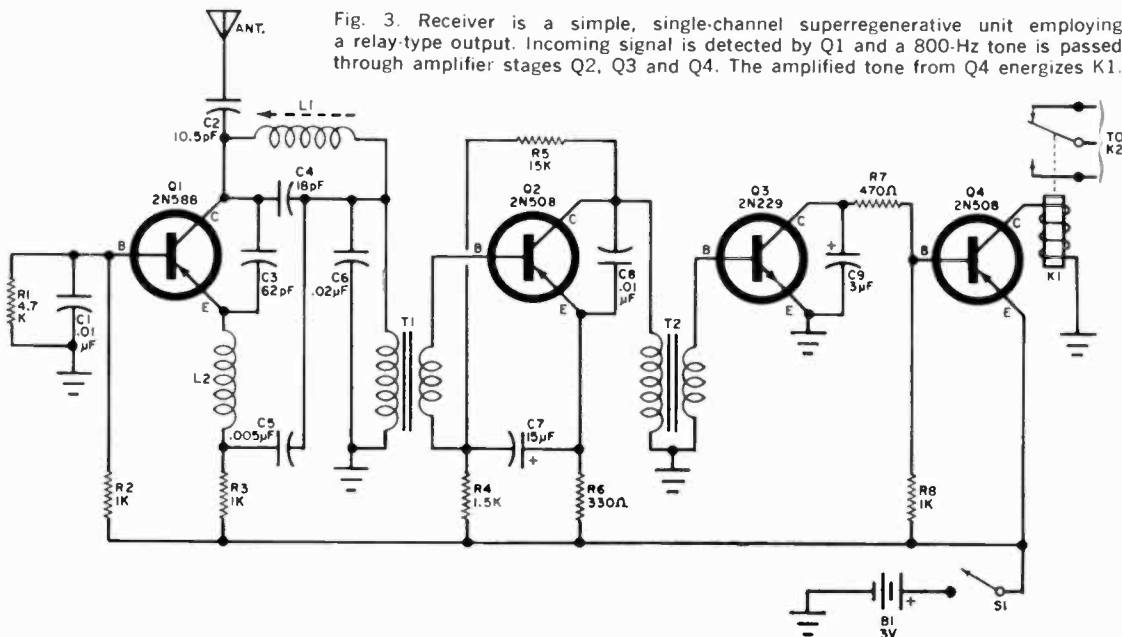


Fig. 3. Receiver is a simple, single-channel superregenerative unit employing a relay-type output. Incoming signal is detected by Q1 and a 800-Hz tone is passed through amplifier stages Q2, Q3 and Q4. The amplified tone from Q4 energizes K1.



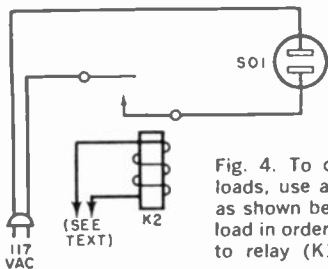


Fig. 4. To control high power loads, use a power relay wired as shown between receiver and load in order to prevent damage to relay (K1) in the receiver.

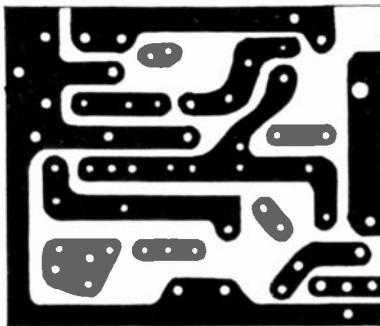
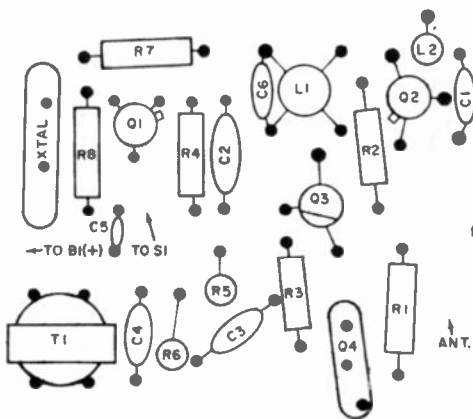
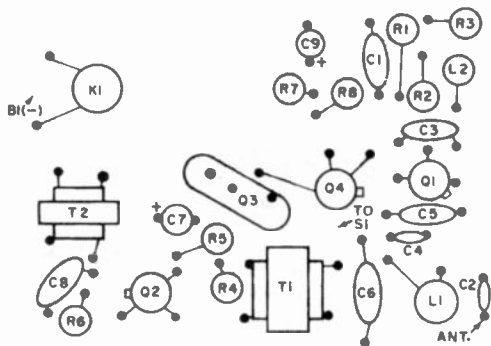


Fig. 5. Transmitter (directly above) and receiver (below right) etching guides are shown actual size. The layouts show parts location and orientation on the boards to facilitate easy component mounting.



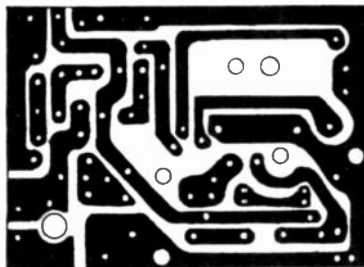
depending on the pair of contacts to which the load is connected. The contacts of *K1* are designed for low-voltage and low-power loads. Therefore, they must be protected against overloading and arcing through the use of low-voltage external power relay *K2* (Fig. 4) and a power source compatible with the requirements of *K2*'s solenoid winding.

For normally-on operation of the load being controlled, *K2* should be connected to the upper pair of *K1*'s contacts. Conversely, for normally-off operation *K2* should be connected to the lower contacts. When wiring *K2* and its power source across the contacts of *K1*, a con-

### RECEIVER PARTS LIST

- B1—3-volt battery
- C1, C8—0.01- $\mu$ F ceramic capacitor
- C2—10.5-pF ceramic capacitor
- C3—0.2-pF ceramic capacitor
- C4—18-pF ceramic capacitor
- C5—0.005- $\mu$ F ceramic capacitor
- C6—0.02- $\mu$ F ceramic capacitor
- C7—15- $\mu$ F, 15-volt electrolytic capacitor
- C9—3- $\mu$ F, 15-volt electrolytic capacitor
- K1—S.p.d.t., 50-ohm subminiature relay\*
- K2—See text
- L1—R.J. coil (See Text)
- L2—12- $\mu$ H radio frequency choke
- Q1—2N588 transistor
- Q2, Q4—2N508 transistor
- Q3—2N229 transistor
- R1—4700-ohm
- R2, R3, R8—1000-ohm
- R4—1500-ohm
- R5—15,000-ohm
- R6—330-ohm
- R7—470-ohm
- S1—S.p.s.t. switch
- T1, T2—10,000- to 1000-ohm impedance matching transformer with tab mount\*
- T—Printed circuit board\*
- 1—Telescoping antenna (See Transmitter Parts List).
- Misc.—Small metal box, 3 $\frac{1}{4}$ " x 2 $\frac{1}{8}$ " x 1 $\frac{1}{8}$ " utility box,  $\frac{1}{2}$ " rubber grommet, 3-lug terminal strip, hookup wire, solder, hardware, insulator, battery clip, etc.

\*These parts obtainable from Controlaire Electronics, World Engines, Inc., 8960 Rossash Rd., Cincinnati, Ohio 45236.



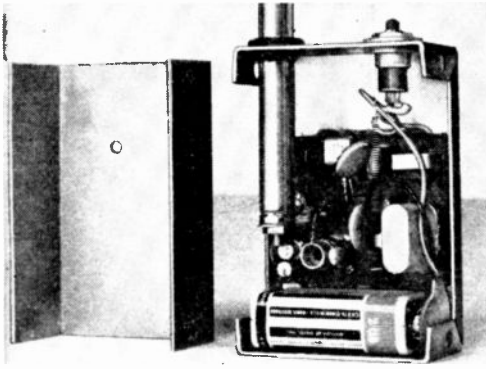


Fig. 6. Transmitter case should be smallest possible size, but large enough to house circuit board, battery and switch, and provide support for antenna.

tinuous series circuit should be obtained, so that  $K1$ 's contacts act as a switch between the low voltage supply and  $K2$ .

**Construction.** While small size and light weight are not important in the receiver, they are absolute necessities in the transmitter for maximum portability. Both circuits should be built on printed circuit boards, if for no other reason than to minimize construction time.

You can etch and drill your own printed circuit boards using the drawings in Fig. 5 to guide you, or you can buy them already etched and drilled (see Parts Lists). Coil  $L1$  in both the transmitter and receiver can also be home brewed. The transmitter coil consists of  $3\frac{1}{2}$  turns (upper winding) and  $10\frac{3}{4}$

turns (lower winding) of #24 enameled wire. The receiver coil consists of 10 turns of #30 enameled wire. Both coils should be closely wound on  $\frac{1}{4}$ "-diameter coil forms with adjustable high-frequency powdered iron cores.

Mount all parts as close to the circuit boards as possible, but allow enough lead length between transistors and boards to permit proper heat sinking when soldering. All the resistors in the transmitter and a few in the receiver should be mounted "on-end" to conserve space.

When all parts are in place, solder them to the boards' foil conductors, being careful to prevent solder bridges between the closely spaced conductors. Then cut away the excess component leads as close to the boards as possible.

Mount the transmitter circuit board in the smallest size metal box that will house the board, battery and switch and provide a support for the antenna as shown in Fig. 6. Place a piece of insulating material between the bottom of the board and the metal box.

Drill a  $\frac{1}{2}$ " hole in the top of the metal box, place a grommet in it, and slide the antenna into place, securing it to the board with a metal strip. Finally, mount the switch on top of the box near the antenna, and drill a small access hole in the box directly over  $L1$ .

The size of the box you use to house the receiver and its associated parts is unimportant. The main circuits—minus power switch, antenna and batteries—

*(Continued on page 153)*

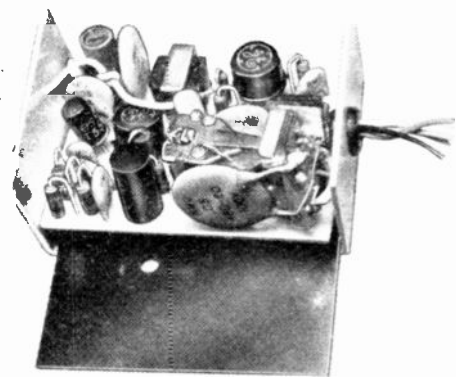
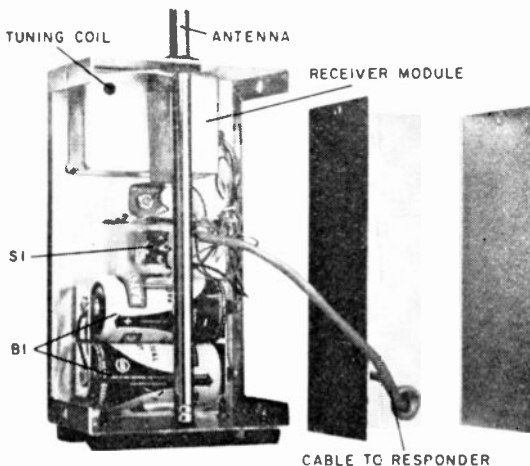


Fig. 7. For maximum shielding from outside interference, receiver circuit board should be mounted in separate metal case (above). Mount receiver module, switch, batteries and antenna in larger metal cabinet (left).

INTEGRATED CIRCUITS  
SIMPLIFY CONSTRUCTION  
OF REAL ELECTRONIC DICE  
FOR FUN,  
PLEASURE, OR PROFIT,  
AND PUT . . .

**T**ECHNICALLY SPEAKING, this is a pair of Mod 6 walking ring counters using six J-K flip-flops and lamp drivers. Decoding is reduced to four circuits each and the readout is an arrangement of 14 low-voltage bulbs. From a practical aspect, this is an electronic pair of dice that can't be loaded.

## SPOTS BEFORE YOUR EYES

By **DON LANCASTER**

While intended primarily for use with parlor-type family games, this gadget will make a dandy science fair project for illustrating the basic principles of probability and computer counter circuitry, and will serve as an immediate attention-getting device at any exhibit or display. It measures 6½" x 3¾" x 2", and should cost from \$18 to \$30, depending on how fancy you care to make your particular version. Complete kits and/or all special parts are readily available.

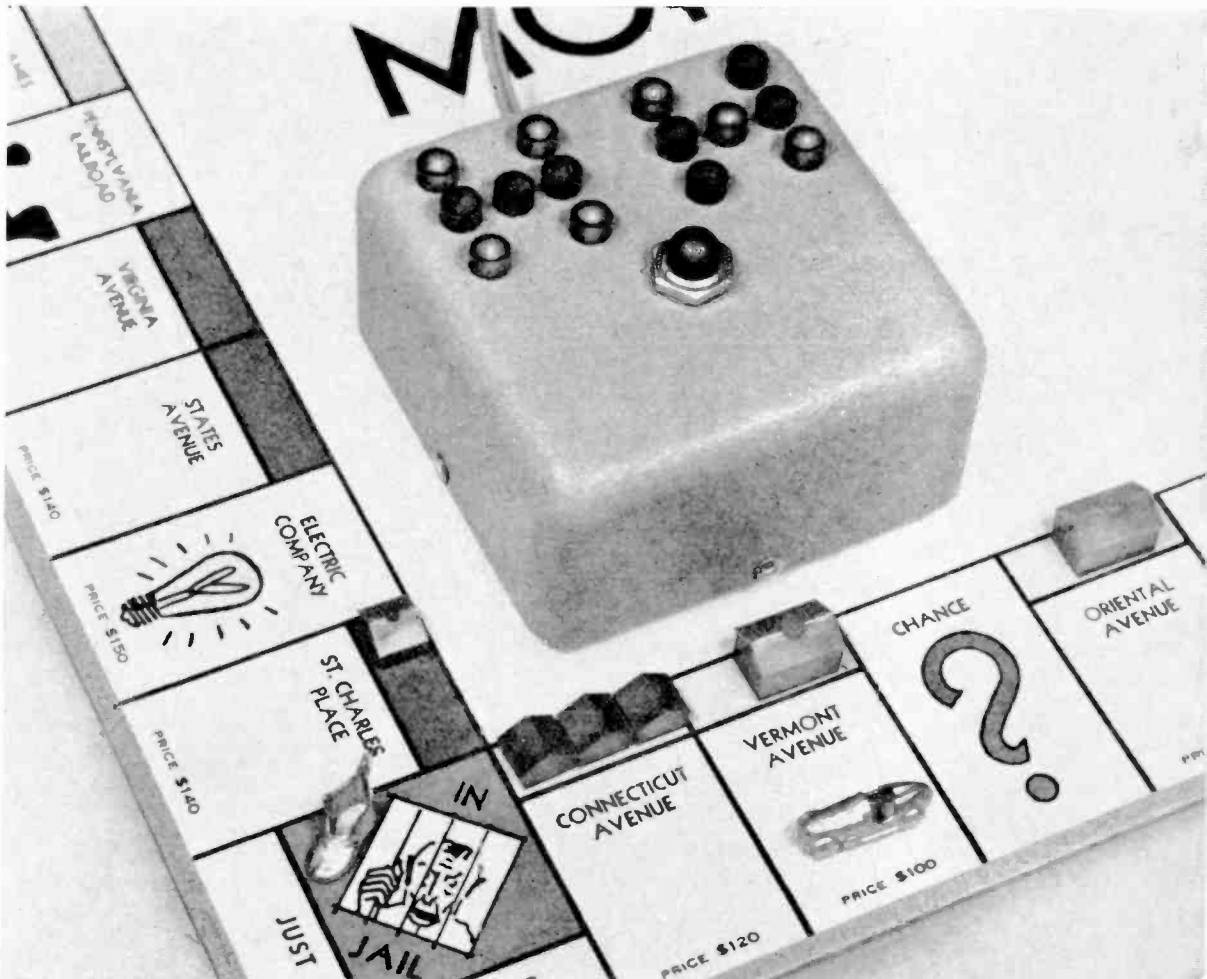


Fig. 1. When push-button switch S1 is depressed, the 3-kHz oscillator starts up. The first counter runs at this speed while simultaneously dividing by six, causing the second counter to run to 500 Hz. When S1 is released, both counters stop and the pertinent indicators light up.

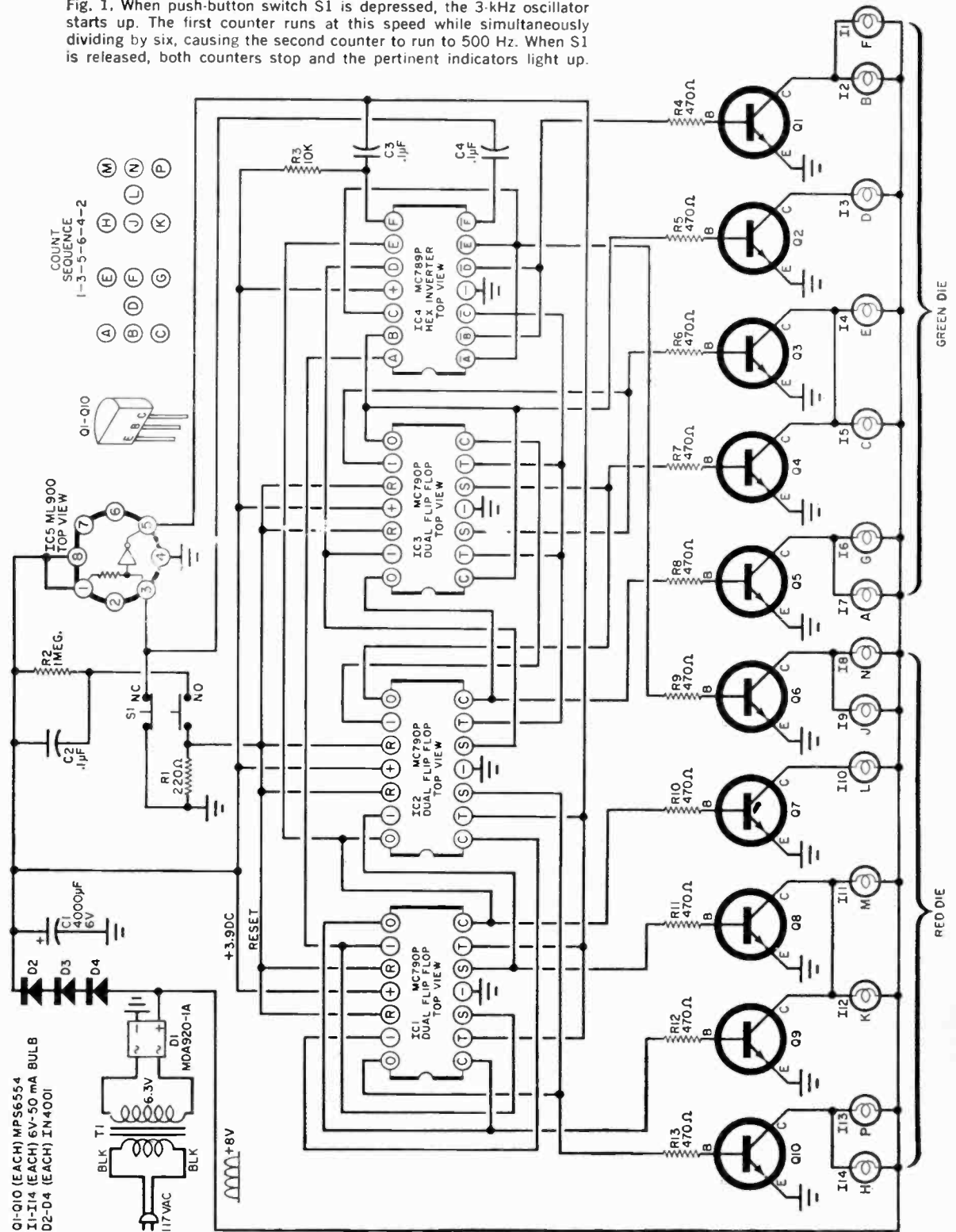
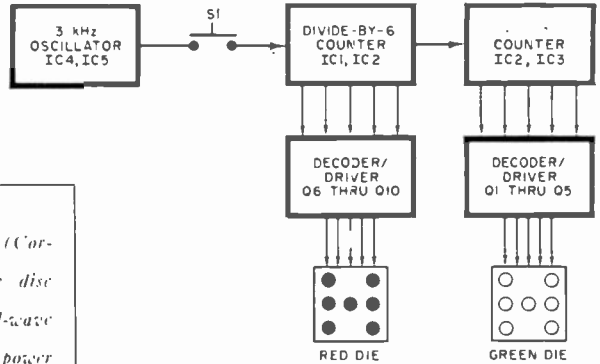




Fig. 2. Since each die is fed from a separate counter, and there is no fixed time during which the counters cycle through their stages, the final lamp indication is random, as with real dice.



### PARTS LIST

- C1—4000- $\mu$ F, 6-volt electrolytic capacitor (Cornell Dubilier BR 4000-6, or similar)  
 C2, C3, C4 0.1- $\mu$ F, 10-volt miniature disc ceramic capacitor  
 D1—MD1920 1A 1-ampere, 50-volt, full-wave bridge rectifier assembly (Motorola)  
 D2, D3, D4—1N4001 or similar silicon power diode  
 I1-I14—6.3-volt, 50-mA, pilot lamp assembly, 7 red, 7 green (Southwest Technical Products Corp. L-92, or similar)\*  
 IC1, IC2, IC3—MC7909P dual J-K flip-flop (Motorola)  
 IC4—MC789P hex inverter (Motorola)  
 IC5—uL900 buffer (Fairchild)  
 Q1-Q10—MPS6554 transistor (Motorola)  
 R1—220-ohm,  $\frac{1}{4}$ -watt carbon resistor  
 R2—1-megohm,  $\frac{1}{4}$ -watt carbon resistor  
 R3—10,000-ohm,  $\frac{1}{4}$ -watt carbon resistor  
 R4-R14—470-ohm,  $\frac{1}{4}$ -watt carbon resistor  
 S1—Two-circuit "make one, break one" push button, snap-action  
 T1—6.3-volt, 0.6-ampere miniature filament transformer (Knight 54D1416, or similar)  
 1—6 $\frac{1}{4}$ " x 3 $\frac{3}{4}$ " x 2" case and cover (Harry Davis #240, or similar)  
 1—3 $\frac{5}{8}$ " x 2 $\frac{1}{2}$ " x 1/16" printed circuit board\*  
 Misc.—line cord and strain relief, wire nuts (2), PC terminals (17), #6 x  $\frac{3}{8}$ " threaded standoffs (4), #6 x  $\frac{1}{4}$ " screws (4), insulated wire jumpers (15), wire, solder, etc.

\*The following are available from Southwest Technical Products Corp., 210 W. Rhapsody, San Antonio, Tex. 78216: etched and drilled circuit board, \$3.50; kit of 14 pilot lamp assemblies including 1 spare bulb, \$4.00; complete kit of all parts including fully punched and finished plastic case, \$30.00; postpaid in USA.

NOTE: Although a metal mounting box is shown in the photo on page 15, the construction given in this article are for the plastic box called for above.

**How It Works.** Each of the two dies consists of seven pilot lamps that are lit or not lit dependent upon the commands of an electronic counter and decoder circuit. Figure 1 shows the circuit, while the block diagram in Fig. 2 illustrates basic operation.

There are two electronic counters, each of which has six possible states, just like the six sides of a die. Whenever the control push button (S1) is depressed, a 3-kHz oscillator is connected in the circuit, and both counters rapidly run through all of their states, the first at a 3-kHz rate; because of the divide-by-six

characteristic inherent in the first counter, the second operates at a 500-Hz rate. Since the push button will be held down a good fraction of a second, each counter runs through all of its states many hundreds of times.

When the push button is released, the counters stop in some random state—truly random, as the operator has no control whatsoever over which number is up on either counter when he releases the button. Since each die cycles at different rates and since the dwell time on any one "side" is identical, true dice odds result.

The six counter states are decoded to produce the familiar die combinations, with the center lamp lit only for a "one," the outside six for a "boxcar," etc. Although seven lamps are used, only those combinations of lit bulbs corresponding to the die patterns are permitted to light.

Each counter requires only four decoding circuits. The first decides "even," or "odd." If the count is "odd," the center bulb lights. The next decoder decides "not one" which lights two diagonally opposite bulbs *except* during a "one." A third decoder decides "four," "five," or "six" and lights the remaining two diagonally opposite bulbs on these counts. The final decoder selects "six" and lights the two remaining bulbs on this count. A bit of reflection will show that these four decodings automatically light the proper number of bulbs in the proper pattern for each die position.

A dual power supply and a special pulse circuit complete the unit. The latter feature resets the counter the instant the push button is depressed, guaranteeing that both counters always start off properly.

Fig. 3. Actual-size layout of printed board. Be careful if you make your own as wiring errors will be hard to find. A commercial board is available (see Parts List).

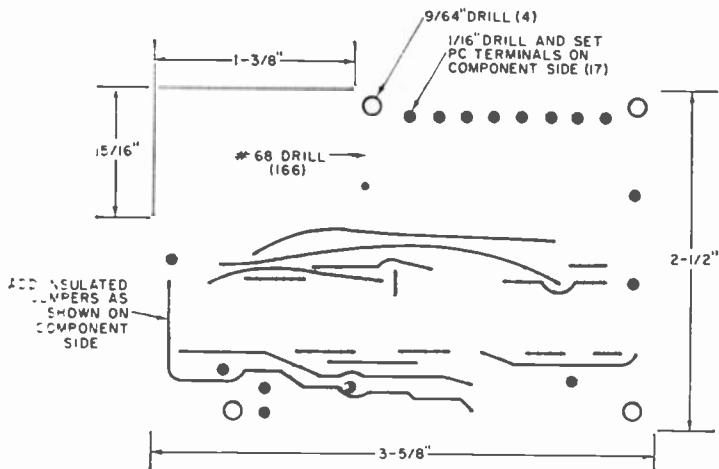
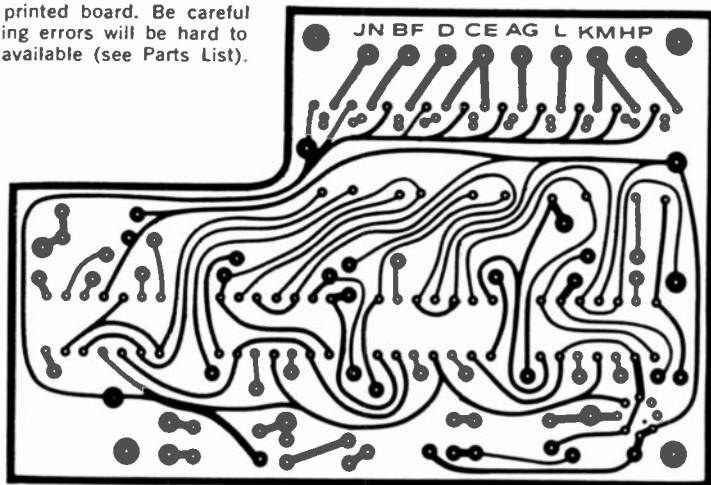


Fig. 4. Before installing components on the board, insert the 16 insulated jumpers as shown here. Observe caution when installing jumpers as errors can be troublesome.

**Circuit Details.** Integrated circuit *IC5* and part of *IC4* form a 3-kHz multi-vibrator that runs only when *SI*, a 2-circuit, snap-action push button, is depressed. This 3-kHz signal is routed to the two counters consisting of *IC1*, *IC2*, and *IC3*. Incidentally, the total cost of all the integrated circuits is slightly under \$8.00.

High-gain transistors (*Q1* through *Q10*) are used to amplify the low-level logic signals and light one or two bulbs each. Resistors *R4* through *R13* limit the base currents and prevent the bulbs and transistors from excessively loading the counters.

Fig. 5. Component layout and wiring interconnections. Note that *IC1-IC4* are identified by notches at one end while *IC5* has one flat side. Lettered bulbs are arranged as per Fig. 1.

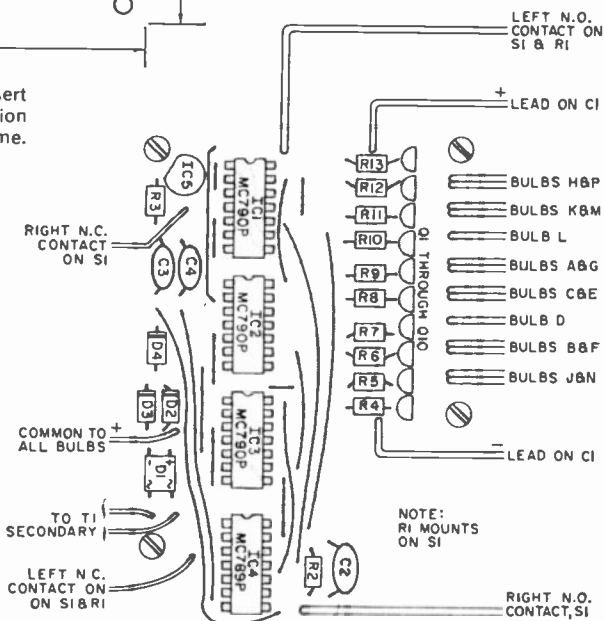


Fig. 6 (right). Finished layout with parts called out in Parts List. Other arrangements can be used if desired.

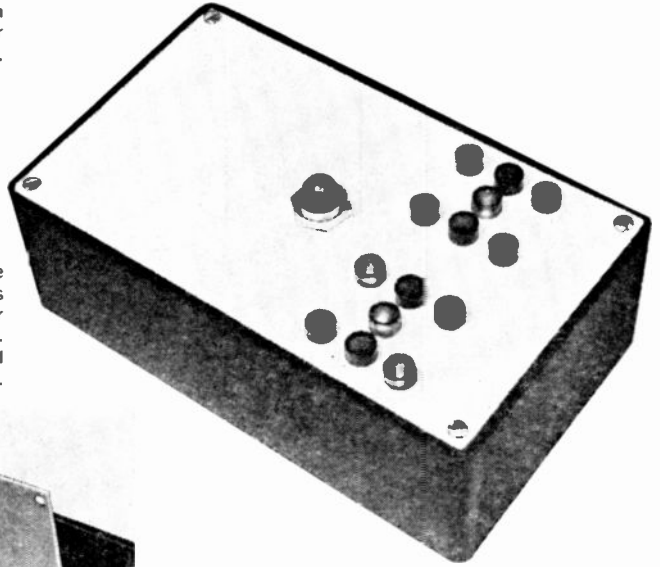
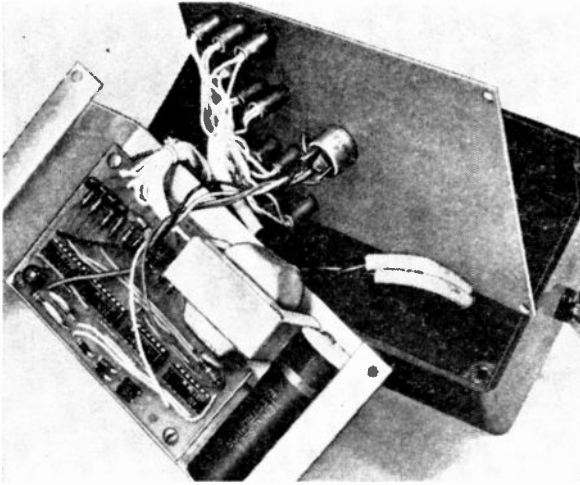


Fig. 7 (below). Internal view of the finished device. Note that R1 is mounted on S1 on the front cover plate along with indicator lamps. Construction details of the U-shaped frame, and the cover, are on page 20.



The bulbs consist of 6-volt, 50-mA units, available as complete, matched red or green panel lamp assemblies from the source listed. Use of higher-current bulbs is not recommended due to the requirement of a larger power transformer and the necessity of using power transistors with exceptionally high gain to obtain any reasonable brilliance and uniformity. Even the transistors selected for the 50-mA bulbs must have a *beta* well over 100, specified at a 100-mA current level. Bear this in mind if you make any substitutions. The particular bulbs and power levels selected are more than bright enough for use under normal viewing conditions, and the actual bulb current is purposely held low to gain a long bulb life.

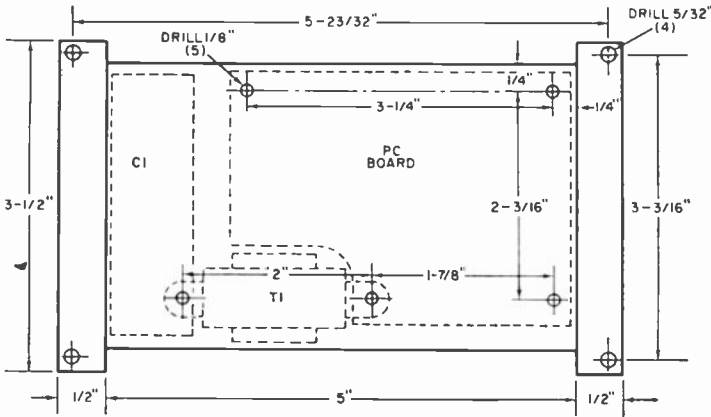
The dual power supply consists of *T1* and diodes *D1* through *D4*. The bulbs and transistors run off the unfiltered, full-wave rectified low-voltage from *D1*. Di-

odes *D2*, *D3*, and *D4* form a dynamic regulator that drops this voltage and feeds it to filter capacitor *C1* and then to the oscillator and counter circuits. The normal level across *C1* is 3.9 volts; this will vary a tenth of a volt or so with the different die combinations. The value of *C1* selected is the smallest one that will allow the circuit to operate properly—do not substitute for *C1* unless you *increase* its value.

Switch *S1* is a “make one, break one” push button. A d.p.d.t. snap-action type can be substituted simply by not using the extra contacts. Network *R1*, *R2*, and *C2* generates a brief reset pulse each time the push button is initially depressed.

**Construction.** A printed circuit board is an absolute must for this circuit, owing to the large number of connections and the mounting techniques required for the integrated circuits. You can buy the board already etched and drilled commercially (see Parts List). If you prefer, you can lay out, etch, and drill your own, by following the details in Fig. 3. Be exceptionally careful with your layout if you make your own, for a wiring error in the counter portion of the circuit is quite difficult to find.

Sixteen wire jumpers are required for the PC board. These are formed of insulated wire and mounted on the *compo-*



Mechanical details of the U-shaped frame. This frame supports the PC board, capacitor C1, and transformer T1. Note that the PC board uses 1/4-inch standoffs. The frame is designed to fit the plastic box specified.

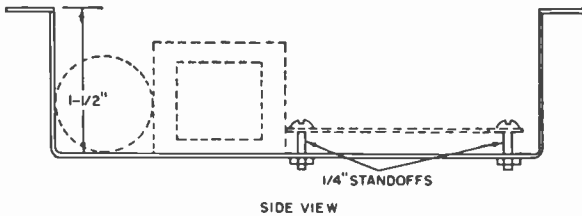


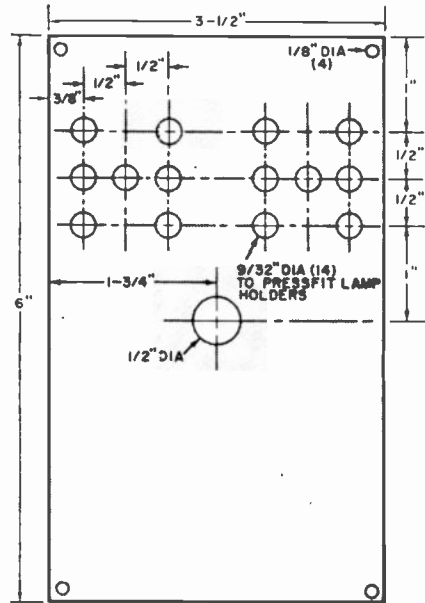
Fig. 8. Drilling details of the front cover. The lamp holes are drilled so that the lamps can be press-fitted.

ment side of the circuit board, before any other parts are inserted. Just follow the layout guide in Fig. 4. Be sure to connect the jumpers *exactly* as indicated.

All the circuit parts except T1, C1, R1, S1, and the bulb mount on the board. Use a very small iron and fine solder. Double-check all connections with a magnifying glass and remove all excess solder flux.

Component layout and wiring interconnections are shown in Fig. 5. Note that the integrated circuits may only be connected in one manner, and that they are identified by a notch on one end of the flat packs, and a flat beside lead  $\pm 8$  on IC5. (All IC's are shown *top view* in the schematic.) Each bulb has its die position identified by the code letters shown in the schematic. Use two contrasting colors of pilot lamp assemblies, one for each die.

The electronic dice may be built in virtually any small enclosure. You can use a deep-drawn aluminum box, a conventional chassis, or a plastic instrument case. Mounting details are shown in the photos (Figs. 6 and 7). The U-shaped frame supports the circuit board, transformer, and filter capacitor. The PC board should be spaced slightly above the bottom of



the metal support to avoid any short circuits. The entire assembly can then be mounted in its case.

Details of the lamp assembly drilling on the case cover are shown in Fig. 8. The cover supports the 14 lamp assemblies grouped according to the color and die patterns as well as S1 and R1 (mounted on S1).



## BUILD THE "BEACHCOMBER"

By DANIEL MEYER

THE ALTER EGO OF OUR  
DEEP SEARCH "IC-67" LOCATOR\*  
WILL FIND THOSE SMALL  
METALLIC OBJECTS AND COINS

**P**ROBABLY EVERY one of us has at one time or another had the urge to go searching for buried treasure. The "treasure" could be really valuable—a pot of gold coins buried during the Civil War, or a platinum locket lost on the beach—or it could be just a few cents dropped in some weeds or an old coffee can lid. A "treasure finder" or metal locator tells you where to dig.

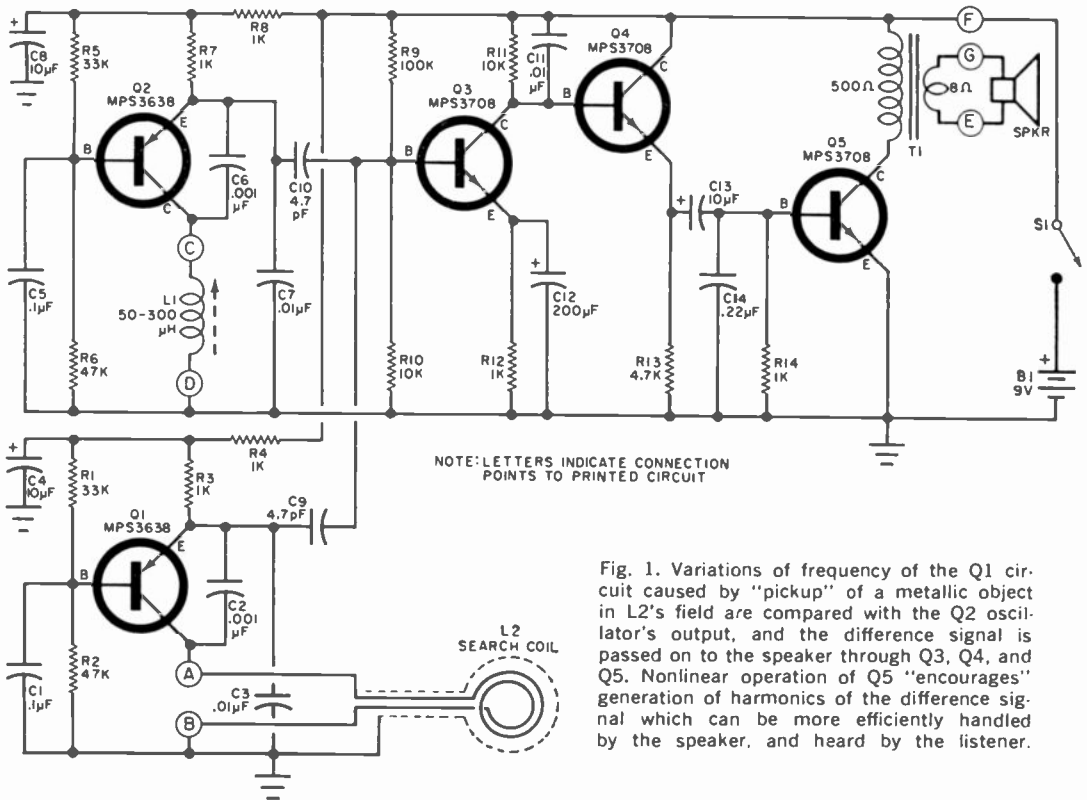
Metal detectors come in two basic types. The one best suited to your needs will depend on just what you are searching for. The bulkier and more expensive

transmit-receive detectors can find large objects at greater depths, but do not detect small objects easily. A simple single-loop beat-frequency locator, like the "Beachcomber," will detect objects at a depth of only about 2 feet maximum (depending on size) but can readily find small objects only 1 or 2 inches in diameter.

The Beachcomber can be a lot of fun to have along on a trip to the coast, or to an old battlefield to search for relics. It is lightweight, and operates 6 to 8 hours on an ordinary transistor radio battery. Its speaker is built in, so there are no headsets or wires to get in the way or get lost. And it only costs about \$15 to build.

**How It Works.** The simple circuit (Fig. 1) consists of two r.f. oscillators—operating around 400 to 500 kHz, a detector, and an audio amplifier. The oscillators are identical, except for the coils used to tune them. One coil, *L1*, is tuned to make this oscillator's frequency slightly

\*See 1968 Winter Edition of this HANDBOOK.



NOTE: LETTERS INDICATE CONNECTION POINTS TO PRINTED CIRCUIT

Fig. 1. Variations of frequency of the Q1 circuit caused by "pickup" of a metallic object in L2's field are compared with the Q2 oscillator's output, and the difference signal is passed on to the speaker through Q3, Q4, and Q5. Nonlinear operation of Q5 "encourages" generation of harmonics of the difference signal which can be more efficiently handled by the speaker, and heard by the listener.

higher or lower than that of the search coil oscillator. The two signals are combined in detector stage Q3, whose output is the audible difference between the two frequencies. This signal is fed to emitter follower Q4 and output stage Q5, and finally to the speaker.

The search coil oscillator frequency changes slightly whenever the conductance of the material in the field of the loop changes. This means that if the coil passes over a metal object, the oscillator frequency will change slightly, and the pitch of the audio beat note you hear from your speaker will also change. It is easier to hear a small frequency change in a low-pitched sound than an equal change in a higher frequency tone.

To get the best results from the Beachcomber, set the oscillators as near the same frequency as possible. Both oscillators must be very stable. Good sturdy construction with no loose parts is a must. The circuit must also be so laid out as to reduce coupling between the two oscillators to the minimum. Other-

### PARTS LIST

- B1—9-volt battery
- C1, C5—0.1- $\mu$ F, low-voltage disc ceramic capacitor
- C2, C6—0.001- $\mu$ F polystyrene capacitor
- C3, C7—0.01- $\mu$ F polystyrene capacitor
- C4, C8, C13—10- $\mu$ F, 15-volt electrolytic capacitor
- C9, C10—4.7-pF ceramic disc capacitor
- C11—0.01- $\mu$ F, low-voltage disc ceramic capacitor
- C12—200- $\mu$ F, 6-volt electrolytic capacitor
- C14—0.22- $\mu$ F low-voltage disc ceramic capacitor
- L1—50-300- $\mu$ H variable inductor (Thordarson WC-11, J. W. Miller  $\approx$  6196, or similar)
- L2—Search coil—see text
- Q1, Q2—MPS3638 transistor (Motorola)
- Q3, Q4, Q5—MPS3708 transistor (Motorola)
- R1, R5—33,000 ohms
- R2, R6—47,000 ohms
- R3, R4, R7, R8, R12, R14—All —1000 ohms
- R9—100,000 ohms
- R10, R11—10,000 ohms
- R13—4700 ohms
- S1—S.p.S.T. slide switch
- T1—Transistor output transformer: primary, 500 ohms CT (do not use CT); secondary, 8 ohms, 150 mW.
- Misc.—Miniature speaker, chassis box, battery clip, enameled wire, spacers, solder, etc.

NOTE: Printed circuit board for this project is available for \$2.50 from Southwest Technical Products, 219 West Rhapsody, San Antonio, Texas 78216. A complete kit (excluding the rod) is also available for \$15 postpaid.

wise, the oscillators will "pull"—suddenly lock together every time the beat frequency is brought down to a low pitch. That is why both oscillators are decoupled from the battery supply and from each other (through  $R4-C4$  and  $R8-C8$ ) and why such small value capacitors are used for  $C9$  and  $C10$ .

The output stage is purposely designed to produce "distortion," so that the low-frequency beat notes can be heard from the small speaker. If the audio circuit were designed for linear operation and little distortion, the speaker would produce little or no output below 150 to 200 hertz. In this circuit the audio output stage is not biased "on" at all. When it is driven with an audio signal from emitter follower  $Q4$ , transistor  $Q5$  conducts and produces an output on each positive half cycle. The signal to the speaker is therefore a series of pulses at the frequency of the beat signal. Since the pulses contain many harmonics, they can be heard down to a few hertz.

**Construction.** The electronic portion of the metal detector is easy to assemble, and there is no chance of coupling problems or shifting parts if the printed circuit board construction shown is used. The board (Fig. 2) serves as a template to locate the holes for  $L1$ , the mounting spacers, and the speaker.

Cut a  $\frac{1}{16}$ "-diameter hole for  $L1$  and another of the correct diameter for your

speaker. Then mount the small parts by simply inserting them in the positions indicated by the parts numbers on the top side of the board, turning the board over, and soldering them in place.

File the switch hole in the cabinet to fit the type of switch used. Mount the switch, speaker, battery clip, and  $L1$  as shown in the photograph (Fig. 3). Wire the switch and battery clip as shown. The lead from the positive terminal of the battery goes to one switch contact, and a short lead should be soldered to the other contact—to go to point  $F$  on the board. A doughnut cut from plastic foam is placed around the rear of the speaker; the board compresses the foam when it is mounted, and thus holds the speaker snugly.

Now connect the battery and speaker wires to the underside of the board at the points indicated on the schematic diagram. Mount the completed circuit

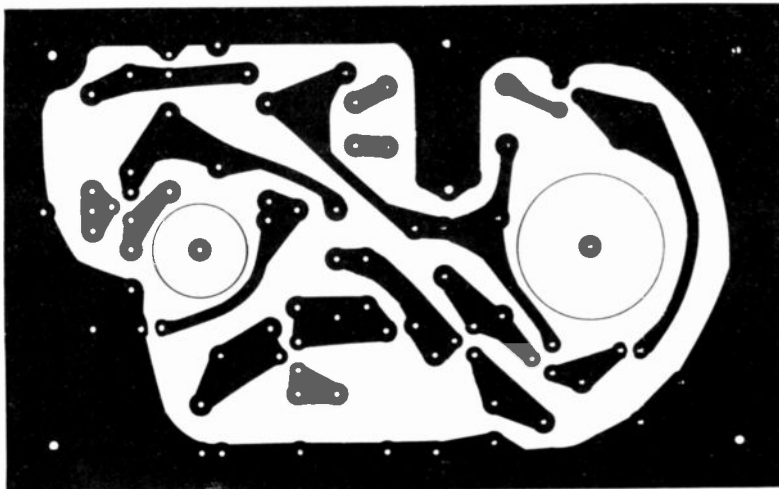
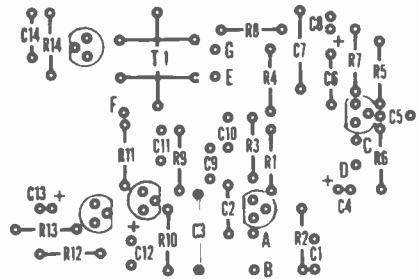


Fig. 2. Actual size drawing of foil side of printed circuit (left) will help you make your own board. Parts are installed on the plain side of the board as shown above. Figure 4 shows parts assembled on board.

Fig. 3. Part of the speaker and coil L1 pass through the circuit board and must be carefully positioned to fit properly. The speaker is not bolted and can be shifted.

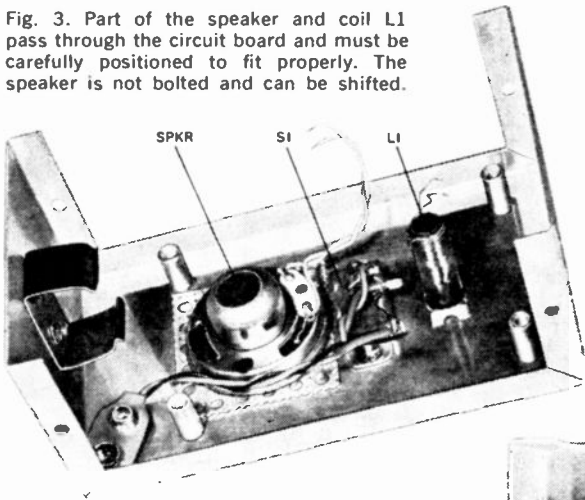
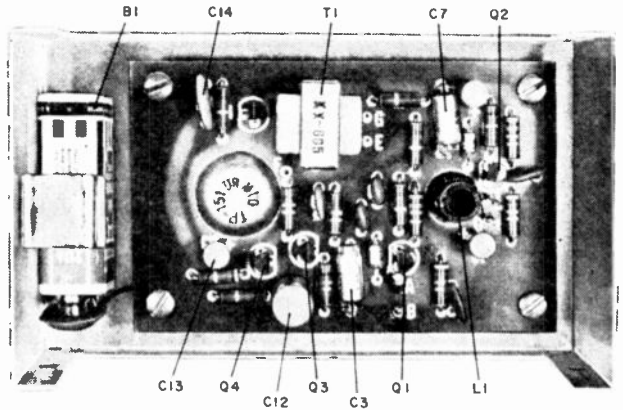


Fig. 5. Clean, firm assembly of internal as well as external components and other hardware means clean operation. Any variations due to movement of parts can cause false readings.



board (Fig. 5) and connect *L1* to the eyelets at points *C* and *D* on top of the board.

**The Search Loop.** This important part of the locator can be made in several ways. Of the two presented here, the copper tubing search coil shown in Fig. 6 is more rugged, but the plastic tubing loop will work well and is much easier to build.

To make the copper coil, obtain a piece of  $\frac{1}{4}$ " soft copper tubing 42 inches long and bend it into as smooth a circle as possible. (Be sure it is straight when you buy it—and bend it around a cylindrical object a little less than a foot in diameter.) Leave a quarter-inch gap between the ends. Drill a  $\frac{1}{8}$ "-hole on the inside of the circle opposite the gap.

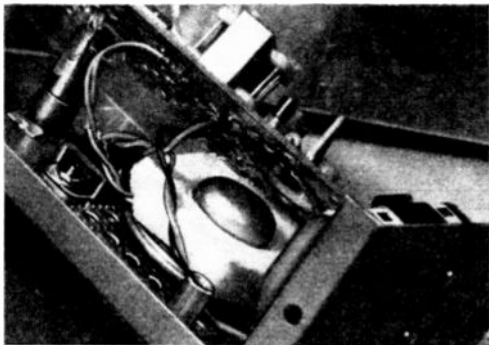


Fig. 4. A "doughnut" of foam rubber or plastic placed around the speaker holds it securely in its correct position when circuit board is installed.

Then take a hacksaw and split the tubing around its outside wall. (Cut through the outside wall only, not completely through the tube.) The edges of the cut can be smoothed with a small file. Solder about 6 inches of insulated hookup wire to one end of a 50' length of No. 24 enameled magnet wire, and slip a piece of insulating tubing over the connection. Thread the insulated wire through the  $\frac{1}{8}$ "-hole in the tubing from the outside (through the slot) and leave about an inch or two of insulated wire inside the split loop.

Now wind 14 turns of wire inside the copper tube through the saw slot, being careful not to pull the  $\frac{1}{4}$ " end gap together. Cut the magnet wire and solder another piece of hookup wire to that end. Insulate the connection and thread the hookup wire through the hole in the tubing. Finally, paint the coil of wire inside the copper shield with coil dope or white glue.

You can make the plastic loop (Fig. 6) in much the same way. Slip a 2" length of  $\frac{3}{8}$ " plastic tubing over the ends of the



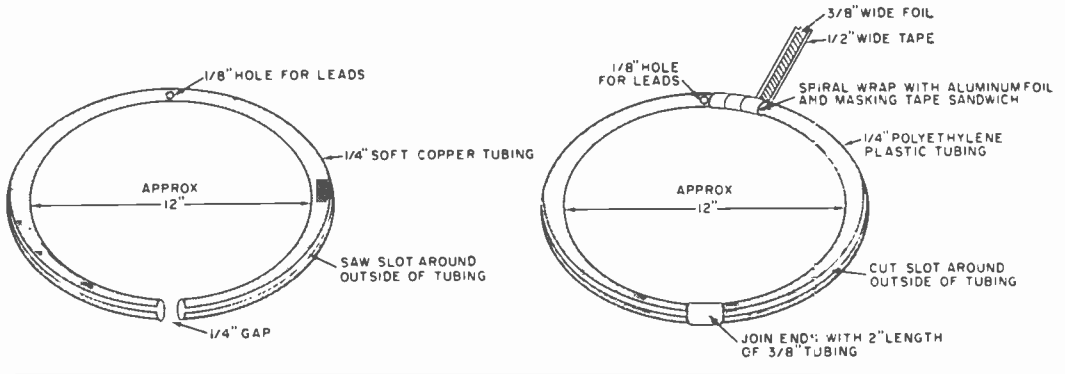


Fig. 6. Loop housing made of copper is shown above, and plastic tubing at right, above. If plastic is used, a metal outer covering can be made from aluminum foil. In either case, there must be a gap.

$\frac{1}{4}$ " plastic tubing to hold the ends in place. Then cut or drill a hole on the inside of the loop opposite the gap, and split the outside of the loop with a knife. Cut out a  $\frac{1}{16}$ " strip all the way around the outside.

Make up the magnet wire as described for the copper loop and wind the search loop with 14 turns. Cement the turns together. Since the plastic loop does not shield the coil—as does the copper loop—it must be shielded before mounting.

You shield the plastic loop by cutting a piece about  $\frac{3}{8}$ " wide from the end of a roll of aluminum foil. Stick the foil to a piece of  $\frac{1}{2}$ " plastic masking tape, leaving a border on each side. Then strip the insulation off of about half of a 6" piece of *stranded* hookup wire, and place the bare portion between the foil and

tape at the beginning of the spiral roll.

Now, starting at the point where the connections come out of the loop, spiral-wrap the tape-foil sandwich around the coil form. When you have gone all the way round, tear the foil off and go round

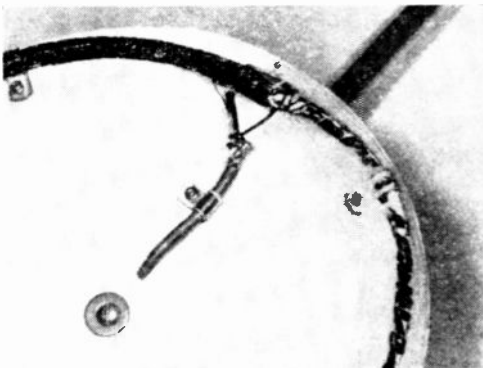
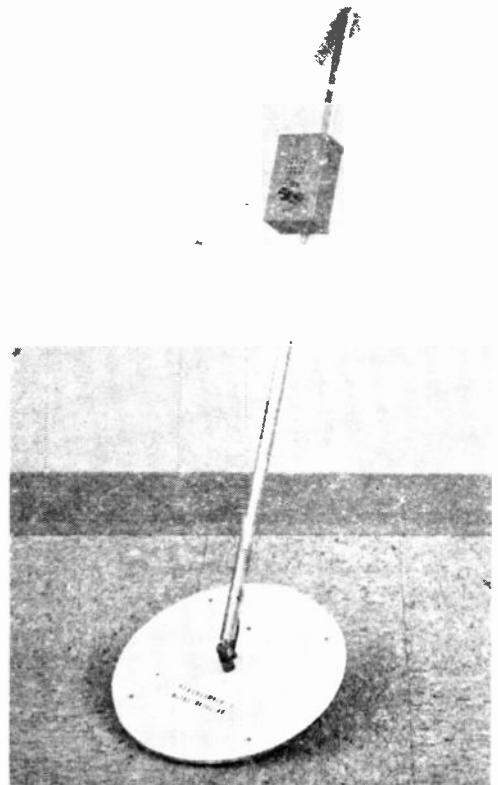
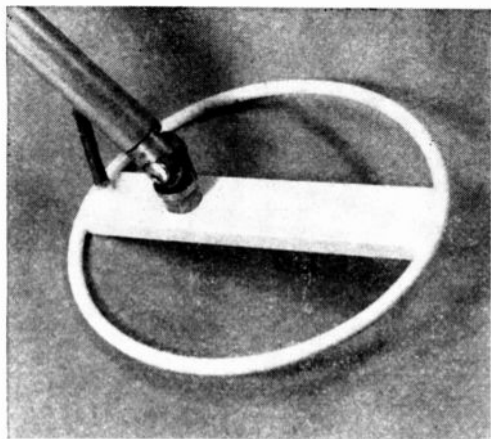


Fig. 7. Plastic-covered loop must be securely positioned. Use plastic cable clamps and putty or cement to hold the entire loop on the plywood board.



Completed "Beachcomber" is ready to "look for" buried treasure. Adjust loop so it is parallel to the ground while you hold unit at comfortable angle.



The copper tubing loop assembly is rigid enough to permit the use of a small wood brace for assembly. Some weight reduction can be gained in this manner.

again with the masking tape only, to hold everything firmly in place. *Note that the foil must not form a continuous loop.* Do not let the end of the foil—where you stop—touch the beginning of the winding.

The finished loop is mounted with plastic cable clamps to a  $\frac{1}{4}$ " plywood base (see Fig. 7). Use at least four clamps. The plastic loop must be potted in place on the plywood base with water putty to make sure it won't move or bend.

**Finishing Touches.** The handle on the Beachcomber can be any convenient length of  $\frac{3}{4}$ " aluminum tubing, and it can be fastened to the plywood base with a universal elbow made for  $\frac{3}{4}$ " tubing. (These items were obtained by the author off a "do-it-yourself" rack in a local hardware store. If you have trouble finding them, the handle can be made of wood. Even an old hoe handle will do.)

Connect the two ends of the loop to the two wires and the shield to the shield braid of a two-conductor shielded cable long enough to run up the handle to the control box. Screw the bottom of the box to the handle and bring the cable through a hole in the bottom of the box to a three-lug terminal strip, which can be mounted with one of the screws that hold the box to the handle.

Connect circuit board points *A* and *B* to the loop wires at the terminal strip with about 3 to 4 inches of hookup wire twisted together. Clip in the battery, put the box together, and you're ready to go.

**Using the Detector.** The Beachcomber is simple to use and—with a little practice—you should be able to find buried metal easily. The first thing to do is to set the tuning control to produce a beat note. Since the adjustment range of the coil is very wide, you should be able to get a beat note even if your search coil is not identical to the one shown.

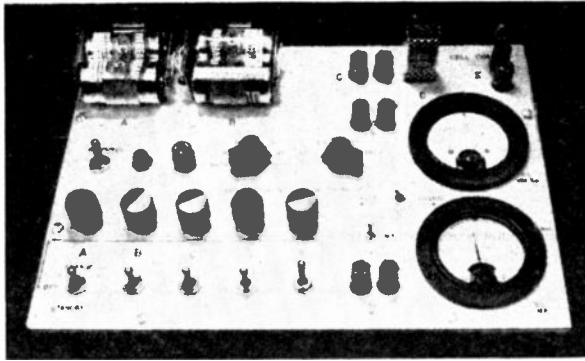
If you are not sure whether the circuit is operating, hold a transistor radio near the detector while you turn the tuning control. You should be able to get a strong signal near the low end of the broadcast band somewhere in the tuning control's range.

Place the search loop flat on the ground and adjust the tuning to give a low beat note. Raising the loop 4 to 6 inches above ground should not change the beat note very much. To search, you simply hold the coil near the ground and swing it from side to side, parallel to the ground. If you hear a change in the pitch of the beat note, move the coil slowly around the area to get an idea of the exact location and size of what you have found.

The change in beat note will depend on the size of the buried object and its area as seen from straight above. Thus, while you can easily find a coffee can lid buried flat, you might miss it if it were buried on edge.

**Operating Notes.** Do not attempt to use the Beachcomber with the two oscillators operating at zero beat (the same frequency). This will reduce sensitivity by about half, due to the slight locking action caused by stray coupling. If you note any sudden changes in pitch when the search coil bumps the ground or vegetation, check the wiring and loop mounting for loose parts. Any movement of parts or wire, inside or outside, on or near the search coil can cause changes in pitch. The better the construction, the more reliable the indications.

If you are primarily interested in smaller objects, coins—for instance, you can make the detector more sensitive by using a smaller-diameter search coil. A 4" loop will work nicely. The only change necessary is to add two turns to the search loop coil. Keep in mind that the smaller loop will not penetrate as deeply as a larger one.



# BUILD A COMBINATION BATTERY CHARGER AND TESTER

By HARLEY H. STOVER

YOU CAN CONTROL AND MONITOR  
CHARGING CURRENT AND VOLTAGE,  
AND TEST BATTERIES UNDER  
ACTUAL WORKING CONDITIONS

**W**HY SHOULD you spend the time and money needed to build a battery charger and tester when you can buy a charger for less than \$5? Well, many of the low-priced chargers are brute-force types, having a single diode rectifier in series with the 117-volt power line and the dry cells. In addition to the possibility of getting no safe power line isolation on some of these chargers, you cannot control and monitor the charge cycle or determine beforehand, without the aid of a separate testing device or meter, if your dry cells will take a charge. With the Combination Battery Charger and

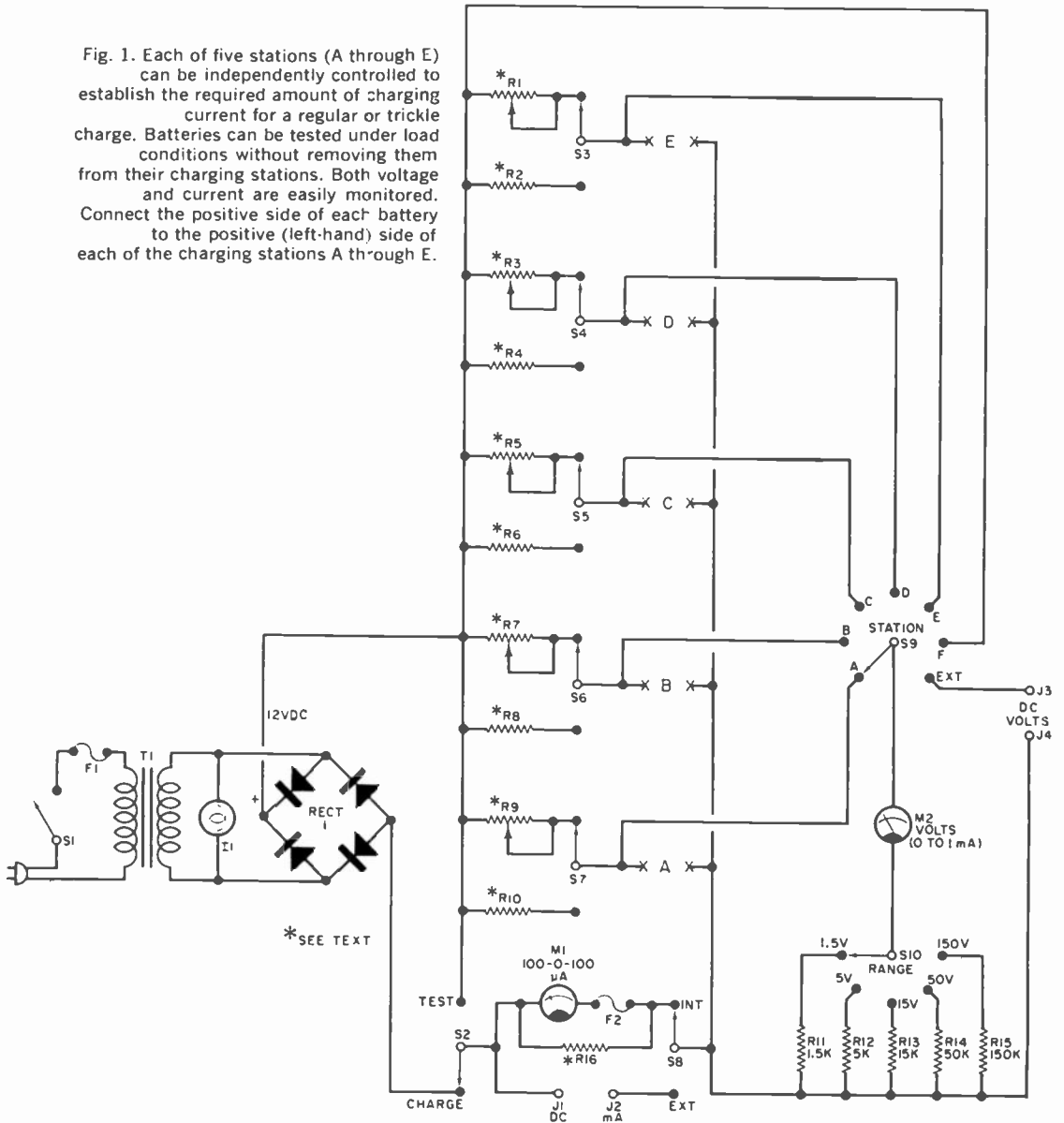
Tester, you can pretty much predict whether or not a particular cell will take a charge, as well as get an indication of the cell's service capability after you have charged it. It is not uncommon to find a dry cell (usually a low-priced 9-volt transistor type) that will, on its first discharge cycle, develop such high internal resistance that it won't take a charge.

A major advantage of the Combination Battery Charger and Tester is its ability to accurately recharge a battery on a current/time or ampere/hour basis. This is particularly desirable when you're us-

ing the more expensive cells and you don't want to risk damage from over-charging. With this charger, you have manual control and monitoring facilities of the charging current, as well as an ability to measure battery voltage under both varying load and charging conditions.

The test feature lets you observe the output voltage vs. load current characteristics. A zero-center milliammeter and the same variable load used to regulate the charging current is used to establish desired loading conditions even while the voltage is being observed on another meter built into the unit.

Fig. 1. Each of five stations (A through E) can be independently controlled to establish the required amount of charging current for a regular or trickle charge. Batteries can be tested under load conditions without removing them from their charging stations. Both voltage and current are easily monitored. Connect the positive side of each battery to the positive (left-hand) side of each of the charging stations A through E.



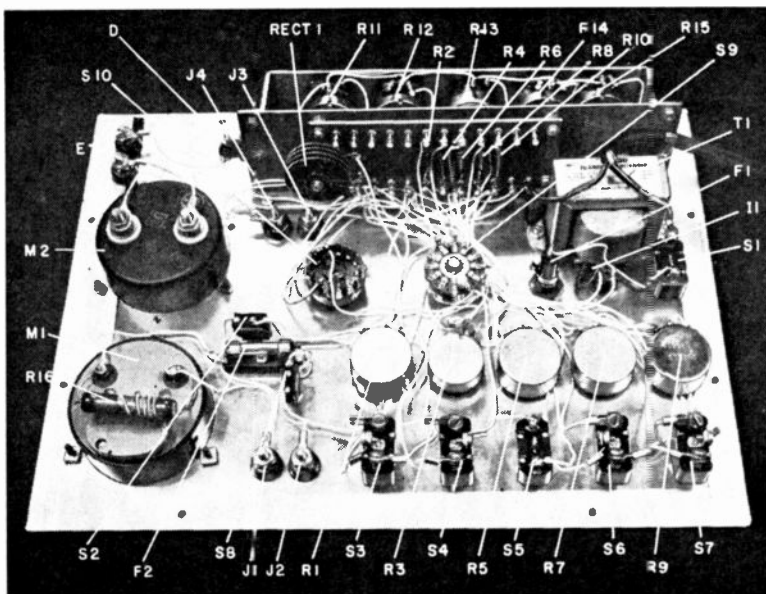


Fig. 2. The entire works is mounted on the front panel. Construction is not as complicated as it looks, nor is parts layout critical. Polarity of the rectifier stack should be observed for proper connections. It is a good idea to complete the wiring and assembly of all components before you mount the meters.

You can process all types of dry cells—ranging in size from the small hearing-aid to the large flashlight batteries. Dif-

ferent sizes of batteries and the variety of terminal configurations found on them present no problems. There are five different charging stations on the Combination Battery Charger and Tester that can be individually used and independently controlled.

### PARTS LIST

*F1*— $\frac{1}{8}$ -ampere fuse  
*F2*— $\frac{1}{10}$ -ampere fuse, fast-acting  
*I1*—12-volt pilot light  
*J1, J2, J3, J4*—Jack (5-way binding post)  
*M1*—100-0-100  $\mu$ A meter—see text  
*M2*—0-1 mA meter—see text  
*R1, R3, R5, R7, R9*—Wire-wound potentiometer  
*R2, R4, R6, R8, R10*—Trickle-charge resistor—see text  
*R11*—1500 ohms  
*R12*—5000 ohms  
*R13*—15,000 ohms  
*R14*—50,000 ohms  
*R15*—150,000 ohms  
*R16*—Shunt—see text  
*RECT 1*—Full-wave 300-mA bridge rectifier  
*S1*—S.p.s.t. switch  
*S2, S8*—S.p.d.t. switch  
*S3, S4, S5, S6, S7*—S.p.d.t. center-off switch  
*S9*—S.p., 7-position rotary switch  
*S10*—S.p., 5-position rotary switch  
*T1*—Filament transformer: primary, 117 volts, secondary, 12.6 volts  
 1—10" x 14" x 2 $\frac{1}{2}$ " chassis and cover  
 Misc.—Battery holders (4), binding posts (4), knobs (7), pilot light holder and bezel, fuse holders (2), wire, solder, machine screws, nuts, etc.

**How It Works.** A 12-volt filament type power transformer and a full-wave bridge rectifier provide power line isolation and a low d.c. voltage for charging, as shown in Fig. 1. The low d.c. voltage permits the use of low-power potentiometers and resistors.

The various charging stations (A to E) can be made to accept batteries of any size or shape within the capabilities of the power supply. In this project, Stations A and B are set up to handle "D" size cells; Station C can accommodate a pair of leads to connect to any battery; Station D takes a standard 9-volt transistor battery; and Station E is another general-purpose charging position outfitted with a special fixture to handle hearing-aid batteries.

Each charge station has a three-posi-

tion single pole switch ( $S3$  through  $S7$ ) which provides a charging position, a standby or trickle charge position, and a center-off position. The trickle-charge resistors ( $R2$ ,  $R4$ ,  $R6$ ,  $R8$ , and  $R10$ ) are selected to allow a few milliamps of charge current for long-term battery storage on the charger. Potentiometers  $R1$ ,  $R3$ ,  $R5$ ,  $R7$  and  $R9$  permit current adjustment for charging and load adjustment for testing.

Current measurements are made with microammeter  $M1$  shunted by  $R16$  to read out 100 milliamperes full scale on either side of 0. Switch  $S8$  and jacks  $J1$  and  $J2$  provide for the insertion of an external meter for heavier current work or for meter calibration purposes.

Voltage readings are obtained from the multirange voltmeter circuit. A set of jacks ( $J3$  and  $J4$ ) lets you use  $M2$  as a general-purpose d.c. voltmeter. You can, with the use of these meters, simultaneously determine current drain of battery-operated devices and actual operating voltage. Station selector switch  $S9$  "throws" the voltmeter circuit across any one station at a time. Range switch  $S10$  lets you go from 150 volts full scale down to 1.5 volts full scale, in 5 ranges, in a conventional manner.

**Construction.** A standard 10" x 14" x 2½" chassis is used as a cabinet, and the entire unit is mounted on the front panel as shown in Fig. 2. Panel lettering can

be made from 3M Scotch-Cal photo sensitive decals and pressed into place (they have their own adhesive backing) after all punching and drilling is completed.

There are many types of battery holders available commercially. However, for the 9-volt transistor battery, don't overlook the idea of removing the terminal board on a used battery and cementing it (with epoxy) to the panel, for Station  $D$ .

A large ceramic resistor can be used as a form to wind your own meter shunt ( $R16$ ). The size of the shunt depends upon the sensitivity of your ammeter. You can eliminate the shunt if the meter is already designed to operate within the desired range.

To avoid calculating and measuring a home-brew shunt, merely insert a VOM into  $J1$  and  $J2$ , set it on the 100-mA range, and add or take away turns of wire on the shunt until  $M1$  reads the same as the VOM. Be careful in the beginning not to overload  $M1$ . Start with about three turns of No. 22 AWG hookup wire. If  $M1$  reads high, remove some wire or use a heavier gauge wire; conversely, if it reads low, add some wire. As you approach the proper calibration point, adjust the current through the meter to allow you to make the final shunt adjustment at a full-scale reading.

It is also a simple matter to build the voltmeter circuit. The resistance values  
(Continued on page 144)

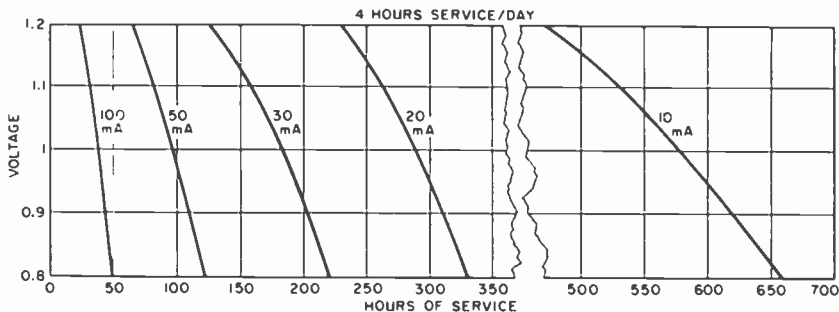
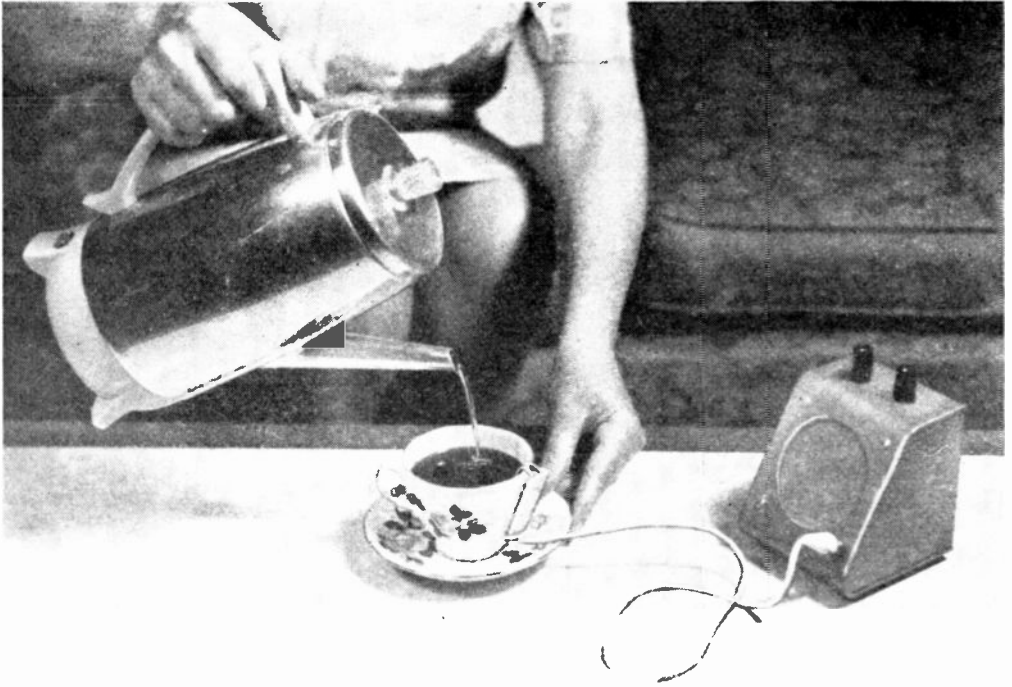


Fig. 3. Graph shows the approximate number of hours of use that can be expected from a certain 1.5-volt cell if the cell is used 4 hours per day. Battery life depends upon many factors, including temperature, current drain, and end voltage. Note that more hours of life can be expected when the current drain is small. This is true for ampere hours also. At the 0.8-volt level, a 100-mA load accounts for about 5 ampere hours. Compare the latter figure with the 10-mA load's approximate 6.6-ampere hour work capability.



## LIQUID LEVEL INDICATOR FOR THE BLIND

ELECTRONIC DEVICE LETS BLIND PEOPLE  
POUR COFFEE, SOUPS, AND OTHER HOT  
OR COLD LIQUIDS—WITH CONFIDENCE

**W**HEN YOU POUR steaming liquids into a cup or bowl, you know when to stop—unless you happen to live in the perpetual darkness of the blind. A continuity checker, rigged up with a suitable liquid-sensing probe which gives an audible signal when the cup is full enough, solves the problem admirably.

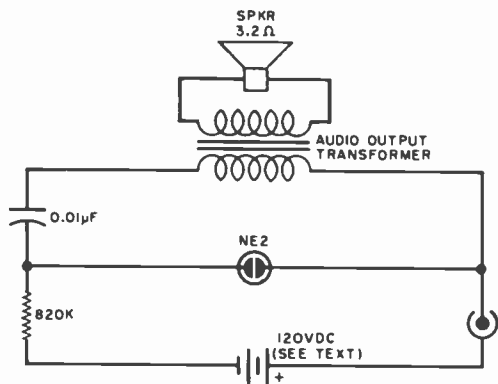
The simple neon lamp relaxation oscillator circuit presented here was devised by the author and has been used with much success by blind clients of the Bureau of Rehabilitation Services in Kentucky.\* This level indicator is not only suitable for use with hot liquids, but with cold liquids such as milk or carbonated drinks—and even with spirits.

\*The author serves as Director, Division of Services for the Blind, Bureau of Rehabilitation Services, Department of Education, Frankfort, Kentucky.

By **T. V. CRANMER**, K4MMB

The first circuit tested for this application was suggested by L. W. Butler of Milwaukee, Wisconsin. Mr. Butler used a single transistor in a conventional Hartley oscillator circuit with the sensing probe connected in the battery lead. This circuit worked well, but the audio level of the output was insufficient to permit its use in noisy surroundings.

Mr. Butler has since made a clever modification of a conventional pocket-size radio which gives a much better output. To make this modification, you need only feed the output from one side of the speaker transformer through a 100-pF capacitor through the probe to the center connection or wiper of the



The value of the resistor can be either increased or decreased to respectively raise or lower the pitch or frequency of the tone heard at the speaker.

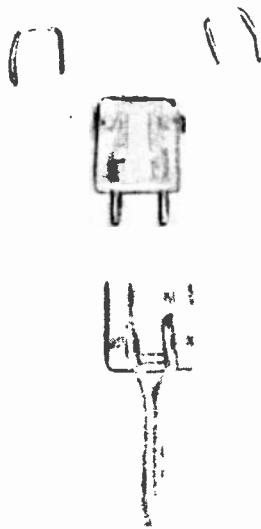
volume control. When the probe is in contact with a liquid, the feedback circuit is completed and the transistor radio goes into strong oscillation.

The neon oscillator circuit shown in the drawing has the advantages of low cost, high reliability, excellent output signal and negligible battery drain. Value of the resistor can be changed to vary the pitch of the sound output. Four small 30-volt batteries (Burgess U-240, or similar) can be used in series to power the circuit. The unit is housed in a 4" x 4" x 5" sloping panel meter case.

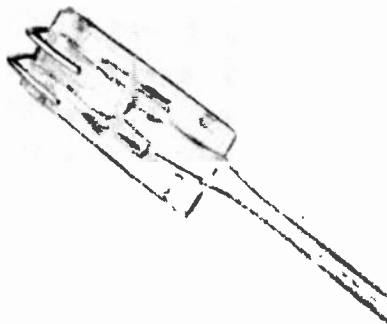
The probe can be made with a twin-lead Mosley 301 and 311 connector. One-half of the connector is attached to a flexible cord. A phono plug on the other end of the cord fits into a jack on the oscillator's case. The other half of the connector holds two horseshoe-shaped pieces of stainless steel rods having a diameter of about 0.050".

Suitable stainless steel wire for the probe can be obtained from dental supply stores. Two 2 1/4"-long pieces of this wire are needed. When each one is bent into the correct shape, the dimensions are: long leg, about 7/8"; short leg, about 3/4"; crown (or width), about 1/2". You insert the short legs into the connector, and tighten the connector's setscrews. Then complete the assembly by plugging the two halves of the connector together.

This arrangement allows removal of the "business" end of the probe for occasional washing. In use, the probe is hung over the side of the cup or bowl.



Two lengths of non-corrosive stainless steel wire make up the probe. These wires should be fitted into a suitable connector as shown and the whole assembly connected to two-conductor flexible wire.



Some of the blind hams in Kentucky have built this equipment for themselves. There are many blind people, however, who have no technical background and would need help in building a liquid level indicator. If you have a blind friend, why not offer your assistance? Besides the satisfaction you would derive from such a gesture, you would help instill in your friend the one thing most needed by the handicapped—confidence.



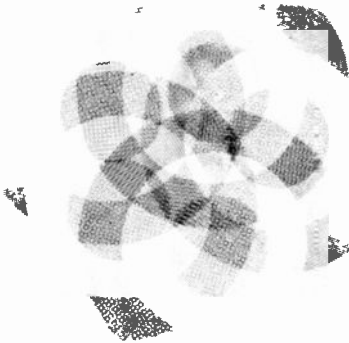
# BUILD A FIRING-RANGE TIMER

YOU CAN IMPROVE YOUR  
RAPID-FIRE ACCURACY  
IF YOU USE THIS  
AUDIBLE TIMER . . . JUST  
KEEP YOUR EYE ON  
THE TARGET, NOT  
ON YOUR STOPWATCH!

By **CALVIN F. HADLOCK**

**I**S SHARPSHOOTING one of your hobbies? If so, are you really as fast as you think you are on the firing range? How would you like to "clock" your rate of fire with an automatic timer that will "beep" at precise 10- or 20-second intervals? You can build the Firing-Range Timer in an evening or two.

When you practice rapid firing, you can lay the timer on a bench or put it in your pocket with the headphone plugged in. Then, with the timing switch set to 10 seconds and the unit turned on, the gun is loaded. Listen to a few beeps to get a fix on how long the 10-second interval actually is. When ready, commence firing at the sound of a beep and cease firing at the sound of the next one. If your timing is perfect, you will be able to get the fifth shot off at the instant the last beep occurs. For time firing,



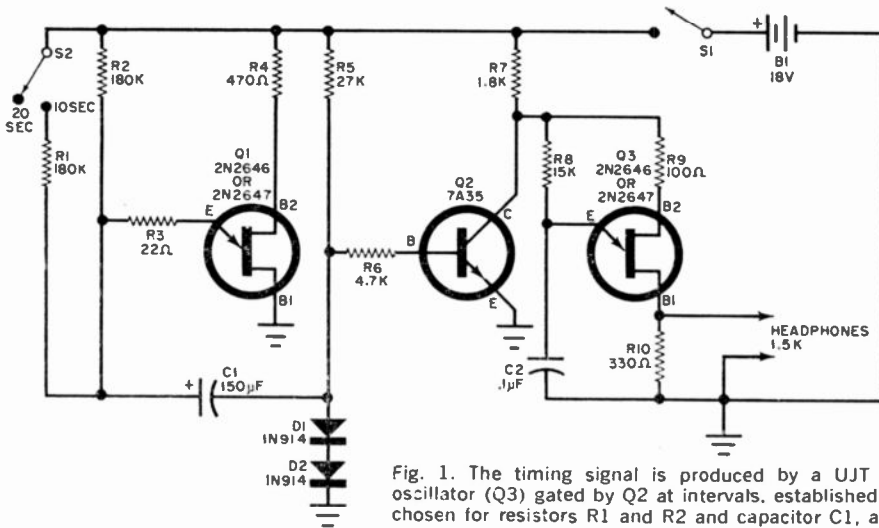


Fig. 1. The timing signal is produced by a UJT relaxation oscillator (Q3) gated by Q2 at intervals, established by values chosen for resistors R1 and R2 and capacitor C1, and by Q1.

set the switch to 20 seconds and follow the same procedure as for rapid fire.

**How It Works.** The timer (Fig. 1) consists essentially of a unijunction transistor timing circuit (Q1), a gating circuit (Q2), and UJT relaxation oscillator (Q3).

With S2 open, a 20-second timing interval is set up by the values chosen for R2 and C1. With this switch closed, the timing period is halved by the parallel combination of R1 and R2 in series with C1, and a 10-second timing is established.

When power is applied through switch S1, the voltage drop across diodes D1 and D2 forward-biases Q2 and causes it to conduct. When Q2 conducts, the emitter and base 2 of Q3 "sees" a very small voltage which is not enough to allow the relaxation oscillator to work.

At the same time, capacitor C1 takes on a charge through R1 and R2, or R2 alone (depending upon the position of S2), until its potential is enough to allow the emitter and base 1 junction of Q1 to

*(Continued on page 138)*

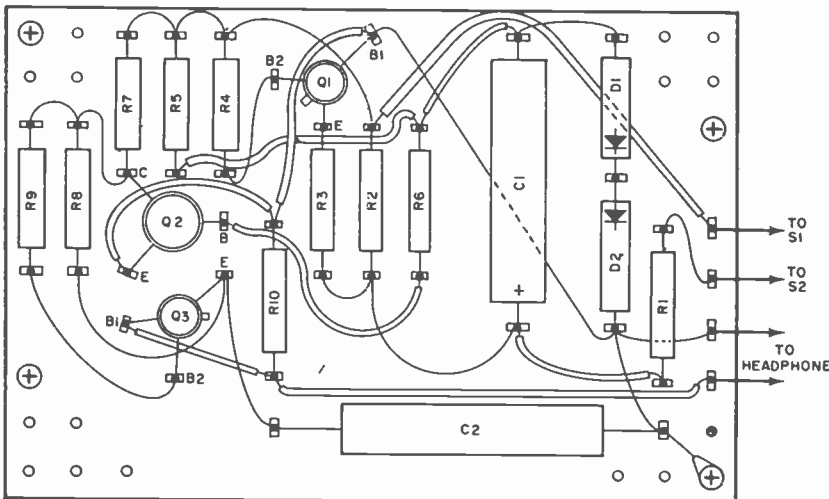


Fig. 2. Parts are first assembled on a circuit board which is then mounted on standoff spacers inside the metal case. Do not overheat the transistors or diodes when soldering the connections.

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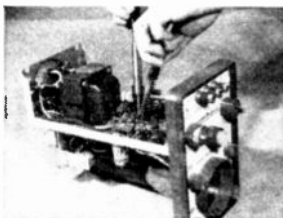
ACCREDITED MEMBER National Home Study Council

# RCA

Transistor experiments on programmed breadboard — using oscilloscope.



Construction of Oscilloscope.



Construction of Multimeter.



# AAH-CHOOO! NOT ANOTHER



**Q**UITE A FEW READERS have built "Pepper," the outboard r.f. amplifier to increase the sensitivity of automobile AM broadcast band receivers. Although the "Pepper" circuit that appeared in the May 1966 issue (page 56) of POPULAR ELECTRONICS could add 8 to 10 dB of gain, it just didn't behave properly for many project builders. Some readers complained of increased sensitivity to ignition noise or susceptibility to motor boating.

The original "Pepper" circuit has been revised as shown in Fig. 1. In the modified circuit a coil/capacitor combination (L1/C3) has been added and the new design calls for installation in a metal or shielded container.

The modified "Pepper" unit need not cost more than \$5 and will obviously cost much less if you have constructed

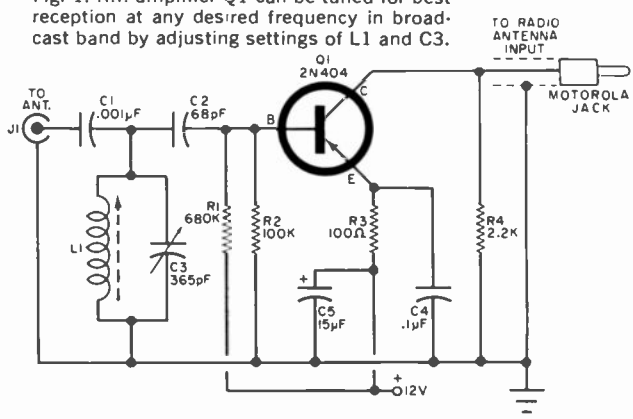
the original circuit. If your car has a positive ground, substitute an *npu* transistor for Q1 and reverse the polarity of capacitor C5.

**Construction.** Although parts layout is not critical, the "Pepper" circuit must be shielded on all six sides. The connection to the AM radio input must be via a coaxial cable.

Drill the appropriate size holes in the box to mount J1, C3 and L1 as shown in Fig. 2. You can use a perforated phenolic board to lay out the circuit components; if you do, use 1/2" long spacers to provide adequate clearance between the circuit board and the metal box.

Run the coax cable through a rubber grommet in the side of the box, and solder the cable directly into the circuit. If possible, connect the 12-volt power lead to the on-off switch in your car radio. However, the current drain is so low that the "Pepper" circuit can be left

Fig. 1. R.f. amplifier Q1 can be tuned for best reception at any desired frequency in broadcast band by adjusting settings of L1 and C3.



# PEPPER?

## OUTBOARD BCB PREAMP PEPS UP AUTO RECEPTION

By GARY MC CLELLAN



Fig. 3. Circuit must be built inside metal box to provide effective shield against r.f. interference that can be caused by ignition and other noises.

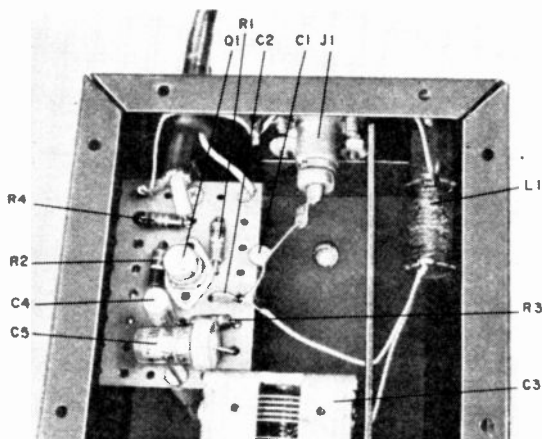


Fig. 2. Optional metal plate shields L1 from rest of circuit. Be careful not to short out trimmers on tuning capacitors. Solidly ground box to car frame.

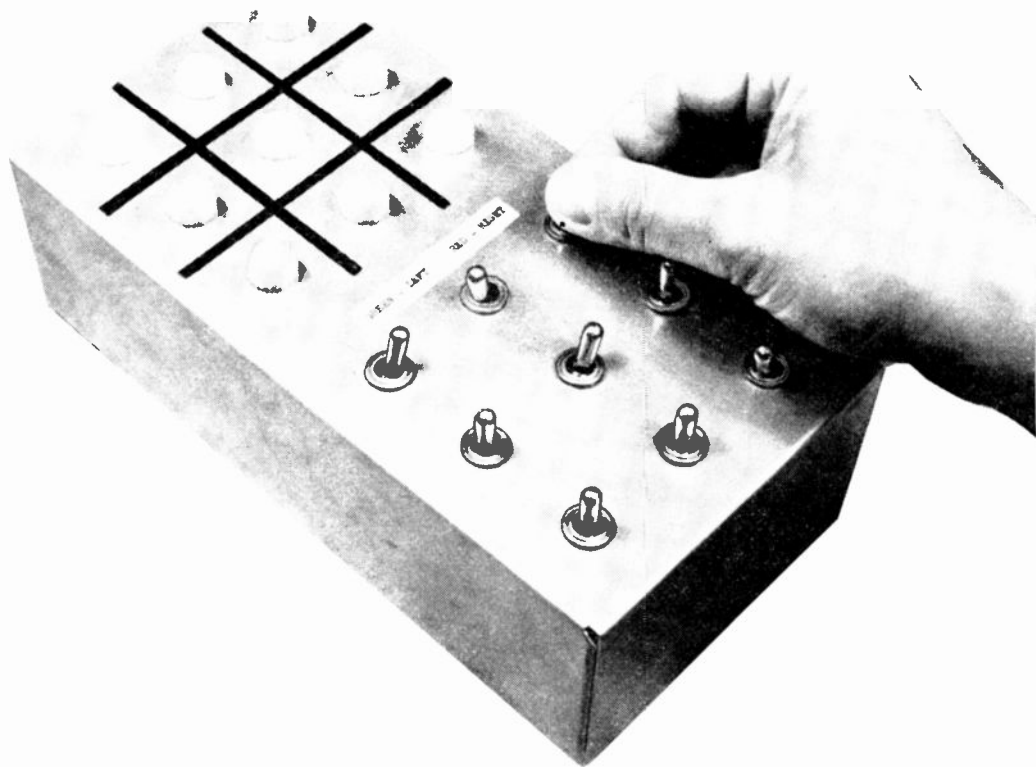
### PARTS LIST

- C1—0.001- $\mu$ F disc capacitor
  - C2—68-pF disc capacitor
  - C3—365-pF variable capacitor
  - C4—0.1- $\mu$ F, 100-volt paper capacitor
  - C5—15- $\mu$ F, 15-volt electrolytic capacitor
  - J1—Motorola antenna jack
  - L1—Ferrite loopstick antenna coil (similar to Lafayette 32H4108)
  - O1—2N404 transistor—see text
  - R1—680,000-ohm resistor
  - R2—100,000-ohm resistor
  - R3—100-ohm resistor
  - R4—2200-ohm resistor—see text
- Misc.—Metal box, coaxial cable, hookup wire, perforated phenolic board, spacers, hardware, solder, rubber grommet, etc.
- } all resistors  
} 1/2-watt

operating even when your radio is turned off by simply tying into the "Accessory" side of the ignition switch.

**Tuning and Use.** Disconnect the antenna from your car radio and plug it into the "Pepper" input jack, J1. Turn on the AM radio and adjust L1 until at one setting you can tune C3 through the entire AM broadcast range. Once set, L1 is not readjusted; but peaking of the circuit is left to C3. On strong local signals, additional peaking of C3 may be unnecessary and you may find that an arbitrary setting of peaking capacitor, C3, will serve your everyday needs. On long trips and when you are away from strong AM broadcasting stations, have "Pepper" positioned so that you can tune C3 for best reception.

For additional gain, try substituting a 2.5-mH radio frequency choke for the collector load resistor, R4.



# BUILD THE ELECTRIC TIC TAC TOE

PERMANENT GAME SETUP  
IS EYE-ATTRACTIVE  
SCIENCE FAIR PROJECT

**YOU CAN BUILD** this tic-tac-toe game with a minimum of parts. The novel feature of the game is that each one of the 9 translucent indicators lights up red or green according to the play. The secret of the design is the use of miniature grain-of-wheat bulbs.

The game shown in the photo was built by the author in a 3" x 10" x 5" aluminum chassis fitted with a bottom plate. If you duplicate the author's model, draw (with a pencil) two sets of 1½" tic-tac-toe squares on the top surface of the chassis. In the center of each of the bottom 9 squares mount a single-pole, double-throw, center-off toggle switch so that the handle moves from side to side.

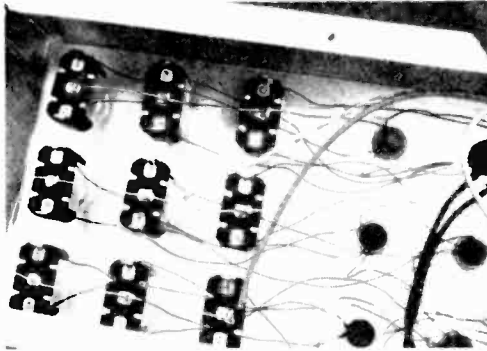
In the center of each of the top 9 squares, drill a ½" hole. Carefully enlarge each hole with a file or reamer so that the plastic lens cap of each of the Dialco lamps can be pushed/twisted into place. The 12-volt red and green grain-of-wheat bulbs are sold by most hobby

shops. Each bulb will cost about 15¢. The leads should be sufficiently long to permit wiring the red and green bulbs directly to the toggle switches as shown in the schematic diagram. Handle the bulbs with care, since they break easily. As each pair of bulbs (one red, one green) is wired to its switch, position them in the lens cap. Cement the bulbs in place with a clear plastic cement, or tape them in place with Scotch or plastic adhesive tape. Also, tape the leads down to the chassis as they go from lens cap to switch.

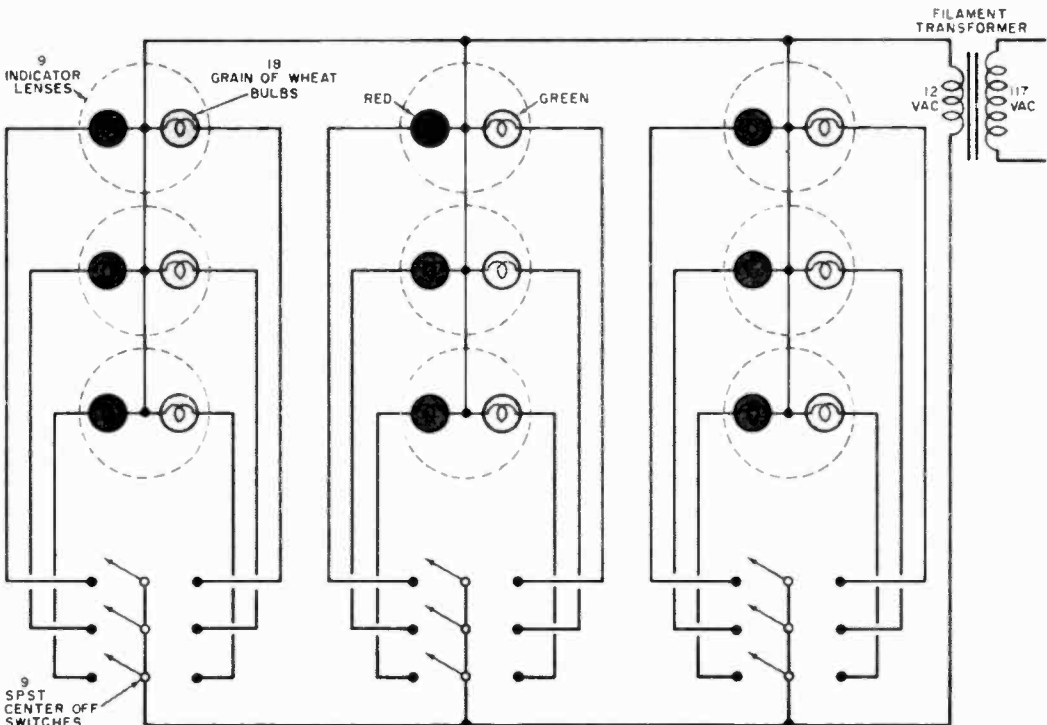
Finally, mount the power transformer on the chassis wall and install a terminal strip under each of the mounting screws to serve as convenient tie points for the 18 common bulb leads which are connected to the transformer.

Erase your pencil lines and paint in heavier black lines to represent each tic-tac-toe square. Lettering or press-down labels to indicate switch positions will simplify operation for the players. The red and green lights are used in place of the usual "X" and "O".

—Ken Greenberg



Generally speaking, the leads from most grain-of-wheat lamps will be long enough to be wired directly to the switches. These leads are fragile, so treat them with care. The white Dialcc lens cap is known as the manufacturer's part number 95-0935. Not all catalogs carry this item, but Allied Radio (Stock 60 E 8033) has these plastic lenses (19¢, ea.).



# AUTOMATIC LIGHT BLINKER

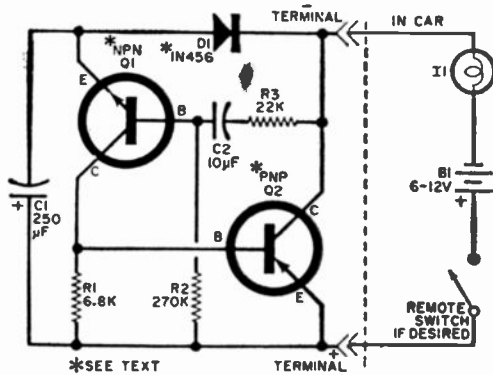
SIMPLE  
TWO-TRANSISTOR CIRCUIT  
CONVERTS IDIOT LIGHT  
TO WARNING LIGHT

By MELVIN CHAN

**H**AVE YOU EVER driven many miles before noticing that your oil pressure warning lamp has been glowing dully . . . or had a cold, clammy feeling out on that deserted highway, after wondering just how long your low-fuel warning lamp had been lit . . . or found that your engine was acting up and then discovered that your parking brake was not fully off and you didn't see the lamp glowing down there? If any of these things have happened to you, you'll be interested in this automatic light blinker.

Because the circuit to be described is a true on/off switch, it can be inserted in series with almost any light bulb in the car (within electrical limits) and cause that bulb to blink at an attention-getting rate.

**How It Works.** Following the schematic diagram, assume that both *C1* and *C2* are completely discharged before power is applied to the switch. As power is applied, *C1* charges through diode *D1*, while *C2* charges through *R2* and *R3*.



Flasher circuit is connected in series with the existing idiot light circuitry. Some parts values depend upon current load of light bulbs in use.

As *C2* is charging, the voltage developed across *R2* keeps *Q1* in the off state. As *Q1* draws no current, there is no voltage drop across *R1*; therefore, *Q2* is also in the off condition. When *C2* reaches full charge, *Q1* starts to conduct and the voltage developed across *R1* causes *Q2* to go into saturation. When this happens, the collector-to-emitter resistance of *Q2* is reduced to a very low value, producing a virtual short circuit across the switch output terminals.

At this time, diode *D1* becomes back-biased and does not allow *C1* to discharge through the effective short circuit. The voltage stored in *C1* keeps *Q1* conducting, and therefore maintains *Q2* in a saturated condition. As *C1* discharges, *C2* is also discharging, and when the charge on *C1* is exhausted, the circuit reverts to its original open-circuit condition.

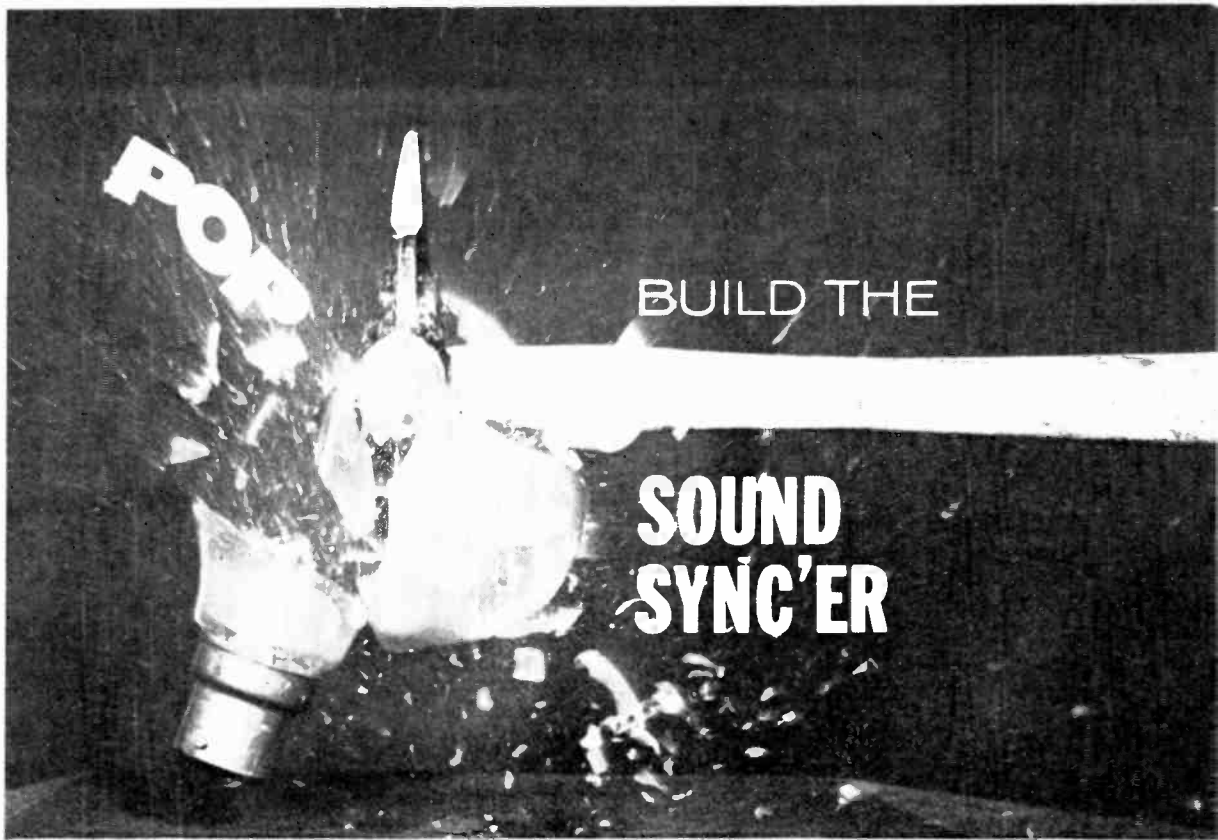
Although no transistors are specified for *Q1* and *Q2*, almost any available transistors will do, except that the  $I_{c(max)}$  of *Q2* (see transistor handbook) must be at least three times the current required by the lamp. Also, almost any diode can be used for *D1* as long as it will pass the current requirements of *Q1*. The series light flasher will operate with any voltage that does not exceed the breakdown voltage of the transistors, the electrolytic capacitors, or the diode.

**Using the Blinker.** Open the circuit to the remote bulb, determine which lead is positive and which is negative and then connect them to the respective terminals on the solid-state blinker. When the power to the bulb is turned on, the blinker operates automatically.

If desired, the flashing rate may be altered by changing the value of *C1* or *C2*. The higher the value, the slower the bulb repetition rate.

-30-





BUILD THE

## SOUND SYNC'ER

**C**APTURING an explosion at the instant of detonation is not new to photographers, but only a few well-endowed amateurs and professionals are equipped with a "motion freezer." However, if you have a camera, a strobe, and a tape recorder or other microphone-amplifier setup, you can add a "Sound Sync'er" to put you on the business end of stop-action photographs. There are only four electronic components in this gadget which should cost less than a sawbuck.

Actually the stop-action effect is made possible by the strobe flashgun, but the trick is to fire the gun at exactly the right time. When a sound burst accompanies and coincides with the action you want to photograph, the "Sound Sync'er" "listens" to the sound and "triggers" the flashgun. Use of an open-shutter technique in a "darkened" room lets you get by with a minimum amount of photographic equipment.

**How It Works.** The input of the "Sound Sync'er" is connected to the amplifier in place of the speaker and the output of

By A. J. LOWE

### SOUND-FIRED STROBE STOPS MOTION FOR SHUTTERBUGS

the gadget goes to your flashgun. A microphone, connected to the input of the amplifier, completes the system, as shown in Fig. 1.

When the desired sound pulse hits the microphone, the signal is amplified and passed on to the silicon-controlled rectifier (SCR1) as shown in Fig. 2. Resistor *R1* provides a suitable load for the amplifier, and *R2* acts as a gate current limiter for SCR1. Diode *D1* permits a "cleaner" gating action to take place by allowing only the positive pulses to hit the gate of the SCR.

The SCR acts like a thyatron tube . . . once it is fired (allowed to conduct) by an appropriate signal on the gate, it conducts until the positive voltage on the anode is dissipated or removed. It is important, therefore, that the SCR's

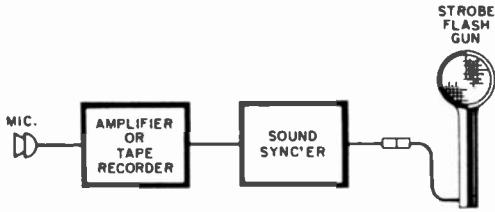


Fig. 1. Block diagram shows the setup required for using the sound from the action to be photographed to trigger the "Sound Sync'er" and strobe.

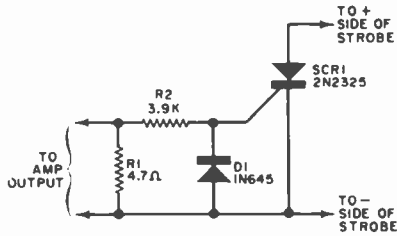


Fig. 2. Use the 2N2325 (available from Allied Electronics for \$7.95) for silicon-controlled rectifier SCR1 and not the 2N2325A which costs \$2 more.

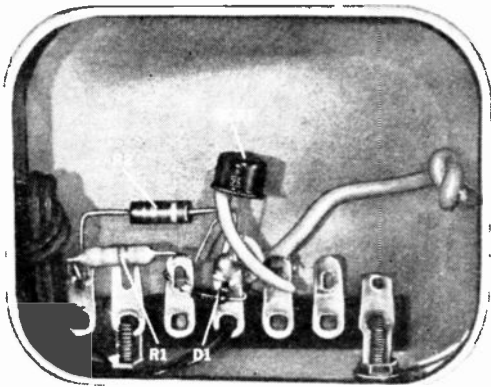


Fig. 3. The "Sound Sync'er" can be assembled on a terminal strip and mounted inside a small metal or plastic box. Use grommets to protect the cables.

anode be connected to the positive side of the strobe. The instant the SCR conducts, the strobe is fired.

**Construction and Use.** Layout is not critical, and you can save a lot of time by mounting the parts on a terminal strip as shown in Fig. 3. A small plastic or metal box can be used to house the parts. However, if you use a metal box, be sure to line the inside with insulating material to prevent accidental short circuits between the box and the strobe.

Observe polarity of the diode as well as the SCR, and heat-sink the leads when soldering them in place.

Set up the microphone close to the object to be photographed, but not within camera view. Turn the volume control on the amplifier all the way down and slowly advance it until the amplifier will respond only to the desired sound signal. Too high a setting will trigger your strobe prematurely, and too low a set-

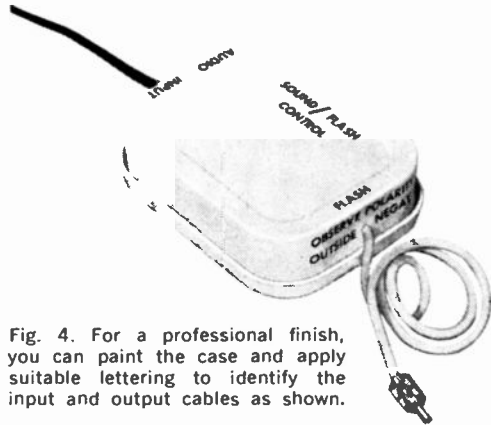


Fig. 4. For a professional finish, you can paint the case and apply suitable lettering to identify the input and output cables as shown.

#### PARTS LIST

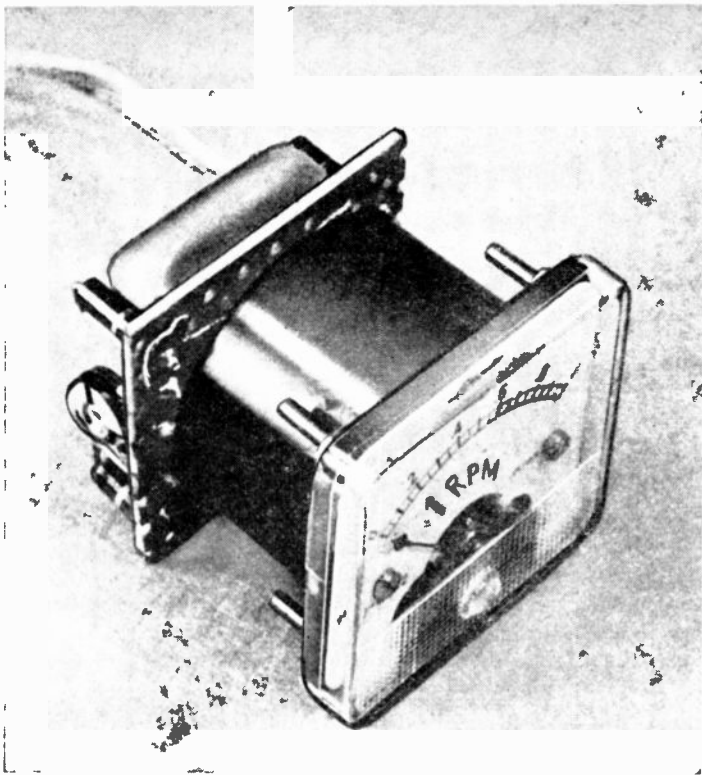
- D1—1N645 diode
- R1—4.7-ohm, 1/2-watt resistor
- R2—3900-ohm, 1/2-watt resistor
- SCR1 2N2325 silicon-controlled rectifier, or similar
- Misc. Small metal or plastic box, terminal strip, wire, strobe extension cable, solder, hardware, etc.

ting will cause you to miss the shot. The speaker must be disconnected from the amplifier to prevent feedback howl.

By changing the distance between the microphone and the action being photographed, you can change the timing of the flash to capture the right "moment." Sound travels at about 1100 feet per second, so figure about a 1-millisecond delay for every foot separating the microphone and the sound source.

When you are ready to take a picture, set up your camera as you normally would for a flash shot, aim, focus, etc., and then turn off all the lights in the room, open the camera's shutter, and start the action. After the shot has been taken, close the shutter and turn the lights back on.

-30-



BUILD

## \$6 ELECTRONIC TACHOMETER

TRANSISTORIZED CIRCUITRY  
KEEPS WATCH  
ON YOUR ENGINE SPEED  
FOR BETTER GAS MILEAGE,  
MAXIMUM EFFICIENCY,  
AND BETTER PERFORMANCE

By **RICHARD E. STAERZL**

**I**F YOU DRIVE a manual shift auto, at what engine speeds—rather than road speeds—should you shift gear for top fuel economy with maximum horsepower and torque? At 65, 100, or 1800 r/min? The answer lies in the horsepower rating, number of cylinders, engine cycle, and other factors related to engine design.

1968 Spring Edition

Car makers' manuals usually contain information on specific engine r/min from idling speed through full acceleration, and specify when to shift gears, or when maximum torque is reached. However, if your car is not equipped with a tachometer, this information will be of little value to you.

For under six bucks you can build and install an accurate transistorized tachometer that can be used with any 4-, 6-, or 8-cylinder, 2- or 4-cycle engine having either a standard or transistorized negative-ground ignition system. This tach will tell you what your idling speed should be, when to up-shift for best acceleration and maximum efficiency, and when to down-shift to avoid engine lugging.

**How It Works.** The tachometer circuit (Fig. 1) is nothing more than a simple monostable multivibrator (*Q1* and *Q2*) triggered by a shaped negative-going rectangular pulse produced by the opening and closing of the auto's ignition

points. Pulse shaping is accomplished by the *C2-R6* combination.

The average current in *Q1*'s collector is monitored by a 0.1 mA full-scale meter. Since the collector current will be directly proportional to the trigger frequency, determined by the engine r/min, the meter can be calibrated in terms of r/min. The accuracy of the reading is determined essentially by the accuracy of the meter used. The economy meter shown is accurate within  $\pm 2\%$  of full scale.

**Construction.** A convenient layout for the tachometer is given in Fig. 2. The parts are laid out on a 1½" x 1½" perforated phenolic board, and the circuit

board is then mounted on the back of a d.c. milliammeter. Although an inexpensive 0.1 mA d.c. meter was selected to keep the cost low, a 3½"- or 4½"-wide view panel meter is preferable.

The entire unit can be housed in a plastic or metal case for use as a portable test instrument, or the meter case can

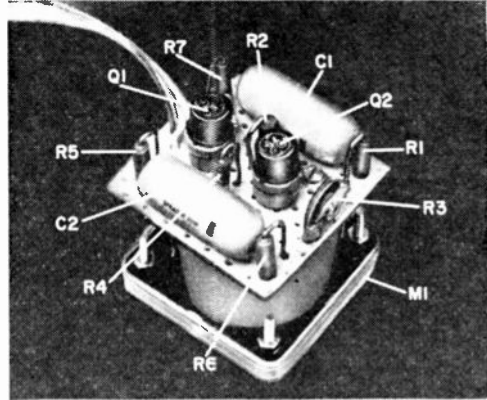


Fig. 2. The electronic circuitry is first put together on a suitable sized circuit board, and the assembly is mounted on the back of the meter case. You could also house the circuit board separately.

### PARTS LIST

- C1, C2—0.1- $\mu$ F, 200-volt capacitor*
- MI—0.1 mA d.c. milliammeter see text*
- Q1, Q2—2N414 transistor*
- R1, R2—2200-ohm, ½-watt resistor*
- R3—10,000-ohm printed-circuit miniature potentiometer*
- R4—6800-ohm, ½-watt resistor*
- R5, R6—1000-ohm, ½-watt resistor*
- R7—47-ohm ½-watt resistor*
- Misc.—Transistor sockets, phenolic circuit board, wire, solder, enclosure (optional)*

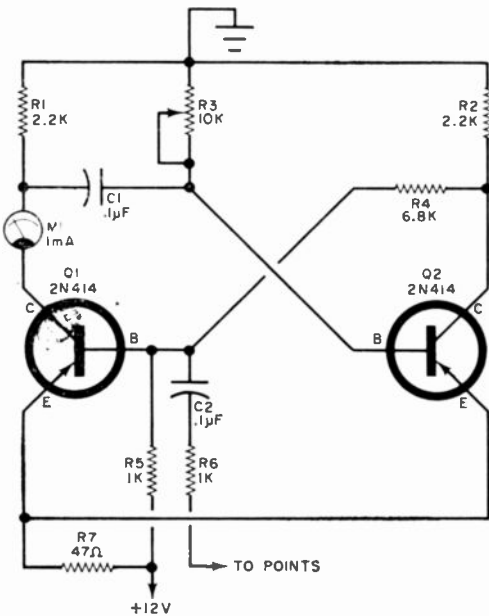


Fig. 1. If you want to use this tachometer circuit with a positive-ground automobile, simply replace transistors *Q1* and *Q2* with 2N1302 transistors.

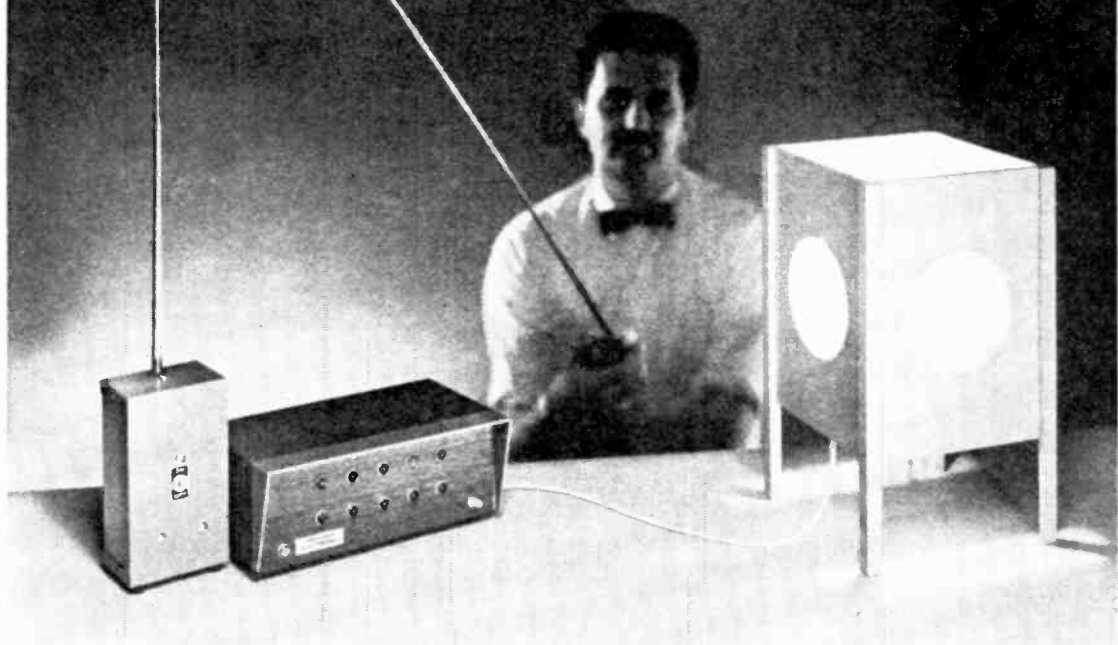
be mounted separately on the dash while the electronic circuitry can be housed and stored in the glove compartment, or fastened under the dash.

**Calibration.** The easiest way to calibrate your tachometer is with another tachometer. Connect both tachs in parallel and rev the engine up to 1000 r/min. Then adjust *R3* for a reading of 0.1 mA on the meter being calibrated. With this adjustment, the meter is calibrated so that each 0.1 mA increment on the dial represents 1000 r/min. If you wish, you can also calibrate the meter directly in r/min.

Another method of calibration is to use a high-output square-wave generator as a signal source. Set the generator frequency to 33 hertz for a 4-cylinder car, to 50 hertz for a 6-cylinder car, or to 67 hertz for an 8-cylinder car, and adjust the generator to any output from 6 to 24 volts peak-to-peak. Now adjust potentiometer *R3* until you get a reading of 0.1 mA on the meter. With this adjustment, your tach is calibrated for 1000 r/min per 0.1 mA.

-30-

# BUILD THE PULSE COMMAND RESPONDER



YOU CAN CONTROL ALMOST ANY NUMBER OF  
ELECTRICAL DEVICES FROM ALMOST ANYWHERE

By **ELDEN C. MAYNARD**, K6SAI

**T**HE "Pulse Command Responder" is perhaps one of the most versatile selective multifunction types of remote control centers you are likely to find anywhere. With just the touch of a single button, you can control many different electrical circuits individually and at any time. You can turn your TV set, lamps, motors, and just about any other electrical device on and off from one or more locations, and at distances of up to several hundred feet.

The Responder can be operated by radio control (R/C), carrier-current remote control, or direct "on-line" switching. For R/C operation, a transmitter and a receiver—of the types for controlling model airplanes—are suitable. The carrier-current remote control also has a transmitter and a receiver; but instead of the signal radiating from the transmitter into space, it is coupled to the

receiver by way of your house wiring. (Construction of a "Carrier Current Remote Control System was described in the 1968 Winter Edition of *ELECTRONIC EXPERIMENTER'S HANDBOOK*.) The "on-line" switching technique calls for a 3-wire hookup going from the Responder to one or more strategically-located push-button switches. A complete R/C system is illustrated in Fig. 1.

Regardless of the type of control employed, operation of the Responder remains the same: a number of pulses are used to trigger an electronic switching circuit, which in turn controls a stepping-type relay. Except for the first two steps, each step on the relay is connected to a different device to be controlled.

Unlike certain sequential or stepping relay control devices, no unwanted circuit or device is energized even momentarily while the stepping relay "finds" a

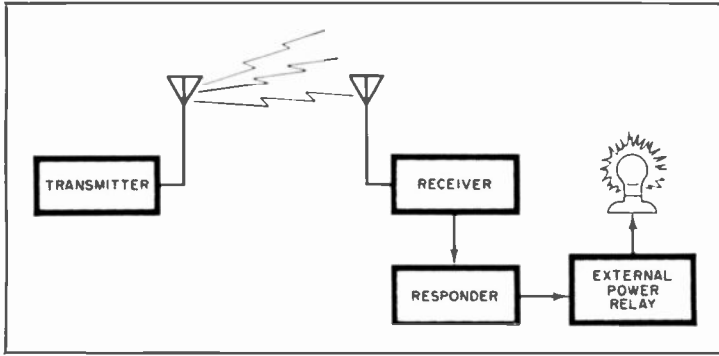


Fig. 1. The Responder can be radio-controlled if it is connected as shown.

wanted position. For example, you can start a motor in step 5, without affecting anything connected to steps 3, 4, 6, etc., and then, at a later time, control the devices on steps 4 or 7 without affecting the action on step 5. (Steps are on *K5* as shown in Fig. 2.)

The Responder is foolproof. It will seek a numbered step in accordance with a like number of pulses on the first round. On the second round, it will reset itself almost instantly in the presence of a single pulse. Sending up to three pulses on the second round will have the same effect as a single pulse. However, not until the stepping relay is in its 0 position can it accurately respond to a given number of pulses for a given position.

By tying steps 1 and 2 together and connecting them to the reset function (*K4* in Fig. 2), a certain amount of noise immunity is built into the Responder. It will not activate any control circuits unless at least three pulses are received in rapid order. This feature is especially desirable for R/C operation, or where the Responder may be accidentally pulsed.

**How It Works.** An s.p.d.t. switching mechanism, such as that shown for *K1* in Fig. 2, is used to connect a positive or a negative voltage as needed to *K3*, *K4*, *K5* and the base of *Q1*. This switch (on *K1*) can be part of a relay in an R/C receiver or in any other appropriate external control device. (Note that *K1* is actually not considered as a part of the Responder, but rather as an integral component of whatever external control system is used.)

Relay *K1* (or its equivalent) switches the voltage from positive to negative and back to positive for each pulse. There-

fore, this switch should be a spring-loaded affair which always returns to an upward position (positive voltage on the normally-closed set of contacts).

Before tracing the action of the positive and negative voltages on *Q1*, the various diodes and relays *K2*, *K3*, *K4* and *K6*, you should know how *K5* works. Both the *Advance* and *Reset* coils of *K5* operate on 117 volts a.c. Since the control voltages are on the order of 6 volts d.c. in the Responder, relays *K3* and *K4* are used to switch the *Advance* and *Reset* coils, respectively.

Each time the *Advance* coil is ener-

## PARTS LIST

- C1, C2*—100- $\mu$ F, 15-volt electrolytic capacitor\*
- C3, C6*—6- $\mu$ F (or 5- $\mu$ F), 15-volt electrolytic capacitor\*
- C4, C5*—0.02- $\mu$ F ceramic or disc capacitor\*
- D1, D2, D3, D4*—1N4004 (or 1N4001) diode\*
- I1, I2*—6-volt lamp - see text
- K1* - See text
- K2*—6-volt s.p.d.t. relay
- K3, K4*—6-volt s.p.s.t. relay
- K5*—117-volt a.c. stepping relay (Guardian MER-115 stepper/reset, 24 contacts, or similar)
- K6*—6-volt power relay
- Q1*—2N217 transistor
- RECT 1—2-amp, 50-PIV rectifier bridge (International Rectifier 10DB2A-C, or similar)\*
- R1, R2*—100-ohm, 1-volt resistor\*
- S1*—S.p.s.t. switch
- T1*—Filament transformer: primary, 117 volts; secondary, 12 volts, 1 ampere, center-tapped
- 1—Printed circuit card, or 3 $\frac{1}{4}$ " x 4" perforated phenolic board - see text\*\*
- 1—Aluminum or steel coil-type utility box
- Misc. - Indicator lamp sockets, line cord, hookup wire, spacers, solder, hardware, barrier strip

The asterisked parts are available from Southwest Technical Products Co., 219 West Rhapsody, San Antonio, Texas 78216.

\*Included in package of components for printed circuit board, \$5.

\*\*Drilled and etched fiberglass printed circuit card, \$2.

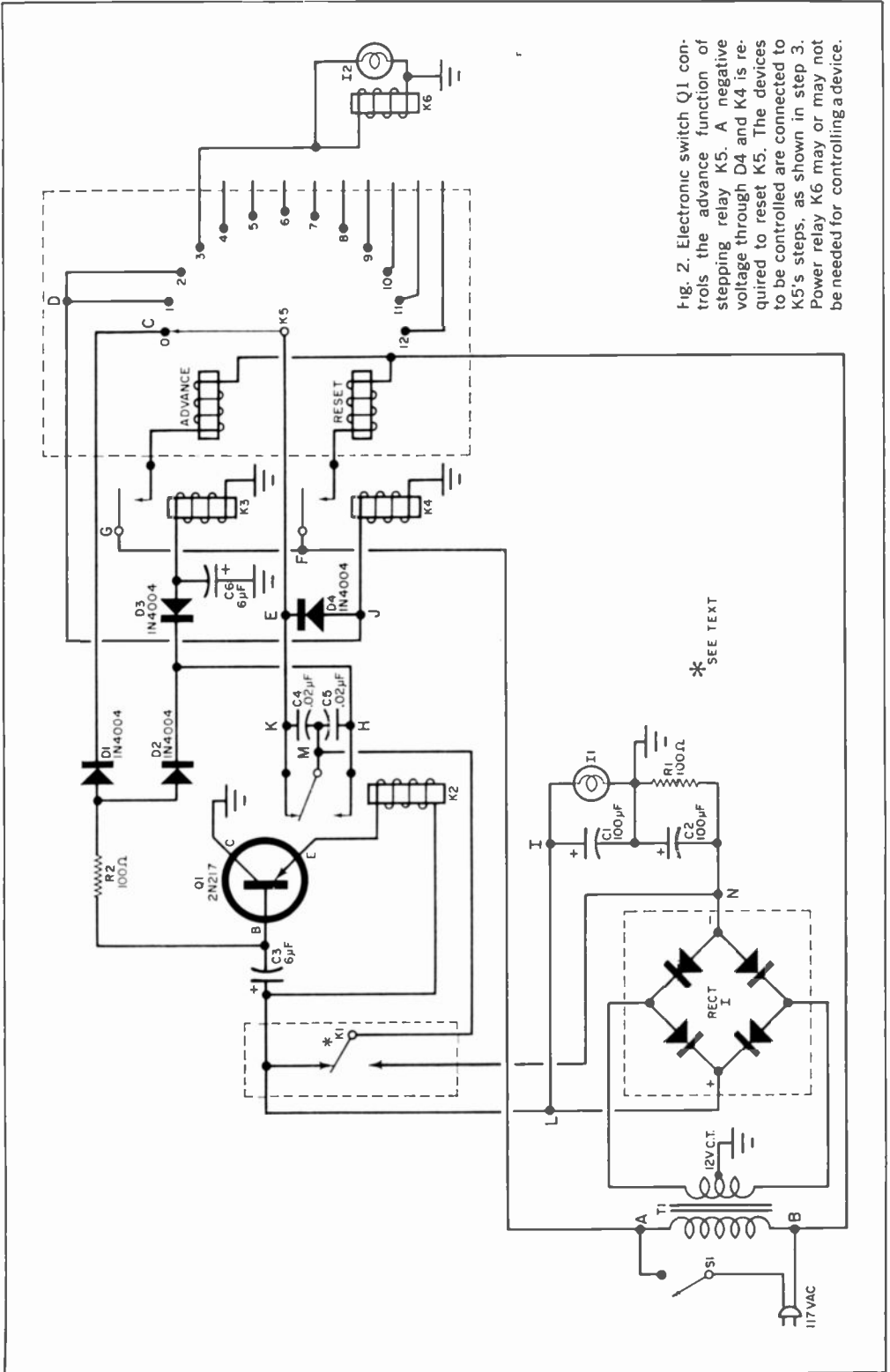


Fig. 2. Electronic switch Q1 controls the advance function of stepping relay K5. A negative voltage through D4 and K4 is required to reset K5. The devices to be controlled are connected to K5's steps, as shown in step 3. Power relay K6 may or may not be needed for controlling a device.

\* SEE TEXT

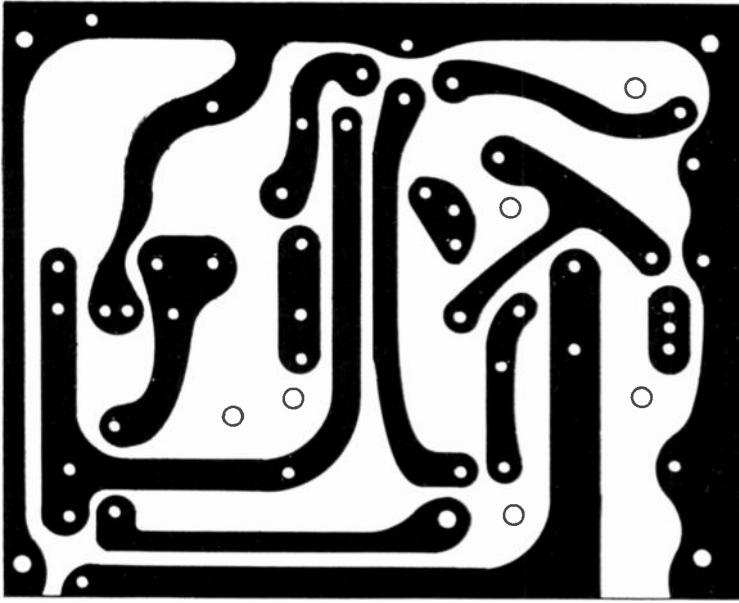


Fig. 3. If you decide to make your own printed circuit board, use this full-size drawing as a guide to proper etching of foil side of board.

gized, *K5* advances one step and holds. When the *Reset* coil is activated, *K5* is spring-returned to its 0 step.

When *S1* is closed and power is applied, the pilot lamp, *I1*, lights and the Responder is ready to go to work. In the Responder's quiescent state, *Q1* does not conduct and all relays and coils are de-energized. Note that *K6*—like *K1*—is not considered to be part of the Responder proper.

When *K1* is energized, a negative voltage is applied through the upper con-

tacts of *K2* to *D4* and the armature of *K5*. In step 0 on *K5*, the negative voltage is fed to *D1* and forward-biases *Q1* to allow it to conduct. When *Q1* conducts, *K2* becomes energized, which removes the negative voltage from the *D4-K4* circuit and applies it to the *D3-K3* circuit. Each time *K3* sees a negative pulse, it advances one step. Capacitor *C3* holds *Q1* conducting and *K2* energized to prevent the *Reset* coil from being activated. As long as *K2* is energized, no control voltage reaches any of the steps on *K5*, and no externally controlled circuits are affected until the Responder settles down to a quiescent state. The train of pulses must come in a rapid enough succession to be within the discharge time of *C3*.

If *K5* is on step 3 or higher when *K1* is energized, the negative voltage cannot get to *Q1*, and now *D4* is able to go to work and pass this voltage on to *K4* and reset *K5*. Notice that steps 1 and 2 on *K5* (the noise immunity circuits) are connected back to *K4*; if for any reason *K5* is advanced only to either step, *K5* will reset itself with a positive or a negative voltage, but not until *K1* de-energizes, *Q1* in turn stops conducting, and *K2* releases.

Transformer *T1*, full-wave bridge rectifier *RECT 1*, *C1*, *C2*, *R1* and *I1* provide suitable positive and negative voltages to

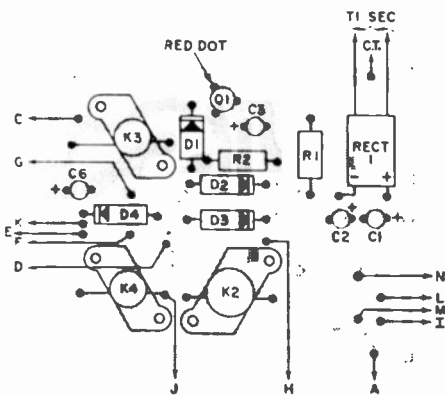


Fig. 4. Parts layout is not critical, but be careful not to confuse polarity of diodes, and the connections to the relays' frames, coils, and contacts.



operate the Responder. Pilot lamp *I1* does double duty; it helps power supply regulation as does *R1*, and it also serves as an on/off indicator. Lamp *I2* is optional. Capacitors *C4* and *C5* are used for relay contact protection; a 0.02- $\mu$ F capacitor can also be placed across the contacts on *K3* and another on *K4*, if you wish. Capacitor *C6* tends to prevent chatter and helps *K3* to perform in a more positive manner.

Circuits to be controlled having voltage and current requirements different from the 6 volts d.c. available at *K5*'s steps, or for continuous operation—once activated, require relays (*K6*, etc.) or other switching devices (SCR's) to be interposed between *K5* and the controlled circuit.

**Construction.** The Responder can be built into any 8" x 6" x 3" enclosure. Parts placement is not critical, but perhaps the most suitable layout for the small parts is on a printed circuit board or plain perforated phenolic board. If you want to make your own printed circuit board, follow the actual-size drawing shown in Fig. 3. You can buy one already etched and drilled for \$2 post-paid (see Parts List).

If you use a circuit board, you can fol-

low the same general layout for parts as shown in Fig. 4. When mounting capacitors, diodes and transistor, be careful to observe polarity. After all parts are mounted, set the circuit board aside.

Drill the mounting holes for the circuit board, power transformer, indicator lamps, switch and stepping relay, referring to Fig. 5 for the general location of these major parts. Actual location of parts is not too important provided that the parts do not interfere with the circuit board or each other. To facilitate mounting of the board and other parts, secure *T1* to the metal case last.

Use 3/8" spacers to get adequate clearance between the board and case. Optional indicator lamps (*I1*, *I2*, etc.) should be mounted on the front part of the case.

After all parts are mounted, wire the circuit in accordance with the schematic. For your convenience, the lettered points in Fig. 4 correspond to the same lettered points in Fig. 2.

Each of the steps on stepping relay *K5* should be connected to a suitable terminal strip or set of output jacks mounted on the back of the case, such as the jack marked "TO *K6*" in Fig. 5. Because only 6 volts d.c. is available at each step at any one time, power relays or circuits to be controlled should also be able to operate on 6 volts d.c.

**Final Check.** When construction of the Responder is complete, connect the pulsing device to satisfy the switching requirements for *K1* as shown in Fig. 1. Turn the Responder on, and pulse it once. Relay *K5* should advance to step 1. After a short delay, as *C6* discharges, the stepping relay should automatically reset to step 0. The same is true when you pulse the responder twice, except that *K5* should first advance to step 2. Check each of the other steps of *K5* by pulsing the Responder the same number of times as the step number you want, but between each selection of steps, reset *K5* to step 0 with one or two pulses.

When you are satisfied that the Responder is operating properly, you can connect your power relays and circuits to be controlled. Once you work with and get to know the Responder, you will find that its applications and functions are practically limitless.

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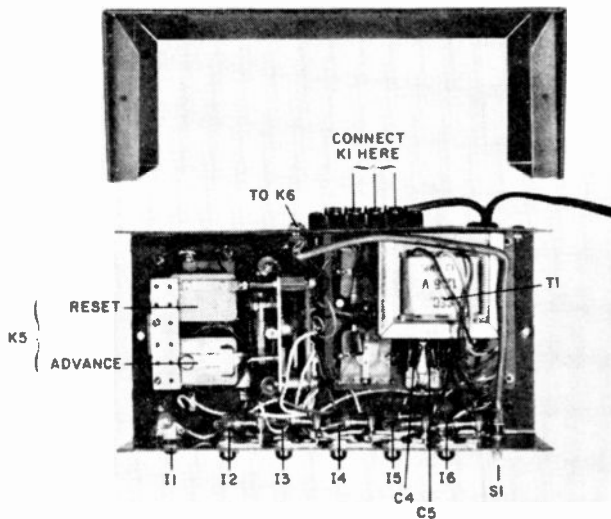


Fig. 5. Position the parts so that they do not interfere with each other or with the circuit board. Both Reset and Advance coils are 117-volt a.c.-operated and care must be exercised to keep them clear of the case. If necessary, use a larger case.

# THE MOST SPECTACULAR SOUND EXHIBITION OF STEREO FIDELITY EVER AVAILABLE ON ONE DISC.

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**CORRETTI:** Concerto Comique Op. 8, No. 6, "Le Plaisir des Dames" (third movement) Connoisseur Society • Recording demonstrates the

## HiFi/Stereo Review **STEREO DEMONSTRATION RECORD**

A stunning series of demonstrations, each designed to show off one or more aspects of musical sound and its stereo reproduction.



sound and special layout of a small performing group (harpsichord, cello and flutes) in fairly resonant surroundings.

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# CHAPTER

## 2

### AUDIO STEREO HI-FI PROJECTS

After a lull of several years, the Editors of the **ELECTRONICS EXPERIMENTER'S HANDBOOK** are seeing a tremendous rebirth of interest in building hi-fi gear. The last edition of EEH (Winter, 1968) contained plans for a 70-watt per channel stereo system. In this chapter there are two hi-fi speaker systems that could be used with that equipment.

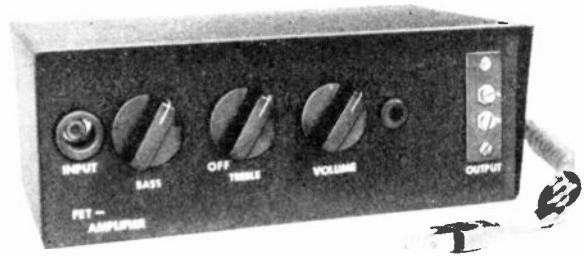
Don't be confused by the 70-watt rating of power amplifiers. Just because the output might peak at 70 watts doesn't necessarily mean that your speaker must equal or exceed that rating. Keep in mind that no one is going to drive his power amplifier at full output at any time—if he did, the windows might break and the walls give way.

For optimum hi-fi reproduction in the average living room, an average output of even 4-6 watts is more than sufficient. The large power ratings are good barometers of music handling capacity and transient response—not of actual or desirable loudness.

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# SOLID-STATE LINE-OPERATED AUDIO AMPLIFIER



HIGH-IMPEDANCE FET DRIVES COMPLEMENTARY  
RECTIFIER-TRANSISTOR COMBO  
DIRECTLY FROM

117-VOLT A.C. POWER LINE

**I**F YOU'VE always wanted a versatile solid-state audio amplifier to put a little zing in your old phonograph, or a good-quality amplifier with separate bass and treble controls for your guitar, tuner, or microphone, look no further . . . for here's a line-operated amplifier with a field-effect transistor (FET) that will give you the high impedance you need for that crystal or ceramic cartridge, and excellent frequency response for more enjoyable listening.

As a bonus, you get instant play the moment you flick the unit on. No more waiting for tubes to warm up when you update that old tube-type phono amplifier with solid-state devices. And you get to hear the beginning of every record you play.

**How It Works.** The audio amplifier (Fig. 1) features a field-effect transistor (*Q1*) for high input impedance, a common collector audio stage (*Q2*), and a power amplifier (*Q3*) driving a speaker transformer (*T1*).

The signal input at *J1* is applied to the gate of *Q1* through limiting resistor *R12* and coupling capacitor *C10*. The amplified output at *Q1*'s drain is coupled through *C9* to a tone control network comprised of *R2* (the bass control) *R5* (the treble control), and *R7*, a compensated volume control with tone correction provided by *C3* and *R6*. The output of the volume control is applied through *C5* to the base of *Q2*, biased by voltage divider *R8-R9*.

As a common collector amplifier, *Q2* provides a high current gain while, at

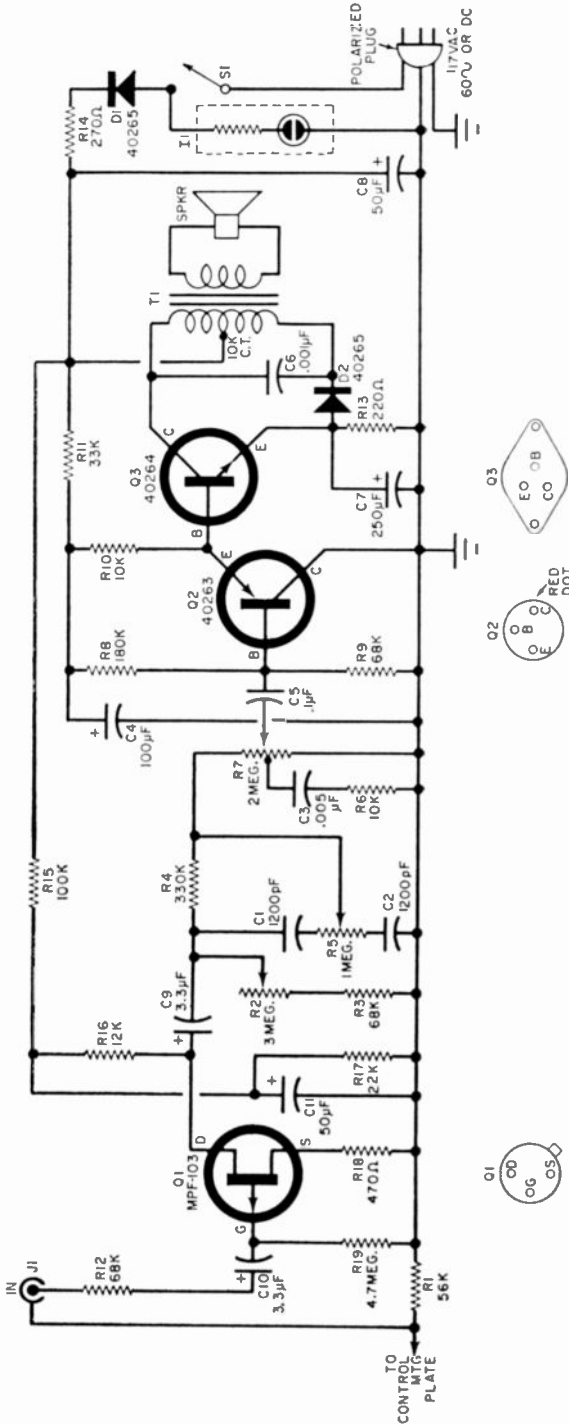
By **LYMAN E. GREENLEE**

the same time, serving as an impedance-matching device for the input and output circuitry. The output of this stage is developed across *R10* and direct-coupled to the base of *Q3*, whose output is coupled to the speaker through transformer *T1*.

Diode *D2*, together with *C6*, forms a transient voltage suppression network to limit voltage surges and protect *Q3* from possible destruction. If the value of *C6* is increased beyond the recommended 0.001- $\mu$ F capacity, high-frequency roll-off can be achieved for operation with small speakers (smaller than 8 inches in diameter). However, if the capacity is increased beyond 0.005- $\mu$ F, tone quality could be adversely affected.

Diode *D1* is the line rectifier, while *R14* and *C8* are filtering elements. Since one side of the power line is grounded directly to the unit's chassis, a polarized line plug must be used. Resistor *R1* serves to isolate the input device from the amplifier's chassis.

**Construction.** You can build the audio amplifier circuitry on a 3 $\frac{1}{2}$ " x 5" piece of perforated circuit board, and then house the entire unit in a 3"-high by 8"-wide by 5"-deep cowl-type metal box. The operating controls, pilot lamp and input jack can be mounted on an L-



- ### PARTS LIST
- C1, C2 - 1200-pF ceramic disc capacitor  
 C3 - 0.005-µF ceramic disc capacitor  
 C4 - 100-µF, 25-volt electrolytic capacitor  
 C5 - 0.1-µF, 200-600 volt Mylar capacitor  
 C6 - 0.001-µF, 600-volt Mylar capacitor  
 C7 - 250-µF, 12-volt electrolytic capacitor  
 C8 - 50-µF, 150-volt electrolytic capacitor  
 C9, C10 - 3.3-µF, 35-volt electrolytic capacitor  
 C11 - 50-µF, 25-volt electrolytic capacitor  
 D1, D2 - Silicon rectifier (RCA 40265 or similar)  
 J1 - Phono jack  
 J2 - Neon lamp with current limiting resistor  
 Q1 - Motorola MPP-103 FET  
 Q2 - RCA 40263 transistor  
 Q3 - RCA 40264 transistor  
 R1 - 56,000-ohm, 1/2-watt resistor  
 R2 - 3-megohm audio taper potentiometer (bass control)  
 R3, R4 - 68,000-ohm, 1/2-watt resistor  
 R5 - 330,000-ohm, 1/2-watt resistor  
 R6 - 1-megohm audio taper potentiometer with switch (treble control)  
 R7, R10 - 10,000-ohm, 1/2-watt resistor  
 R8 - 2-megohm linear taper potentiometer tapped at 1 megohm (volume control)  
 R9 - 180,000-ohm, 1/2-watt resistor  
 R11 - 35,000-ohm, 1/2-watt resistor  
 R12, R20 - 68,000-ohm, 1/2-watt resistor  
 R13 - 220-ohm, 1/2-watt resistor  
 R14 - 270-ohm, 5-watt wire-wound resistor  
 R15 - 100,000-ohm, 1-watt resistor  
 R16 - 12,000-ohm, 1/2-watt resistor  
 R17 - 22,000-ohm, 1/2-watt resistor  
 R18 - 470-ohm, 1/2-watt resistor  
 R19 - 4.7-megohm, 1/2-watt resistor  
 S1 - S.p.s.t. switch  
 T1 - Output transformer, 10,000-ohm center-tapped to 3.2-ohm voice coil (or to 8-ohm voice coil if 8-ohm speaker is used)  
 1 - NF213 transistor heat radiator, push-on type (Wakefield Engineering Type D, or similar)  
 1 - Cowl-type 3" x 8" x 5" metal box (Bud SC-2132, or similar)\*  
 Misc. - Knobs, rubber grommet, line cord, interlock, wire, solder, push-in terminals, hardware, four-lug terminal strip, two-terminal barrier strip, neon pilot light with current limiting resistor, 3/8"-thick sheet aluminum, perforated phenolic board, etc.  
 \* A black crackle finish cabinet with control mounting plate, heat sink, circuit board, output barrier strip and chacter cord with interlock is available from Mobil Electronics, Inc., P. O. Box 1132, Anderson, Ind. 46015 for \$9.95 postpaid in the U.S.A.

Fig. 1. FET input stage (Q1) matches most high-impedance pickups to low impedance transistor circuits. Tone control is provided by R2 (bass) and R5 (treble). If available, a Siliconix U-110 FET may be substituted at Q1 with promise of more gain.

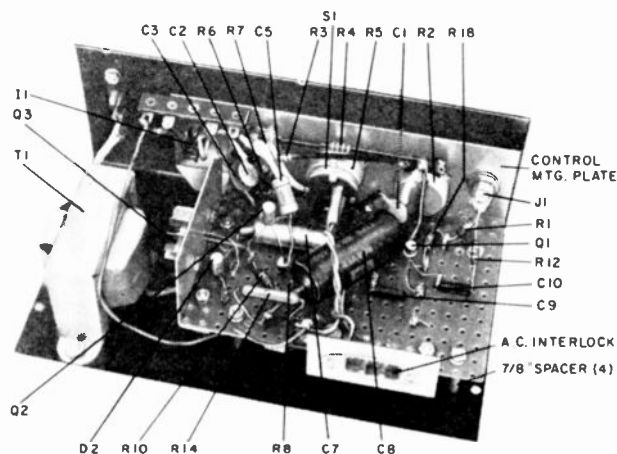


Fig. 2. Components are mounted on both sides of circuit board to conserve space. Use metal spacers (as shown) to provide adequate clearance between parts mounted on underside of board and metal cabinet.

shaped plate cut and drilled, and then screwed to the long edge of the circuit board (see Fig. 2).

The heat sink for the power transistor (*Q3*) is fabricated from a thin sheet of aluminum. An interlock for the special TV-type line cord used by the author can be mounted on a small bracket screwed to the rear of the circuit board, as shown in Fig. 2. (If you prefer to use an ordinary line cord, you can eliminate the bracket.)

The parts are mounted on both sides of the board to conserve both space and wire run, and are interconnected by means of regular push-in terminals. The top side of the board is shown in Fig. 2, and the reverse side of the board is shown in Fig. 3.

Be sure to heat-sink the transistor leads while they are being soldered. Also, observe polarities when wiring the diodes and electrolytic capacitors in the circuit.

After mounting the output transformer on the bottom plate, connect the leads to the circuit board and install the board on four 7/8"-long standoff spacers.

**Operation.** Before you plug the unit into the line outlet, check it over carefully to verify the correctness of your wiring. If you are satisfied that there are no errors, plug it in and turn it on. Touch the cabinet. If you feel a slight tickle or hear a loud hum, reverse the line plug. With an input connected, adjust the *BASS*, *TREBLE* and *VOLUME* controls for normal listening.

-30-

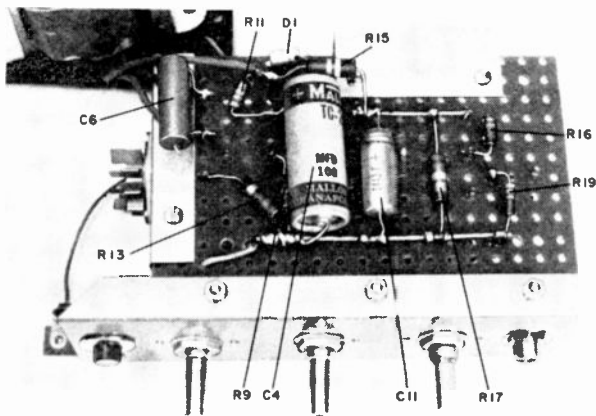
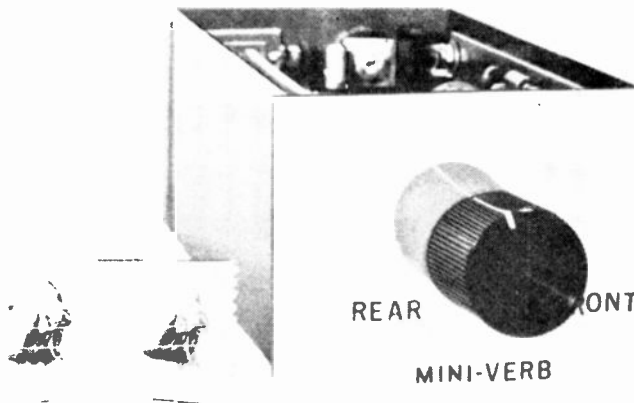


Fig. 3. Busbars eliminate the need for extra push-in solder terminals on underside of board. Solder the components directly to the busbars.



BUILD  
THE

## **“MINI-VERB”**

**R**EVERBERATION systems are offered as “accessory” equipment with many cars, included in many high fidelity systems or electronic organs, and even in public address amplifiers. Reverb systems give music a warmer tone and add a feeling of spaciousness by simulating the reverberation—or echo—effect of large concert halls. A car—or even the average living room—is not big enough to have an audible natural reverberation. So adding electronic reverberation makes the reproduction more pleasant and gives a feeling of concert-hall space.

The “Mini-Verb,” an updated version of the system described in the Spring, 1967, *ELECTRONIC EXPERIMENTER’S HANDBOOK*, was originally built for use in a car. It was miniaturized by using a smaller delay line than the one in the older system. However, it is also usable with your home hi-fi installation and can be hooked up to most stereo systems with little trouble. Quality and output power have been kept high in spite of the fact that the size has been brought down.

**By DANIEL MEYER**

IMPROVED AUTO REVERB  
CIRCUIT USES NEW  
MINIATURIZED UNIT;  
SUITABLE FOR ATTACHMENT  
TO STEREO HI-FI RIGS

A standard high-fidelity solid-state circuit is used in the amplifier. The transformerless class-B output stage will deliver at least 3 watts into a 3.2-ohm speaker with less than 1% distortion. Silicon transistors are used throughout for maximum temperature stability.

The small delay line reverb unit (Gibbs Type VII) makes possible a compact system that can be installed almost anywhere. The case measures 2" x 2<sup>3</sup>/<sub>4</sub>" x 6" and includes the fader control and power switch. If you have room in your

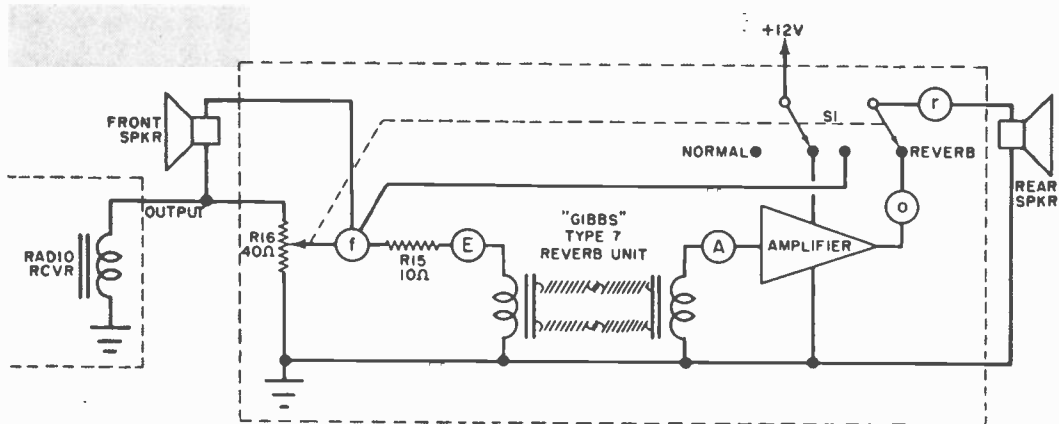


Fig. 1. In an automobile installation, reverberation is achieved by delaying and "reverbing" the sound from the rear seat speaker. The delay of sound fools the ear into believing the sound is in a large concert hall.

### PARTS LIST

- |  |   |                               |
|--|---|-------------------------------|
| C1, C7—10- $\mu$ F, 15-volt electrolytic capacitor               | R9—100-ohm, $\frac{1}{2}$ -watt resistor  | } All resistors 10% tolerance |
| C2—30- $\mu$ F, 6-volt electrolytic capacitor                    | R11—1000-ohm, $\frac{1}{2}$ -watt resistor  |                               |
| C3, C4—5- $\mu$ F, 15-volt electrolytic capacitor                | R12, R13—220-ohm, $\frac{1}{2}$ -watt resistor  |                               |
| C5—200 $\mu$ F, 6-volt electrolytic capacitor                    | R14—470-ohm, $\frac{1}{2}$ -watt resistor   |                               |
| C6—500- $\mu$ F, 25-volt electrolytic capacitor                  | R15—10-ohm, $\frac{1}{2}$ -watt resistor  |                               |
| C8—100- $\mu$ F, 15-volt electrolytic capacitor                  | R16—40-ohm, 5-watt wire-wound potentiometer with slide actuator                       |                               |
| D1, D4—1N645 silicon diode, 600-mW                               | Rb—220-ohm, $\frac{1}{2}$ -watt resistor—see text                                     |                               |
| D2, D3—1N3754 single-ended diode (RCA)                           | S1—D.p.d.t. slide switch  |                               |
| F1— $\frac{1}{2}$ -A Slo-Blo fuse                                | I—Gibbs Type VII reverberation unit   |                               |
| Q1, Q2, Q3—MPS-3708 transistor (Motorola)                        | Misc.—Case, printed circuit board, fuse holder, nuts, bolts, knob, wire, solder, etc. |                               |
| Q4—MPS-3638 transistor (Motorola)                                |   |                               |
| Q5, Q6—TIP-24 transistor (Texas Instruments)                     |   |                               |
| R1, R3, R6, R10—4700-ohm, $\frac{1}{2}$ -watt resistor           |   |                               |
| R2, R7—22,000-ohm, $\frac{1}{2}$ -watt resistor                  |   |                               |
| R4—1000-ohm miniature trimmer control (Mallory MTC-1 or similar) |   |                               |
| R5—2200-ohm, $\frac{1}{2}$ -watt resistor                        |   |                               |
| R8—25,000-ohm, $\frac{1}{2}$ -watt resistor                      |   |                               |

A complete kit of parts including a special case is available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216, for \$16.74 (postpaid). Prices of individual components are available on request.

car to mount a speaker selector switch, you will probably have enough room for the reverberation system.

**How It Works.** The heart of any reverberation system is the audio delay line. It consists of two electromagnetic transducers and a pair of different-diameter springs coupling them. Audio frequency signals drive the input transducer, which twists the springs slightly. This mechanical motion travels down the springs and creates an electrical signal in the output transducer. Not all the mechanical energy is reconverted to an electrical signal—some energy continues to travel back and forth and gradually decays, resulting in both a delay and a decay of the original sound, as with natural echoes.

The audio signal is split between the speakers through a fader control (R16)

and selector switch S1 (Fig. 1). When the selector switch is in *normal* position, the same signal is applied to both front and rear speakers. The fader serves as a variable divider to balance or shift the sound output from each speaker as desired. When the fader control knob is pulled out, S1 switches the power onto the reverb amplifier and connects the rear speaker to the amplifier's output.

The signal from the radio now drives the front speaker and the input transducer through R15. The output transducer of the reverb unit is connected to a high-gain amplifier (Fig. 2). The amplifier makes up the 40 to 45 dB loss in the delay line reverb unit. In this circuit, Q1 drives voltage amplifier Q2, which is directly coupled to a pair of complementary driver transistors, Q3 and Q4. The driver transistors drive the class-B output pair on alternate half cycles.



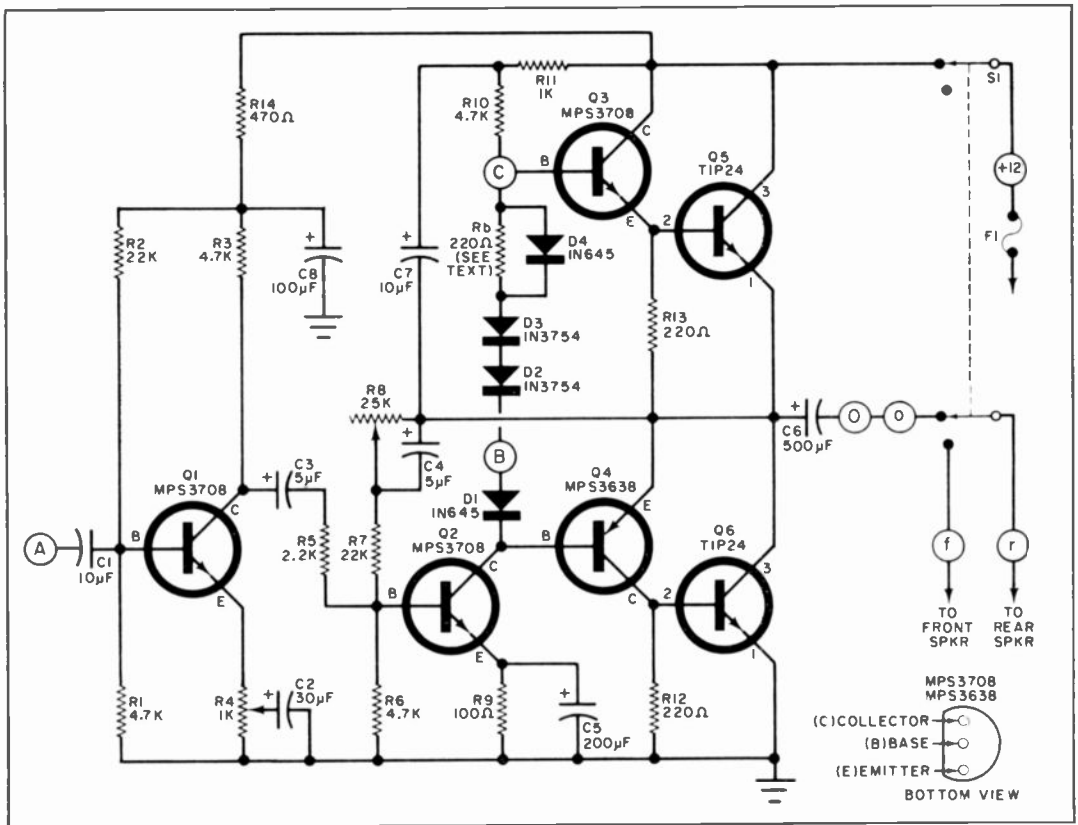


Fig. 2. Schematic diagram shows the simple solid-state high-gain amplifier required to compensate for the audio signal in the reverberation springs. The amplifier has a 3-watt output and is powered by 12 volts d.c.

The diodes between the base of  $Q_3$  and the base of  $Q_4$  provide a small forward voltage bias to prevent crossover distortion and also provide temperature compensation. Diodes  $D_2$  and  $D_3$  are in direct physical contact with the output stages, as shown in Fig. 3. Any heating which would increase output transistor idle current is quickly sensed by the diodes. The heat reduces the diode voltage drop, reducing the transistor forward bias and idle current.

The reverb system's gain is controlled by  $R_4$  and the fader ( $R_{16}$ )— $R_4$  for the coarse settings and the fader to make variations to suit the taste of the listener. The amplifier is efficient and draws only about 10 mA with no signal input. At full 3 watts output, the current is 0.4 to 0.5 ampere.

**Construction.** To make the system small but still easy to assemble, the amplifier is built on an etched board and the whole

system is housed in a specially designed case. (See Fig. 4). If you follow the instructions, there should be no construction problems.

Begin by mounting the power transistors and diodes in the rear of the case. Use a  $6-32 \times 1\frac{1}{2}$ " screw, with a shoulder washer on the outside of the case and a mica spacer between the inside of the case and the transistor mounting flange. Be sure to coat both sides of the mica washer with silicone grease to insure good heat transfer.

The 1N3754 bias diodes are pushed into their clips and mounted with the same screw that holds the transistors. The diode leads are insulated from the case, so the clips can contact the transistor mounting tab. Turn the diodes so that the red cathode identification dots are opposite each other. Cut the lower leads and solder them together—cathode of one to anode of the other—as shown in Fig. 3. Mount the terminal strip next

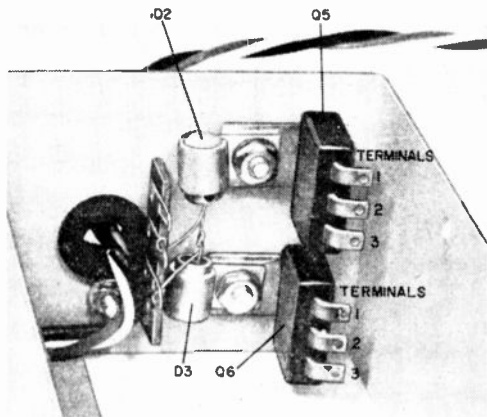


Fig. 3. The npn output transistors are of unusual construction and have not previously appeared in ELECTRONICS HANDBOOK projects. Each transistor is bolted to the chassis wall along with biasing diodes D2 and D3. You must follow this plan.

to the diodes and connect the remaining two leads to the center and lower lugs. Check for possible shorts between the transistors and case.

Now mount the fader control and reverb unit. Wire the leads for the front speaker, radio input, and ground to the fader control. Dress the wires behind the reverb unit and to the case bottom,

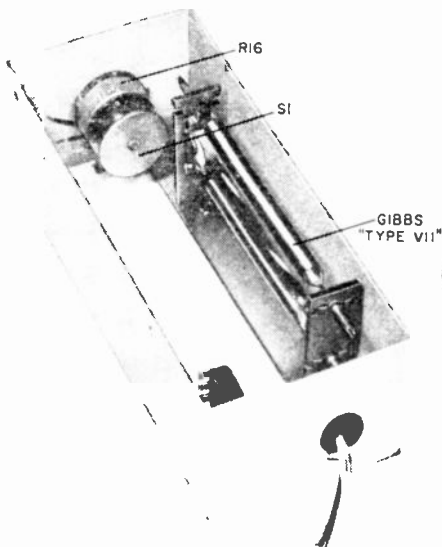


Fig. 4 (above). Due to the intense interest in this project, a special mounting case is available.

install the grommet, and bring the wires out through the grommet.

Mount the various parts on the circuit board (Fig. 5) as indicated by the printed part numbers (see p. 62). Be sure the electrolytic capacitors and diode are mounted with correct polarity. Solder leads to Q5 and Q6 as shown in Fig. 3. Connect wires to points +12V and *r*, for the power and rear speaker, and to *B* and *C* for the bias diodes. Use a piece of lamp cord or equivalent to wire the rear speaker.

Connect the ground side of the rear speaker to the board's ground strip near the output transistor connection. Do *not* attempt to use the frame of the car for the ground lead to the rear speaker—this can result in noise and even circuit oscillation. Connect a short piece of hook-up wire to point *f*. Connect the green lead from the reverb unit's output (red coil) to point *A* and the green lead from the input to point *E*. Be sure all wires and connections are soldered.

Mount the circuit board on the side of the case (Fig. 6) with  $\frac{1}{4}$ - $\frac{1}{10}$  x  $\frac{3}{8}$ " machine screws. Be sure the switch knob slides between the plates at the rear of the fader control. Use quarter-inch spacers between the case and the circuit board. Connect the wire from point *f* to the

Fig. 5 (below). View of partially completed printed circuit board shows location of some of the components. The numbers alongside C6 pertain to connections to transistor Q6.

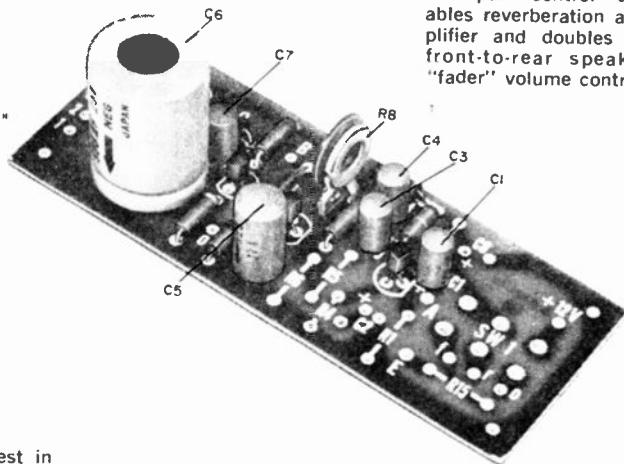


Fig. 6 (right). Photo of the completed unit. Push-pull control disables reverberation amplifier and doubles as front-to-rear speaker "fader" volume control.

arm of the fader control. Mount a soldering lug under the mounting screw at the bottom front of the board, and connect it to the black wires from the reverb unit coils and to the ground side of the fader control, using a short piece of bare wire.

Connect the leads from the board to the power transistors. The numbers on the board and the transistors must match: 1 to 1, 2 to 2, etc. Connect the wire from point *C* to the upper (unused) lug on the terminal strip. Install  $D\frac{1}{4}$  and  $Rb$  on the terminal strip and, observing polarity, the other end to  $D3$ 's anode. Connect a wire from point *B* to the cathode side of  $D2$  on the terminal strip. Connect a lead at +12V and run it out through the grommet in the rear of the case to the fuse holder. (This in-line type holder can be picked up at an auto supply house, and is used with a half-ampere Slo-Blo fuse.) Label the leads—to protect the transistors.

**Installation.** The circuit is designed to work with an ungrounded front speaker. If one side of your speaker is grounded at the speaker frame rather than at the radio, simply clip the ground lead and splice on a piece of wire for connection to the reverb unit. Be sure the car has

4- or 8-ohm speakers. (There are some 40-ohm systems around which require a matching transformer from the radio to the reverb unit.) Also, be sure the speaker is not "hot." Some speakers have 12 volts on the leads.

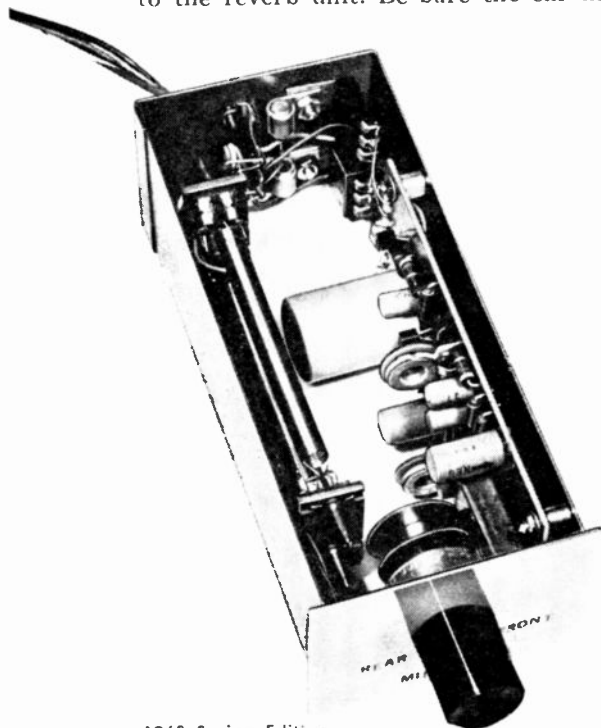
Connect the +12-volt lead from the fuse holder to the radio, or connect it to the accessories terminal on the ignition switch. Connect the ground lead to an unpainted screw or to some other point that you are sure is a good ground on the car's frame. Connect the lead from point *f* on reverb input to the front speaker. Run the two rear speaker wires to the rear speaker.

Turn the radio on, with the reverb unit knob pushed in. The control should vary the volume of the front and rear speakers as it is turned, with near-zero volume on the front speaker at the extreme rear position, and vice versa. Now pull the fader knob out. You should have about the same volume as before with  $R\frac{1}{4}$  set for full gain (the resistor is partially bypassed by  $C2$ ). Sound will probably be best with a bit less volume on the rear speaker when the system is in the reverb position. Set the fader control in the center position and adjust  $R\frac{1}{4}$  for the most pleasing rear speaker level.

The reverb unit cover can be fastened under the dash with sheet-metal screws, or mounted through the dash and held by the fader control bushing.

**Testing.** The system will work quite well without exact circuit adjustments. You can, however, get lower distortion and slightly greater output if you have the proper equipment to make a few tests.

Resistor  $Rb$  is specified as 220 ohms. This is slightly lower than the best value but safe in all cases. A slightly higher value may reduce crossover distortion. To check for the proper value, connect a milliammeter (VOM) in the +12-volt lead. Short the meter leads and turn on the amplifier. Unshort the meter leads and read the idle current. Now short  $Rb$  with a clip lead and watch the meter reading. If it drops between 5 and 10 mA, the value of  $Rb$  is okay. If the drop is less, increase the value of  $Rb$  to 270 ohms, and check again. The initial current reading should not be more than 15



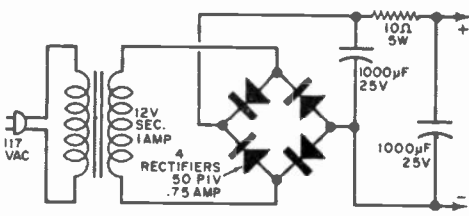


Fig. 7. This simple power supply will enable the builder to operate his Mini-Verb off the 117-volt a.c. lines. All components are easily purchased.

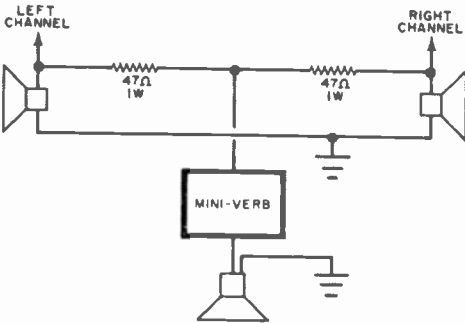


Fig. 8. Reverberation in your home calls for using the Mini-Verb as a third channel. Mixed signal from the right and left channels is derived as shown in this diagram. See text at right for more information.

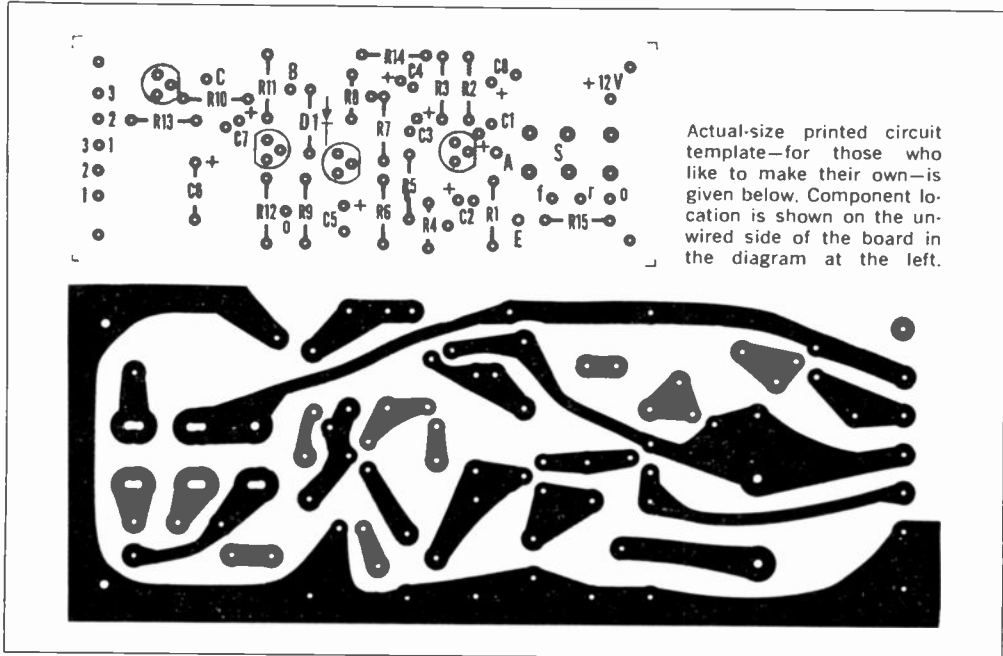
mA, and  $R_b$  must not be increased past the value that gives a 10 mA increase in current.

You can adjust  $R_8$  in either of two ways. If you have only a voltmeter, it can be set for a reading of +6 volts at the emitter (terminal 1) of  $Q_5$ . If an oscilloscope and signal generator are available, drive the amplifier to full output (clipping level) with a 4-ohm load at about 1 kHz and adjust  $R_8$  for symmetrical clipping of the observed waveform.

**“Stationary” Applications.** To use the “Mini-Verb” with your high fidelity system (or public address equipment), you will need a 12-volt power supply that can deliver 500 mA with good regulation and low hum. A typical circuit is shown in Fig. 7.

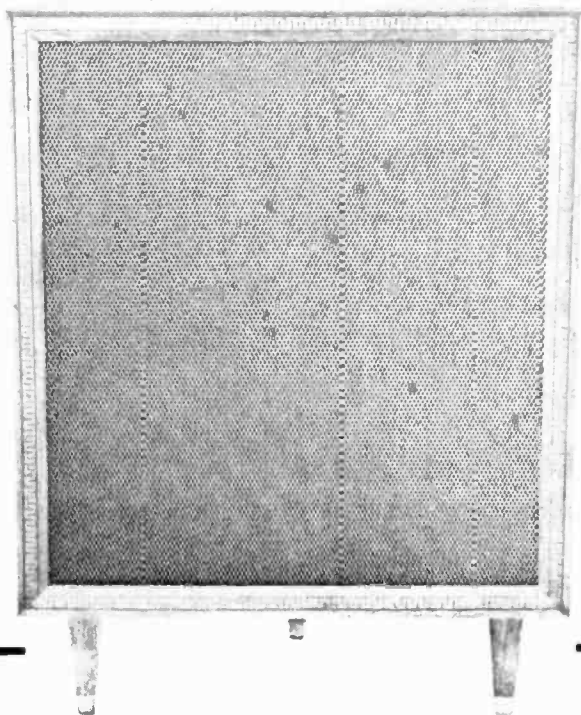
To use the “Mini-Verb” with your stereo system, follow the circuit of Fig. 8. (The resistors should be about 47 ohms, 1 watt; reduce the resistance if reverb volume is too low.) This circuit will give you a driving signal that contains information from both channels. Little separation remains in reverberation sound, so two channels are unnecessary in the reverb system.

-30-



Actual-size printed circuit template—for those who like to make their own—is given below. Component location is shown on the unwired side of the board in the diagram at the left.

# THREE-CORNER SPACE SAVER



TRIANGULAR ENCLOSURE GIVES  
SPEAKER SYSTEM TOP-QUALITY  
HI-FI SOUND

By **DAVID B. WEEMS**

**U**NTIL STEREO SOUND became popular about eight years ago, use of the triangular-shaped corner speaker system was quite common among hi-fi enthusiasts who wanted top-quality sound reproduction. Today, it is a rare home that has a corner speaker system—the triangular enclosure has all but disappeared from the hi-fi scene. Yet this type of enclosure is considered by many speaker system experts to be superior to the limited-volume rectangular or bookshelf designs that have replaced it.

G. A. Briggs of Wharfedale Wireless Works in England, one of the foremost authorities on loudspeakers and speaker system design, rates the triangular enclosure as one of the two best designs (see Enclosure Design Table). According to him, the triangular enclosure insures maximum bass response in the average listening room. This type of enclosure can maximize speaker system efficiency and, if carefully constructed, will occupy little more than a cubic foot of floor space.

**ENCLOSURE DESIGN TABLE\***

TYPE	ACOUSTIC MERIT
Triangular	10
Hexagon	9
Concrete Column	10
Average Cabinet	7
Circular Pipe	5
Slimline	5
Cube	3
Sphere	1

\*From *More About Loudspeakers*, G. A. Briggs, 1965, page 102.

Because the triangular enclosure is so highly rated by Briggs, the author designed the speaker system to be described here. The "Three-Corner Space Saver" is a slightly modified version of the system presented on page 97 of Briggs' book, *More About Loudspeakers*. To avoid compromising sound quality, a pair of Wharfedale speakers was used in the enclosure. The speakers selected account for the slight variation in dimensions between Briggs' system as described in his book and the hi-fi speaker system presented here.

The "Three-Corner Space Saver" derives its name from its characteristic design and the fact that it requires so little floor space. But any way you slice it, this system will perform as well as, and possibly outperform, many more expensive hi-fi speaker systems on the market today.

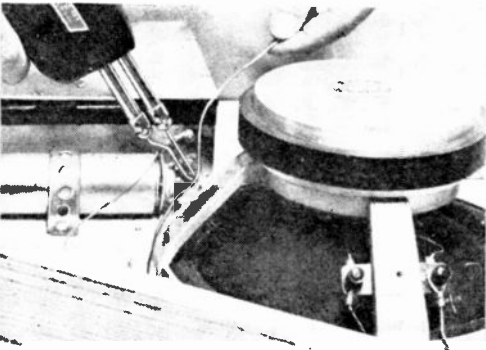


Fig. 1. Full-range "Super 10" speaker has heavy cast aluminum basket to minimize support resonance. Large 7-lb magnet extends bass response.

**The Speakers.** The fullest possible frequency response is obtained from the system through the use of the moderately priced Wharfedale speakers. A Model "Super 10" 10"-diameter full-range speaker reproduces the bass and mid-range frequencies, while a 3" Model "Super 3" tweeter provides more than adequate response in the high frequency range. Paired together in a well-designed enclosure, these two speakers provide a smooth response over virtually the entire audio frequency spectrum.

The "Super 10" shown in Fig. 1 sports a big 7-lb. ceramic magnet, and the speaker has a characteristic free-air resonance of somewhere between 38 and 43 Hz. The "Super 3" tweeter, shown in Fig. 2, also has a large (3-lb.) ceramic magnet; high frequency cutoff is 20 kHz on the average. Both speakers have cast aluminum baskets that reduce the possibility of undesirable support resonance.

Since the tweeter, like the full-range speaker, has an open back, it requires a separate enclosure, designed to reduce diffraction of the high frequencies. This simply means that the front of the tweeter board must be chamfered around the speaker mounting hole. However, the Wharfedale people have eliminated the necessity of fashioning this board since the "Super 3" is shipped mounted to a board that can be used as the front of the tweeter enclosure as shown (left in Fig. 2).

**The Enclosure.** An almost complete absence of parallel surfaces is perhaps the most favorable feature of the triangular enclosure design. (The top and bottom surfaces, although parallel to each other, are such small areas that they can be disregarded.) Without parallel surfaces to bounce the sound around, standing waves are minimized and the enclosure is less apt to "peak" or favor a given band of frequencies.

The triangular enclosure used for the "Three-Corner Space Saver" speaker system contains a port that tunes the system, providing extended low-frequency response. Since the port is located in the bottom rear of the enclosure, the additional space between the bottom of the enclosure and the floor acts as an expanded port.

Construction of the enclosure is quite simple, as can be seen from the drawings in Fig. 3. However, it is almost a necessity that you have a power saw equipped for making angular cuts to properly mate the speaker board to the front of the enclosure.

To make the cutout for the port (small triangular shape at apex of top view

the top plate, and align the right-angle corners flush with each other (there should be  $\frac{3}{16}$ " distance between the front edge of the top plate and the front edges of the sides). Draw the interior outlines of the sides and side cleats on the top plate, and remove the bottom-side assembly.

Cut two pieces of  $\frac{3}{4}$ " x  $\frac{3}{4}$ " clear pine; one  $14\frac{1}{4}$ "-long, the other  $13\frac{3}{4}$ "-long. Glue and nail these top cleats in place along the side outlines on the top board. After applying wood cement to the outer surface of the cleats and the top edges of the sides, set the top in place, and drive  $1\frac{1}{2}$ "-long wood screws through the top cleats and into the enclosure sides.

Cut the ends of two  $21\frac{1}{4}$ " pieces of  $\frac{3}{4}$ " x  $\frac{3}{4}$ " clear pine at a  $45^\circ$  angle, and glue and nail these to the top and bottom of the enclosure, each end touching opposite side cleats. The outer edges of the cleats should now be  $\frac{3}{4}$ " in from the front edges of the top and bottom of the enclosure.

Secure the port wall in place, and mount the legs. The only dimension of the legs that is somewhat critical is their length—6 inches. Otherwise, they can be square, round, tapered, or any other shape that suits your fancy, and they can be located as desired.

Prepare the small sealed enclosure for the "Super 3" tweeter, using the dimensions given in Fig. 2 as a guide. The front of the enclosure will be the board on which the tweeter was shipped to you, as mentioned earlier, and the sides and back should be  $\frac{1}{4}$ "-thick plywood or hardwood board. Before sealing the tweeter enclosure, however, drill a small hole through one of the sides of the enclosure, bring out the tweeter wires, and line the walls with  $1\frac{1}{2}$ "-thick fiberglass or cotton batting. Then fill the hole around the tweeter wires with cement to make an airtight seal.

Prepare the speaker board as shown in Fig. 3, front view. Smooth the front surface and walls of the speaker cutout with medium emery cloth, and apply a coat or two of flat black paint. When the paint dries, glue and screw the front and side braces, orienting them approximately as shown in Fig. 4

Sand and stain or paint all exterior surfaces of the enclosure.

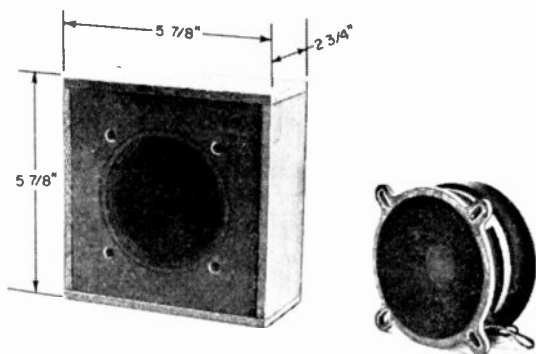


Fig. 2. An enclosure (left) must be used with "Super 3" tweeter (right). Speaker mounting hole should be chamfered to reduce high-frequency diffraction.

drawing), measure  $5\frac{3}{4}$ " from the  $90^\circ$  corner along the adjoining sides, draw a straight line connecting the two measurement points, and cut along this line. Discard the small triangular piece, but save the remaining piece of plywood for later use as the bottom of the enclosure.

Glue and nail a side cleat flush with one of the longer edges of each side plate (see Bill of Materials for dimensions). When the glue sets, cut the cleated edges of both side pieces at a  $45^\circ$  angle. To do so, place the saw against the uncleated side, or outer wall, and angle the saw blade toward the edge opposite the cleat.

Except when securing the speaker board and decorative trim to the front of the enclosure, use wood cement liberally between all surfaces to be joined.

Glue and nail the sides together as shown in the top view drawing, and set the side assembly on the bottom plate (plywood board with port cutout), recessing it  $\frac{3}{16}$ " in from the front edge of the bottom plate. Glue and nail the sections together.

Invert the bottom-side assembly onto

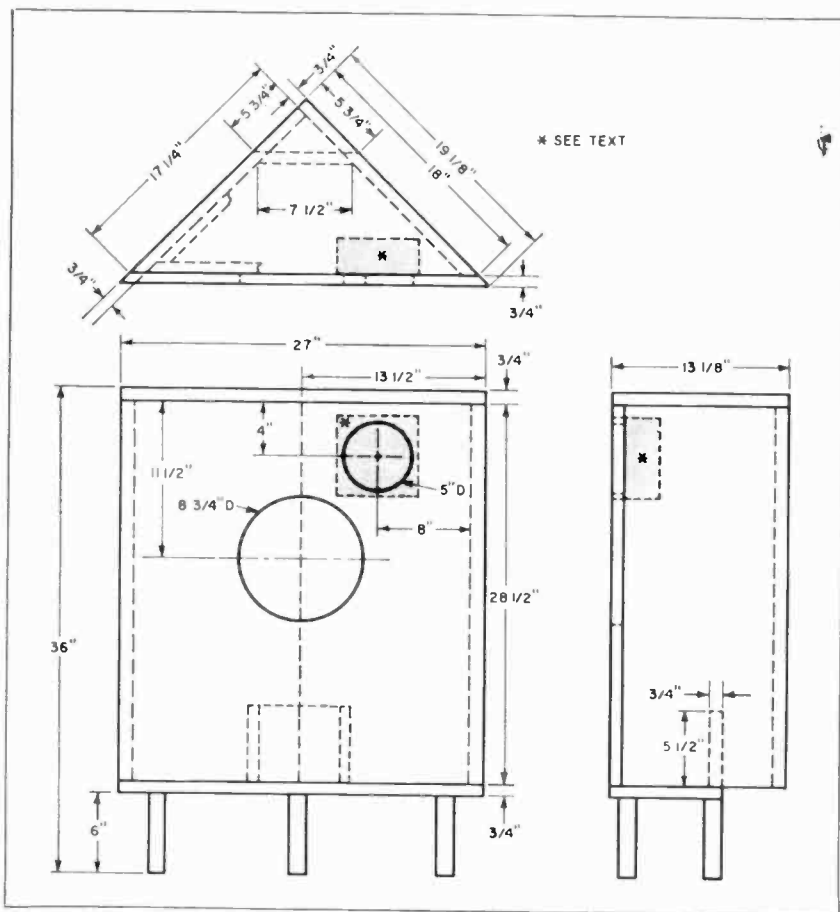


Fig. 3. Mating surfaces between speaker board and sides of enclosure (as well as port front) must be cut at 45° angles to insure proper mating of parts and airtight seal.

### BILL OF MATERIALS

- 1—27" x 28½" piece of ¾" fir plywood for speaker board
- 1—18" x 28½" piece of ¾" fir plywood for side
- 1—17¼" x 28½" piece of ¾" fir plywood for side
- 1—19½" x 19½" piece of ¾" fir plywood, cut diagonally, for top and bottom
- 1—5½" x 7½" piece of ¾" fir plywood for port
- 2—2½" x 5¾" pieces of ¼" plywood for tweeter enclosure top and bottom
- 2—2½" x 5¾" pieces of ¼" plywood for tweeter enclosure sides
- 1—5¾" x 5¾" piece of ¼" plywood for tweeter enclosure back
- 2—28½" lengths of ¾" x 1½" clear pine for side cleats\*
- 2—22" lengths of ¾" x 1½" clear pine for side braces\*
- 1—20" length of ¾" x 1½" clear pine for front brace\*
- 1—14½" length of ¾" x ¾" clear pine for top cleat\*\*

- 1—15¾" length of ¾" x ¾" clear pine for top side cleat\*\*
- 2—21¼" lengths of ¾" x ¾" clear pine for front top and bottom cleats\*\*
- 3—6"-long legs—see text
- 1—Wharfedale Model "Super 10" 10-inch full-range speaker (Allied Radio No. 20-8173X, \$47.50)
- 1—Wharfedale Model "Super 3" 3-inch tweeter (Allied Radio No. 20-8185X, \$26.50)
- 1—2-μF paper or oil-filled capacitor
- Misc.—#8 x 1½" flat-head wood screws (72), #8 x ¾" flat-head screws (8), 1½" finishing nails, 1" wire brads, wood cement, grille cloth or expanded aluminum mesh, picture frame molding for decorative trim, open-weave black cloth, felt strips (4), fiberglass or cotton batting, speaker wire, mounting bolts for woofer (4), solder, etc.

\*Sold as 1" x 2" clear pine

\*\*Sold as 1" x 1" clear pine



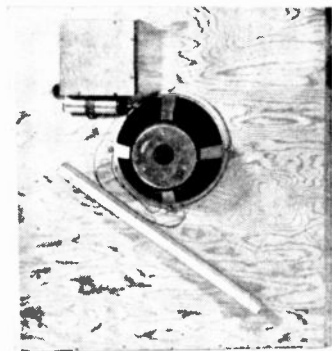
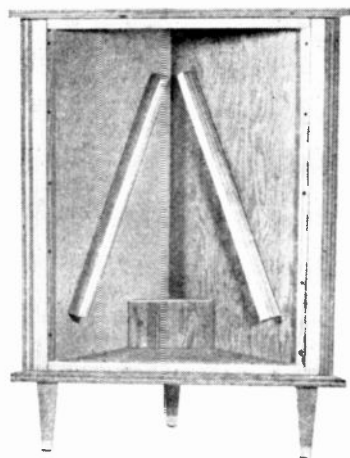


Fig. 4. After constructing enclosure and mounting speakers in place, glue and screw appropriate length braces to speaker board (above) and sides of enclosure (right). Brace locations are not critical.



Symmetrically orient the tweeter assembly over its hole and secure it in place with glue and screws. Use a metal strap to mount the  $2\text{-}\mu\text{F}$  capacitor near the full-range speaker. Now install the woofer, using four bolts ( $\frac{3}{16}$ " x  $1\frac{1}{2}$ " flat-head).

Finally, line the entire interior of the enclosure with 1"-thick (or more) damping material, such as cotton batting or fiberglass, and glue a strip of felt to each of the front cleats.

**Installation.** Wire the speakers and capacitor exactly as shown in the schematic drawing (Fig. 5). The red wire from the tweeter must go to the positive terminal of the full-range speaker for proper phasing.

Set the speaker board in place on the

front of the enclosure, and screw it down. The screws should be located 4" apart around the front, or speaker board, to insure the proper seal.

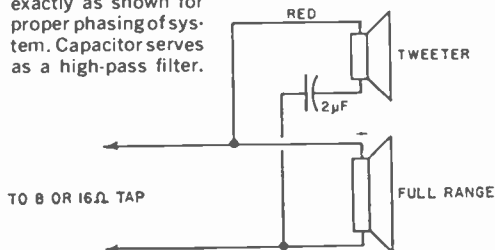
Cover the entire front surface of the speaker board with open-weave black cloth, and tack the cloth in place. The picture frame molding selected for the decorative trim should be cut to size with mitered corners that can be joined together with glue and only one finishing nail through each corner.

Speaker grille material or expanded aluminum mesh can be used to attractively set off the front trim. Tack the grille cloth or aluminum mesh to the trim, and mount the assembly on the front of the enclosure with small wire brads.

Connect the speaker cable to the 8- or 16-ohm output terminals on your amplifier—either tap will do. Set the speaker system in a corner, turn your amplifier on, and start a record spinning. If the bass is too "throaty" or deep, pull the system out from the wall until you are satisfied with the way it sounds. If you want to, you can even set it out in the middle of the room and still get good hi-fi reproduction.

You'll be surprised at the superior quality of sound possible with the "Three-Corner Space Saver" speaker system—so surprised that you'll want two (one for each channel) if you have a stereo system.

Fig. 5. Wire speakers exactly as shown for proper phasing of system. Capacitor serves as a high-pass filter.



# BUILD THE "2 + 2" REMOTE VOLUME CONTROL

By LYMAN E. GREENLEE

...AND CONTROL AUDIO DEVICES  
FROM UP TO 50 FEET AWAY

**D**O TV AND RADIO commercials irritate you? If so, you can build a remote volume control that will let you reduce or blank out the sound from up to 50 feet away, and the whole thing will cost about \$2 and require just 2 hours of work. With a remote volume control, you don't have to leave your easy chair or make an extra trip to the TV set when the telephone rings. Simply flip a switch or set a control.

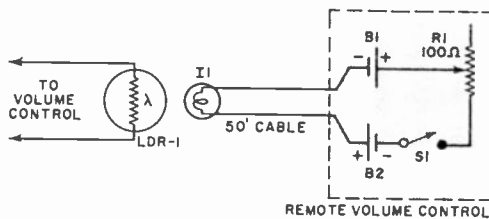
The "2 + 2" remote volume control gets its name from the cost and construction time. Once built, it can be connected to your set in a matter of seconds and can be removed just as quickly. While connected and turned off, it has no detectable effect on the normal operation of the set, nor can it cause any damage or introduce hum.

Light-dependent resistor *LDR1* in the schematic diagram is the heart of the "2 + 2." It is optically close-coupled to a controlled intensity lamp (*I1*) that causes an increase or decrease in the resistance of *LDR1*. The intensity of the light is dependent on the amount of current flowing through *B1*, *R1* and *B2*, and it can be increased or decreased by varying the setting of *R1*. Any increase or decrease in the intensity of the light results in a corresponding decrease or increase in the resistance of *LDR1*.

Although *B1* and *B2* develop a total potential of 3 volts, there is little danger of burning open the 2-volt ( $\pm 48$ ) lamp since the maximum current through the circuit is limited by the d.c. resistance of the 50'-long twin-line cable connecting *B1* and *B2* to *I1*.

To use the "2 + 2" remote volume

control in your TV set, radio, or phonograph amplifier, simply clip one of the leads from *LDR1* to the wiper lug and the other to the signal ground lug of the set's volume control. With the "2 + 2" turned off, adjust the set's volume control for the desired maximum loudness. Then operating the "2 + 2" will reduce the volume from this point.



Lamp *I1* and light-dependent resistor *LDR1* must be mounted in light-tight box. Parts in shaded area are contained in separate box at remote location.

The batteries, switch and potentiometer can be mounted in any convenient size box. However, *LDR1* and *I1* should be hooked in a small i.f. transformer can to take up as little space as possible and facilitate easy sealing with tar or pitch to exclude outside light.

The bottom of the transformer can should be cut to make the can about 1 $\frac{3}{4}$ " long, but leave enough metal to provide a pair of  $\frac{1}{8}$ " tabs on opposite sides (bottom) of the can. Mount *LDR1* on a 1" x  $\frac{3}{4}$ " piece of phenolic board, set it at the bottom of the transformer can, and fold the tabs over to hold it in place. If necessary, enlarge the hole in the top of the can, and mount *I1* and a  $\frac{3}{4}$ " rubber grommet here. Finally, seal the can. -50-

# Build The “CINDERELLA”

By DAVID B. WEEMS

*Half-cubic foot sealed enclosure costs under \$10*

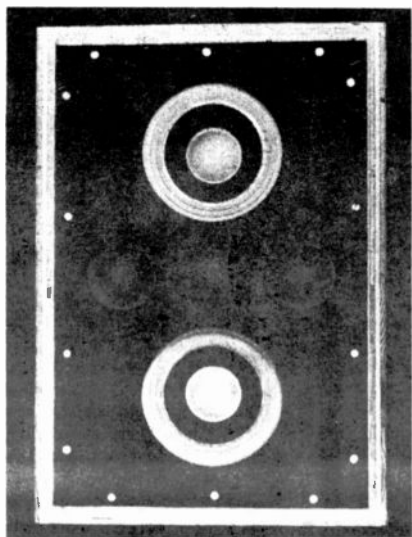
IF YOU'RE thinking of putting down \$30 or more for one of those department store "no name" speakers in a box, wait. Here is a little hi-fi speaker system that can save you money and will probably sound better. At least you will know what went into the box! And you won't find a similarly well-constructed enclosure with a good-quality small speaker system on the market for anything like this price. If your idea of what \$10 will buy in speaker systems is based on what was available just a few years ago, the *Cinderella* system will amaze you.

The secret of the *Cinderella* is in the design and construction of its XS-5052 woofer. This woofer's distinctive qualities are noticeable in two ways. The first is the obvious visual differences between it and a normal 6-inch speaker. Second, and more important, there is a distinct aural difference, which can be made apparent by a frequency test run.

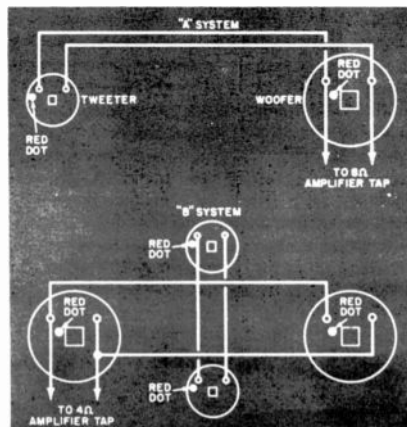
**Test Results.** I set one of these woofers on my workbench and hooked it up for the usual bass resonance frequency test, starting downward from 200 cycles. Although most 6-inch speakers resonate at about 120 to 150 cycles, a few "hi-fi" 6-inchers have a bass resonance of around 70 cycles, and, frankly, that is where I expected this woofer to fall. Low resonance is the crucial characteristic for woofers to be used in small sealed enclosures; the restricted air volume in such systems will raise the point of resonance.

My eyes were glued to the oscilloscope screen as the audio generator dial passed 70 cycles, then 60. Not until 48-49 cycles did the voltage across the speaker reach a peak, indicating resonance. A remarkably low frequency for a \$4 speaker.

The remainder of the system consists of a small cone tweeter with its self-contained capacitor which acts as a high-pass filter, and an enclosure that occupies



Front view of an experimental "B" system built by the author to test front and side panel vibration. This enclosure was built using cleats and screws, unlike the plans on page 50. Fir plywood was also used and the enclosure covered with a plastic veneer. It was determined that gluing and nailing of the panels would be adequate if care was exercised in fitting the panels together. A grille cloth was later installed to protect the speakers. Wiring of the "B" speaker arrangement is shown below. Try the 8-ohm tap instead of the 4-ohm output of your amplifier if the bass response seems a little thin.



Be sure to follow this wiring diagram to keep the speakers in phase. Once the enclosure is sealed, you may find it fairly difficult to change the wires.

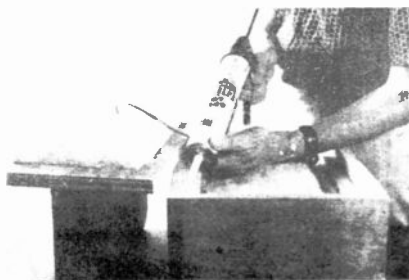
though they seem to be thoroughly sealed by glue. The caulking material can be purchased in a cylinder for use with a gun, or in a squeeze tube. Most building supply stores have guns to loan, but some rent them. Force the caulking material along the joint and wipe away excess with a rag so it won't flow onto the speakers.

The speakers are mounted and wired as shown in the diagram. The back should be drilled to allow speaker connections to pass through. The wires can be brought out through a small hole which is later filled with caulking material or sawdust and glue, but a better method is to use small bolts as connectors through the back.

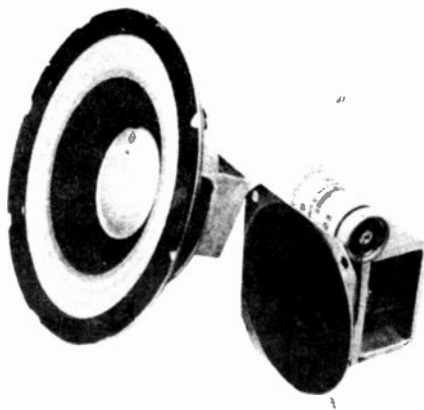
Padding is extremely important in a small sealed enclosure. Tests indicated that the *Cinderella*'s resonance could be lowered 10 cycles or more and the bass range greatly extended by the use of proper padding. The whole interior of the model shown is lined with a 1-inch layer of fiberglass. You can get fiberglass from most electronics stores; a common size measures 1" x 24" x 60", enough for two cabinets. Cut the fiberglass to fit all interior surfaces, except the front baffle, and secure it in place with tacks or glue. Then fold the remainder of your sheet of fiberglass so that it will fit into the enclosure loosely. This should fill the enclosure.

Now fasten the back in place with the screws specified, hook the *Cinderella* up to your amplifier, and try on the "glass slipper." That, naturally, is a suitable wide range program source. When you do, you'll be glad you didn't settle for a pig in a poke.

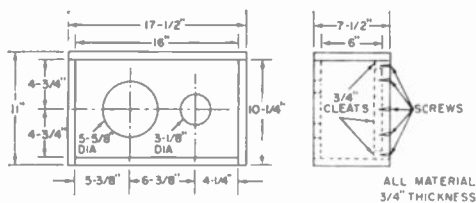
-30-



After filling cavity behind speakers with padding, cleats should be caulked and back-nailed into place. The usual household caulk works out just right.

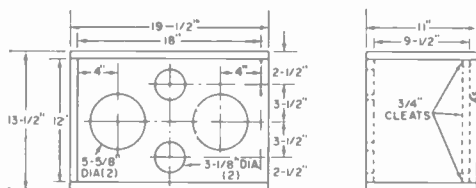


Six-inch woofer costs only \$3.95 but has surprising low end response. Tweeter is not sold separately.



"A" SIZE ENCLOSURE  
FOR ONE WOOFER-TWEETER PAIR

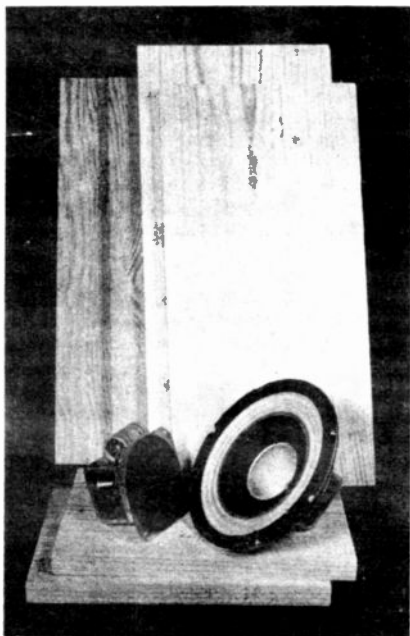
ALL MATERIAL  
3/4" THICKNESS



"B" SIZE ENCLOSURE  
FOR DUAL WOOFER TWEETER COMBINATION

ALL MATERIAL  
3/4" THICKNESS

Most builders may be satisfied with single woofer-tweeter combination, but dual system sounds better.



The Cinderella enclosure is caulked and sealed, requiring use of sturdy front, top, back, and side panels. The author was satisfied with 3/4-inch pine.

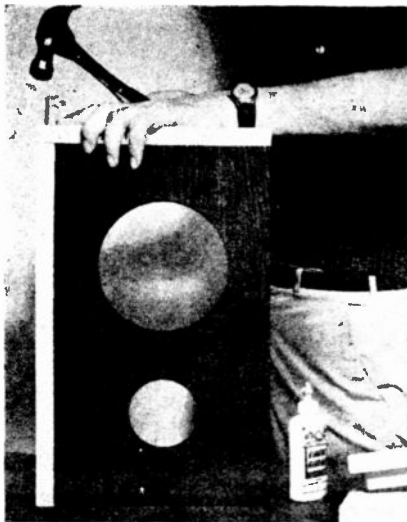
### BILL OF MATERIALS

A System—Total cost, \$10

- 1—Woofer-tweeter combination (Stock No. XN-TS-63, McGee Radio Co., 1901 McGee St., Kansas City 8, Mo.; woofer available separately as XN-5052 for \$3.95)
- 2—0 1/2" x 16" pieces of 3/4" fir plywood for front and back
- 1—7 1/2" x 17 1/2" piece of 3/4" clear pine for top (1 x 8)
- 1—7 1/2" x 16" piece of 3/4" clear pine for bottom (1 x 8)
- 2—7 1/2" x 10 1/4" pieces of 3/4" clear pine for sides (1 x 8)
- 2—1/2" x 9 1/2" pieces of 3/4" pine (side cleats for back)
- 2—3/4" x 14 1/2" pieces of 3/4" pine (top and bottom cleats for back)
- 12—#8 x 1 1/4" wood screws for back
- 8—#6 x 1/2" sheet metal screws for speakers
- 1—1" x 24" x 30" sheet of fiberglass
- Misc.—#6 finishing nails (1/2 lb.), caulking material, glue, and grille cloth

B System—Total cost \$18

- 2—Woofer-tweeter combination (Stock No. XN-TS-63, McGee Radio)
- 2—12" x 18" pieces of 3/4" fir plywood for front and back
- 2—11" x 19 1/2" pieces of 3/4" fir plywood for top and bottom
- 2—11" x 12" pieces of 3/4" fir plywood for sides
- 2—3/4" x 12" pieces of 3/4" pine (side cleats for back)
- 2—3/4" x 16 1/2" pieces of 3/4" pine (top and bottom cleats for back)
- 14—#8 x 1 1/4" wood screws for back
- 16—#6 x 1/2" sheet metal screws for speaker mounting
- 1—1" x 24" x 60" sheet of fiberglass
- Misc.—#6 finishing nails (1/2 lb.), caulking material, glue, and grille cloth



Nail side to bottom and front of the enclosure. Good fit and a liberal use of glue are important.

only  $\frac{3}{4}$  sq. ft. of shelf space. The system is called the *Cinderella* because, while it bears no apparent pedigree, it does show inborn quality. For example, even in the small enclosure, the *system* resonance is a little over 70 cycles. The transient response is surprisingly good for a low-cost system. As in all small sealed enclosure systems, efficiency is lower than in a large system, but a 7-watt amplifier supplied all the sound you would want in a very large but very live room. The *Cinderella* is rated at 12 watts.

**Budgeting Your Money.** The enclosure is sturdy, contains sufficient damping material, and is thoroughly sealed. Any one of these features may be missing from a department store box. For the skeptic, here is a rundown of how to budget your money to build the *Cinderella* "A" system for only \$10.

Speakers	\$6.90
Plywood for front and back	.55
Pine for top, bottom and sides	.75
Screws	.26
Glue	.25
Fiberglass	.66
Caulking material	.20
Nails	.06
<b>Total</b>	<b>\$9.63</b>

That leaves 37 cents to squander on grille cloth and trim. You can use screen molding for trim (as I did—15 cents for a cabinet) and decorator burlap will serve as grille cloth at 49 cents a yard (17 cents). If anyone mentions finishing the wood, you will find that 5 cents is still available, and that is just about the amount of shoe polish I used to stain and "oil finish" the model shown. For very little more, you can use a veneer plastic, such as Contact. Or choose a hardwood if you want fine cabinetry.

The sound can be improved by putting two sets of the woofer-tweeter combination (\$12.95) in one "B" size cabinet (see page 52) at a cost of about \$18. Used in multiples, these little speakers sound even better. There is more solidarity in the bass and somewhat smoother sound throughout the whole spectrum. Also, the impedance curve tends to flatten out when two woofers are hooked in parallel.

In buying material, note that the  $\frac{1}{2}$ " x 7 $\frac{1}{2}$ " pine shown in the drawing is, of course, what lumber yards sell as "1 x 8". When you have cut all parts to the specifications shown, set them up as in the finished enclosure. At this time you can trim any of them that do not fit satisfactorily. One of the economies in this system, in time as well as money, is the avoidance of many cleats which would require the use of extra screws, nails, and glue. The nailing system shown in the diagram is quite adequate for such a small enclosure, but a good fit is necessary.

**Construction.** Begin construction by nailing the bottom to the front, using plenty of glue between these two parts. Next, nail one end to the bottom and front. Continue with the other end, and finally nail down the top to the sides and front.

The cleats for the back can now be attached, using glue and nails as with the exterior parts; but if you use the same kind of nails, they must be cut just short enough so they will not penetrate the outer surface of the sides and top. A somewhat easier method is to use a different nail, such as sheet rock nails which have a large head and are the correct length.

The joints should be caulked even

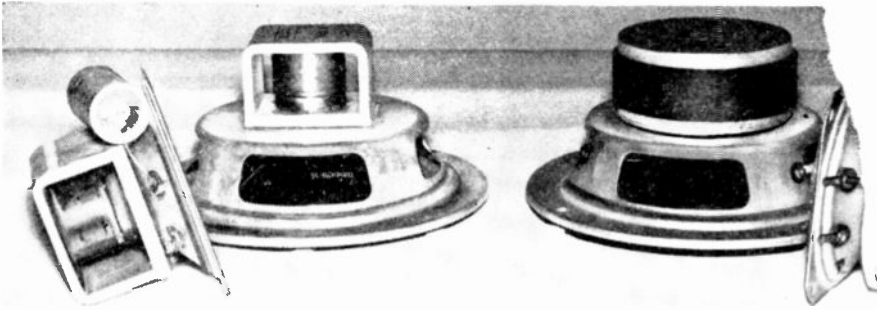


## “PRINCESS CINDERELLA”

BUILD THE UP-RATED  
VERSION OF THE  
CINDERELLA BOOK-SHELF  
HI-FI SYSTEM

By **DAVID B. WEEMS**

**T**HE HALF-CUBIC FOOT sealed enclosure called “Cinderella” (described in the 1966 Fall Edition of this **HANDBOOK**) was a reasonable example of what \$10 will accomplish if you build your own hi-fi speaker system. Inside the original “Cinderella” enclosure was a 6” woofer and a miniature cone tweeter. Both speakers could be purchased for just under \$7. The 6-inch woofer had a very flexible suspension and a 5-oz. magnet.



Both earlier model speakers (left) had 4.6-ounce alnico V magnets; improved model speakers (right) have 10-ounce magnets in tweeters and 20-ounce magnets in woofers for superior damping and transient

During the intervening two years, an improved woofer has been developed with a 20-oz. magnet. This magnet weight is rarely found in small speakers—at least those with a diameter of less than 8 to 10". You can build a "Princess Cinderella" speaker enclosure using this new woofer for about \$15.

Although the size of the enclosure must be increased, this new system is still classified under the category of *small bookshelf systems*. The sound it can produce will compare favorably with many similar size units that sell for as high as \$40.

**New Speakers.** The really interesting characteristics of the original "Cinderella" woofer was that the cone suspension was free enough to allow a fundamental resonance between 45 and 50 Hz. The woofer in the "Princess Cinderella" has a somewhat more rugged suspension and the free air resonance has been measured by the author to be about 60 Hz. Since this 10-15 Hz increase in fundamental resonance would be detrimental in a

sealed enclosure, the author has designed the "Princess Cinderella" as a ported enclosure. Simultaneously, the use of a port has raised the efficiency of the overall system while the increased magnet weight has provided superior damping and transient response.

The top end response of the system has also been extended. Efficiency of the tweeter has been improved due to the use of a 10-oz. magnet. The roll-off at the high end of the audio spectrum appears to be around 17,000-18,000 Hz.

**The New Enclosure.** A somewhat larger volume enclosure is required to compensate for the alterations in the woofer cone suspension. As in the original "Cinderella" system, rigidity of the enclosure is critical. (Continued on page 142)

### PARTS LIST

- 1—Woofer (McGee Radio Co. Model SX-6071)
- 1—Tweeter (McGee Radio Co. Model TS-6070)
- 2—10" x 14" pieces of 3/4" fir plywood for speaker and rear boards
- 1—15 1/2" x 9 1/2" piece of 3/4" pine shelving for top
- 1—14" x 9 1/2" piece of 3/4" pine shelving for bottom
- 2—10 3/4" x 9 1/2" pieces of 3/4" pine shelving for sides
- 1—4 1/2" x 3/4" x 3/4" piece of pine for cleats
- 1—5-ft. length of 1/2" quarter-round molding for trim
- Misc.—=6 x 1 1/2" finishing nails, =8 x 3/4" sheet metal screws, =8 x 1 1/4" flathead wood screws, steel brads, grille cloth, glue, wire, etc.

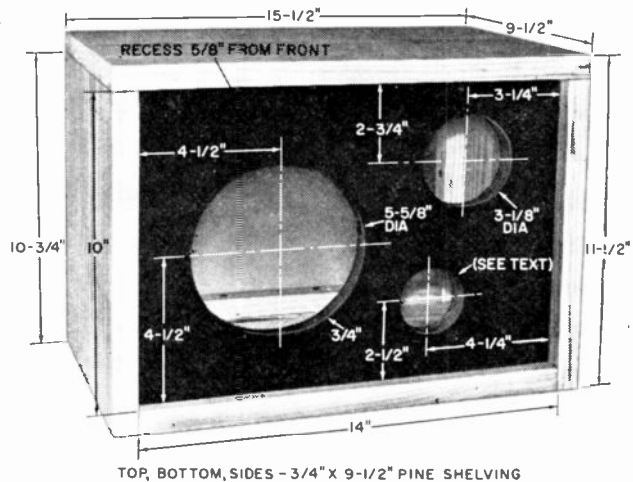


Fig. 1. Dimensioning of speaker board is critical. Speaker hole sizes are given, but outer diameter of mailing tube selected determines size of port hole.



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# CHAPTER 3

## SPECIAL FEATURE

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# ABC'S

## of JUNCTION TRANSISTORS

ONCE YOU UNDERSTAND  
HOW THE JUNCTION TRANSISTOR WORKS,  
TROUBLESHOOTING BECOMES EASY

BY BOB BARKLEY

**O**NE OF THE MAJOR problems most experimenters encounter when working with transistor circuits is—what should be the polarity and levels of the d.c. voltages at each of the three transistor leads? In the case of some commercial equipment, the various voltages are indicated on the schematic for a particular item. In most cases such information is lacking.

However, if you have a basic understanding of how semiconductor junctions—and, therefore, junction transistors—work, you can use this knowledge and a reasonably high-input impedance voltmeter to solve this problem and a number of other troubleshooting problems. This article will not make you a solid-

state expert, but will go a long way to enable you to understand just what is going on in semiconductor circuits.

### BASIC JUNCTION THEORY

Most solid-state devices function as a result of the electrical characteristics of their junctions—two semiconductor materials, usually *n*- and *p*-types, that make intimate contact with each other. Before a transistor—or almost any other solid-state device—can be understood, several fundamental facts covering basic junction theory must be known.

(1) Junctions can control current flow through themselves with external help (called bias).

(2) Junctions can be biased in two ways: forward-biased (with battery polarity the same as the semiconductor materials), as shown in Fig. 1(a), where a lot of current can flow through the junction; and reverse-biased (with battery polarity opposite to that of the semicon-

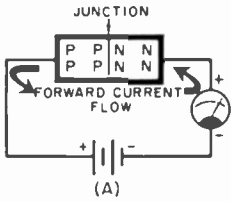
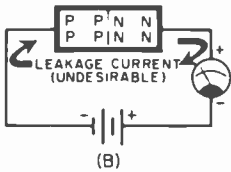


Fig. 1. The two methods of biasing a junction—(a) forward, (b) reverse.



ductor materials), as shown in Fig. 1(b), where no current should flow through the junction. In the latter case, if any current does flow, it is called leakage current and is not desirable.

(3) The type of bias tells the junction to turn on—or off.

(4) With no bias applied to the junction, no current should flow through it.

(5) If the forward bias is increased, the junction turns on heavily and a lot of current should flow.

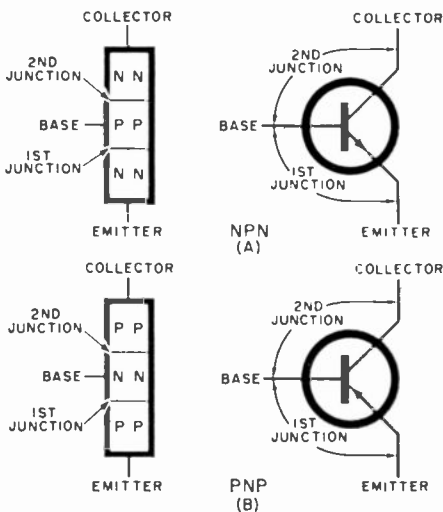


Fig. 2. Most transistors consist of two junctions.

**Junction Transistors.** These transistors are fabricated by making a “sandwich” of two junctions, and can be arranged in two ways—the *npn* method as shown in Fig. 2(a), or the *pnp* method as shown in Fig. 2(b).

Basic biasing techniques for both types of transistors when used as a common-base amplifier are shown in Fig. 3. Note that in both cases the first junction (emitter-base) is forward-biased and the second junction (base-collector) is reverse-biased. This reverse bias should not be

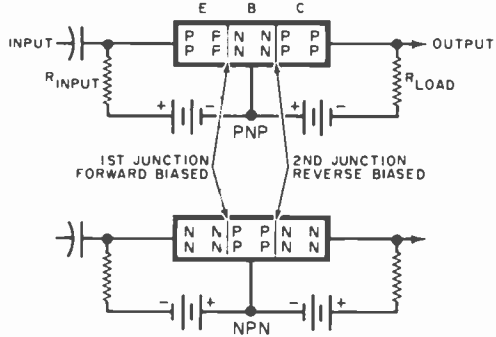


Fig. 3. Old method of biasing uses two batteries.

so large as to present the possibility of breaking down the junction.

Current flow through the two types of junction transistors is shown in Fig. 4. An understanding of this concept will help in troubleshooting transistor circuits later on.

In both types of junction transistor circuits, all the current originates at the emitter. Once it crosses the first junction (emitter-base), the current divides, with a small amount going into the base circuit and a larger amount passing through the collector circuit.

Note that in the *pnp* transistor diagram (Fig. 4), mention is made of “hole” flow. Please do not fight the concept of “hole” current flow, but accept it as a current flow as real as that of electrons. All current flow begins at the emitter and must go through the first junction (emitter-base) for proper distribution to the base and collector. The forward bias on the first junction controls the amount of current flowing through it.

The arrow in the transistor symbol always points to the negative side of the power supply. In an *npn* transistor,

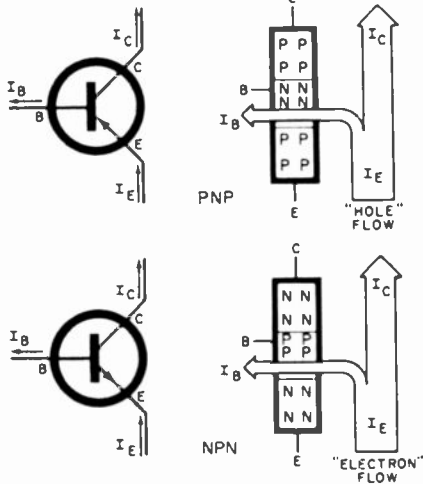


Fig. 4. How current flow divides in a transistor.

both base and collector are positive with respect to the emitter, and a positive-going signal at the base (input) produces more forward bias on the first junction (base-emitter) and produces more current flow through the transistor. In an *pn*p transistor, both base and collector are negative with respect to the emitter, and a negative-going signal applied to the base (input) increases the forward bias on the first junction and thus increases the current flow through the transistor.

**Basic Bias Methods.** Correct bias is the key to the operation of the junction transistor. As previously explained, there are two types commonly used—forward and reverse bias. For proper operation of the transistor, forward bias must be obtained on the first junction (emitter-base), and reverse bias on the second junction (base-collector). Broadly speaking, there are two bias methods—the two-battery bias and the single-battery bias.

The two-battery bias method is used in most textbook discussions of the junction transistor, and is usually shown only for a grounded base circuit (because of simplicity of explanation). It is the oldest method devised and uses two power supplies as shown in Fig. 3. In practice, this method is seldom used.

There are several variations in using a single battery to provide the necessary

bias for a transistor. All are simple, and can provide the necessary forward and reverse bias required by the transistor. The reverse bias for the second junction (base-collector) is obtained first and in the same way for all approaches. The variations are in the methods devised to obtain the forward bias for the first junction (base-emitter) from the same power source used to get the reverse bias for the second junction.

The matter is simplified if you remember that in an *npn* transistor both the collector and base must be positive with respect to the emitter; and in the *pn*p type the base and collector must be negative with respect to the emitter.

The first variation in single-battery biasing is called "constant current without compensation" and the reverse-biasing of the second junction is shown in Fig. 5(a). For a *pn*p transistor, simply reverse the battery polarity. Base bias is obtained as shown in Fig. 5(b). Note that the base bias resistor is connected from the base directly to the battery. The fact that this voltage is taken directly from the battery where the d.c. voltage is constant accounts for the "constant current without compensation" expression.

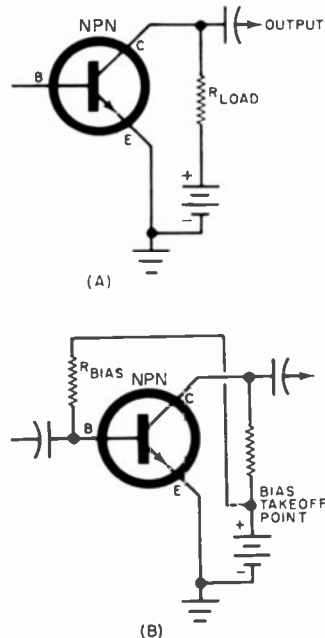


Fig. 5. How a single battery can bias a transistor.

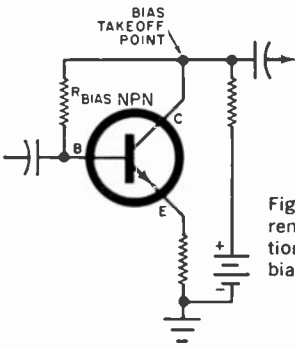


Fig. 6. Constant current with compensation method takes base bias from collector.

The second variation in single-battery biasing is called "constant current *with* compensation," and a typical circuit is shown in Fig. 6. This variation places the base bias resistor between the base of the transistor and its collector. As the collector voltage varies with signal, so does the base bias.

The third variation is called "voltage divider without compensation" and a typical circuit is shown in Fig. 7(a). The forward bias for the base is obtained from a voltage divider network consisting of  $R_1$  and  $R_2$  connected in series across the battery. This voltage divider is connected *directly* across the battery; that is why it is called a "without compensation" biasing system.

If the voltage divider is connected between the collector and ground, with the junction of  $R_1$  and  $R_2$  going to the base—the fourth variation—the biasing is

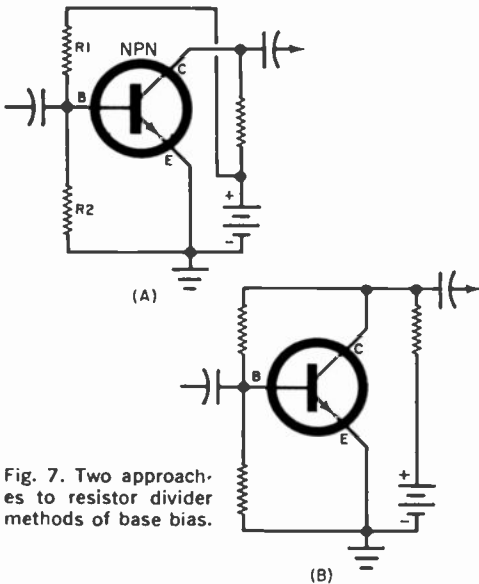


Fig. 7. Two approaches to resistor divider methods of base bias.

called a "with compensation" method. If the collector voltage changes, so does the base bias. This method of biasing protects the transistor in the event that the collector voltage changes drastically.

The fifth variation found in single-battery biasing provides a degree of stability and allows you to substitute transistors which may have different characteristics from that used originally in the circuit. This method actually provides an amount of reverse bias for the first junction, and some external circuit must provide enough forward bias to overcome this reverse bias in order to make the first junction (base-emitter) become properly forward-biased. Such a system, called the "emitter resistor method," is shown in Fig. 8 and consists of a resistor connected in series with the

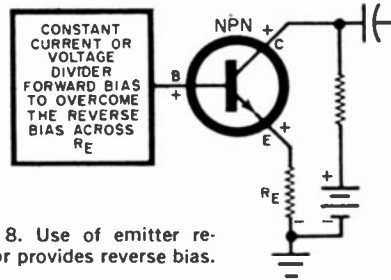


Fig. 8. Use of emitter resistor provides reverse bias.

emitter. The voltage developed across this resistor is actually a reverse bias for the transistor and some level of forward bias must be applied to the base circuit (from the external circuitry) so as to overcome the reverse bias introduced by  $R_E$  and enable the circuit to operate properly.

The sixth variation is actually a combination of the other methods. Figure 9(a) illustrates constant current without compensation using an emitter resistor for stability; (b) shows constant current with compensation using an emitter resistor for stability; (c) is a voltage divider without compensation using an emitter resistor for stability; and (d) is a voltage divider with compensation using an emitter resistor for stability.

**Thermal Runaway and Stability.** The bias methods covered in the preceding paragraphs enable the first junction to be forward-biased. To maintain the correct bias when the transistor temperature

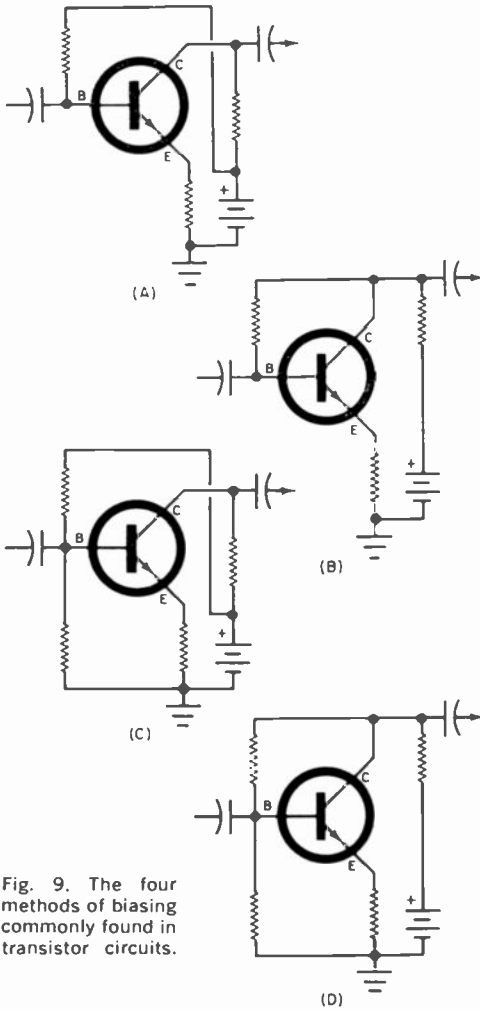


Fig. 9. The four methods of biasing commonly found in transistor circuits.

risers, or when a substitute transistor having slightly different characteristics is used, requires some form of thermal runaway compensation.

The first method to be described is called "d.c. bias compensation" and is provided by obtaining the base bias voltage directly from the collector of the transistor as shown in Fig. 9(b) and (d). In these circuits, as the collector current begins to "run away" (increase greatly), the voltage at the collector drops. The drop in voltage is also reflected back at the base, and tends to reduce the collector current through the transistor. This "runaway self-defeating" measure prevents the collector current from getting off to a fast start and thus ruining the transistor. To prevent a.c. feedback from causing the transistor

stage to oscillate due to the action of the feedback resistor, in many cases the feedback resistor is split into two portions and the center junction is coupled to ground through a bypass capacitor as shown in Fig. 10.

The second method of preventing thermal runaway is the use of emitter biasing as shown in Fig. 8. Placing a low-valued resistor in the emitter lead of a transistor produces a reverse bias for the base-emitter junction. If the collector current starts to increase rapidly due to thermal runaway, the voltage drop (and hence the reverse bias) developed across the emitter resistor increases. This, in turn, brings the collector current down, and stops the current run-

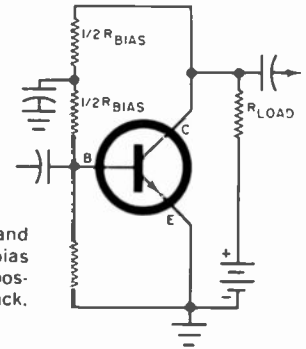


Fig. 10. Dividing and bypassing base bias resistor reduces possibility of feedback.

away. The use of an emitter resistor in this fashion also allows the substitution of transistors having somewhat different gain characteristics, as the bias developed across the resistor automatically adjusts to different transistors.

The third method of thermal runaway compensation requires the use of a bias diode, and is called "diode compensation." Because the voltage drop across a diode decreases with a rise in temperature, a so-called bias diode can be used as part of the base bias voltage divider as shown

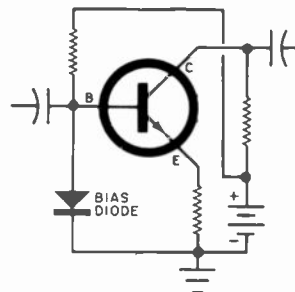


Fig. 11. Diode compensation is often used for stability.

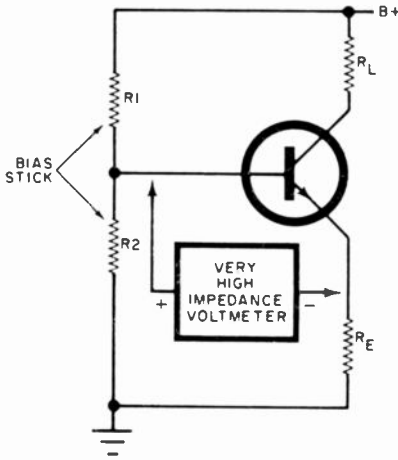


Fig. 14. Method of measuring forward bias voltage.

shown in Fig. 14. No current will flow through a good junction transistor until the first junction is forward-biased properly. If this junction ever becomes reverse-biased, the stage will cut off.

Two practical in-circuit tests can be made to find the condition of the junction transistor; (1) the cutoff test (decrease in current flow test); and (2) the forward gain test (increase in current flow test).

The first test can be applied to see if the transistor is capable of decreasing the amount of current flowing through the first junction. It should be capable of stopping all current flowing through the first junction, or go to cutoff. This test is performed by connecting a short circuit between the emitter and base of the transistor. All current will then flow through the short.

If no current flows through the first junction (because it is shorted out), then nothing is left to go to the collector. (Current must cross through the first junction to go to the collector.) Shorting effectively removes the forward bias and all current flow through the junction transistor should go to zero; and a voltmeter across a resistor in the emitter or collector circuit should show a very definite drop in voltage.

If the voltage across the resistor goes to nearly zero, the transistor is capable of controlling the current in one direction—toward cutoff. If the voltage across the resistor drops very little, the transi-

tor is faulty, has leakage, or is shorted, and should be replaced.

This test should be applied if the forward bias is too large, to see if the transistor can control current flow through the first junction in the cutoff direction, to check leakage ( $I_{cbo}$ ), or if a shorted transistor is suspected.

The second test (see Fig. 15) is applied to see if the junction transistor is capable of increasing the amount of current flowing through the first junction. This test should be capable of doubling the normal current flow as a minimum. You place a test resistor, equal in value to the bias resistor, in parallel with the bias resistor to increase the forward bias. A good junction transistor will conduct much harder. And a voltmeter across a resistor in either the emitter or collector circuit will show a definite increase in reading, indicating that the transistor is passing more current.

In constant-current biasing, there is only one bias resistor. You should have no trouble finding it. In voltage divider biasing, the top resistor of the voltage divider is the correct resistor to parallel.

If the voltmeter reading increases, the transistor has forward gain and can control the current flow in the forward direction. If the voltmeter reading does not increase, the transistor is bad, leaky, shorted, or saturated.

The cutoff test and the forward bias measurement (reading too high) will verify a condition of saturation. If the transistor is not saturated, then it has leakage or is shorted and should be replaced.

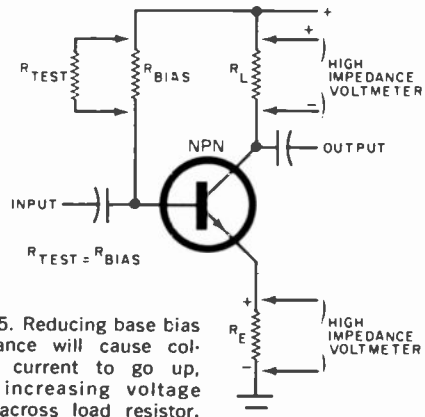


Fig. 15. Reducing base bias resistance will cause collector current to go up, thus increasing voltage drop across load resistor.

“Saturation” means that the first junction is too far forward-biased and the collector current cannot increase any more. The forward bias must be corrected in the supporting circuitry.

“Shorted” means that the junctions have broken down and cannot control the current flow through the transistor. The transistor behaves like a piece of wire and must be replaced.

“Leakage” means that the junctions are beginning to break down and cannot effectively control the current through the transistor. The unit should be replaced.

These tests can be performed by using a current monitor meter in one side of the power supply (as shown in Fig. 16) if a very high impedance voltmeter is not available. If, after the tests are per-

In dealing with shorts or opens, solder blobs and wiring errors must be cleared by visual inspection and all components must be checked. Open components can be found by signal tracing or injection in the signal path.

No device or troubleshooting chart will work if you do not apply some common sense while using it. *You* are the most important device of all. Use good old horse sense, and you will find your problem—and its solution. The chart is just an aid.

**Type of Meter Required.** To obtain useful meter indications for troubleshooting, a meter with at least the following four characteristics must be used:

(1) Since junction transistor circuits are very small to begin with, do not

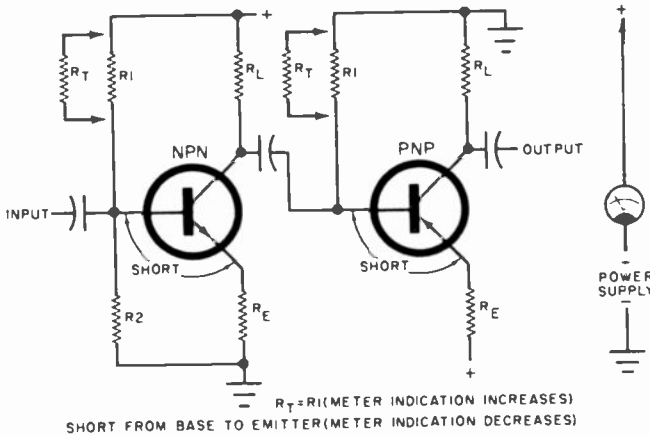


Fig. 16. Saturation and cutoff tests will determine if transistor is good.

formed and the transistor is found to be all right, the fault most likely is in the supporting circuitry.

**Supporting Circuitry Faults.** A troubleshooting chart, such as that shown on page 82, is a useful device for finding certain types of supporting circuitry faults. The most useful meter readings—from a very high-impedance meter—and the trouble area are given in the chart.

Circuit faults can be placed in two categories: (1) opens (usually found in transformers, printed circuit boards, capacitors, or caused by wiring errors); and (2) shorts (found in transformers, or caused by bad soldering or wiring errors).

complicate matters by trying to read a meter scale which is too small. Get one with a scale as large as you can afford. A 4" or larger meter scale is recommended.

(2) The probes for the meter should have a needle or piercing point for the tips. Clip-on types are highly recommended; they have the piercing point and can be clipped onto a component lead or wire, leaving your hands free to perform tests.

(3) To measure the forward bias on the first junction, the meter requires a 0 to 0.5 and a 0 to 1.5 volt range—full scale. Both ranges are needed but only on d.c. volts.

(4) The signal-type transistor will be forward-biased on the order of 50 to 100

## TRANSISTOR TROUBLESHOOTING CHART

Defect	Base Voltage to Reference	Normal Bias Voltage From Base to Emitter	Voltage From Collector to Emitter	Collector Current Flowing*
Open in base circuit	wrong	no	yes	no
Open in emitter circuit	correct	no	yes	no
Open in collector circuit	correct	yes	no	no
Open lead in transistor	correct	high	yes	no
Leakage in transistor	correct	no (depends on leakage)	yes (depends on leakage)	high
Shorted coupling capacitor	wrong	no (probably forward biased)	no	high

\*Voltage drop across collector load is measured.

$\mu$ A. When a meter is used to measure the voltage in such a circuit, and the meter draws current from the circuit, the circuitry may be upset. The ideal

meter draws no current from the circuit it is used on. A meter with a very high input impedance is needed, and there are three types of meters available which have this characteristic:

- (a) VTVM-tube type, with 11 to 22 megohms input impedance on d.c.
- (b) VOM-taut-band movement, with a sensitivity of 1 to 10  $\mu$ A full scale (up to 1 megohm per volt).
- (c) TVM, or transistor voltmeter, which uses a field-effect transistor or a special high-impedance input circuit to produce an input resistance equivalent to a tube type VTVM.

### TROUBLESHOOTING SUMMARY

Isolate the faulty stage by means of signal tracing with an external detector, signal injection with an internal detector, a current monitor meter, or a combination of any of these methods.

Check the first junction forward bias for germanium or silicon transistors, signal or power types.

Determine if the fault is a transistor problem by performing cutoff and saturation tests.

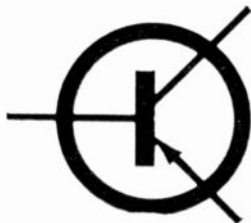
Determine if the fault is in the circuit by checking the wiring and testing components.

Use a voltmeter having a large viewing scale (4" or larger is recommended), a 0.5- and 1.5-volt d.c. range, and a very high input impedance.

Use meter probes that have a needle or piercing point for insulation penetration. Clip-on probes will leave the hands free.

**In Conclusion.** At this point you have all the basic information needed to troubleshoot junction transistor circuits. Read this article often, and underline specific points that have special meaning for you. And use common sense when troubleshooting.

Junction transistors can be fun to work with if you know what they're doing. -30-





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# CHAPTER

## 4

### COMMUNI- CATIONS

### SWL

### CB & HAM

What is the "first" project of most electronics hobbyists? We feel a survey would show that a simple broadcast-band or short-wave receiver would rank pretty high. Some of the reasons for building a receiver are obvious: the project when completed does something, mistakes are relatively easy to spot, and a receiver is the type of project from which you learn something about electronics. This chapter has two receiver projects—both battery-operated and both about as fool-proof in construction and operation as you can find anywhere. Both receivers use the field-effect transistor which, for all means and purposes, can be considered the modern-day version of the pentode tube.

Readers might also note the 100-kHz oscillator—L'il Richie (page 100)—which is a prime example of how simple a working electronic circuit can get through the use of an integrated circuit. Last—but not least—if you're a CB'er, read Dan Meyer's comments on tuning up your CB transmitter; this article explodes some of the myths about modulation power or percentage vs. carrier strength.

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## INTRODUCING THE FET SET

A RADIO RECEIVER WITH A  
POWER DRAIN SO LOW  
THAT IT PLAYS FOR A YEAR  
ON A 6-VOLT BATTERY

**W**HAT IS a FET set? It is an ultra-modern version of the once-popular tube-type regenerative receiver, with the vacuum tubes directly replaced by field-effect transistors—the high-impedance solid-state devices that “think” and act like tubes. The FET set is battery-operated and able to pull in BCB DX stations with more selectivity and sensitivity than you would expect from such a simple circuit.

So, if you have an evening or two to spare, and the \$10-15 required for all the

By JACK ALTHOUSE

parts, you'll be in for a rewarding experience building the FET set. And you'll have the satisfaction of knowing that you are working with the very latest member of the transistor family—the FET.

**How It Works.** The theory of operation of the field-effect transistor is discussed in detail in the February, 1967, issue of *POPULAR ELECTRONICS* (page 47) and is summarized later on in this article.

The circuit for the FET regenerative receiver is shown in Fig. 1. Field-effect transistor  $Q1$  functions as a regenerative detector in a Hartley circuit arrangement, while  $Q2$  operates as an audio amplifier.

Signals at the antenna appear across  $L1$ , and the desired frequency selected by tuning capacitor  $C1$  is induced in  $L2$  and applied to the gate of  $Q1$ . Since the circuit is regenerative, a portion of the signal at the drain is fed back to

the gate. The amount of feedback is controlled by *C3*. The FET is self-biased by *R1*, bypassed by *C2*. Coil *RFC1* eliminates r.f. from the output circuit.

The detected audio is developed across *R2* and is coupled to the gate of *Q2* through capacitor *C4*. Transistor *Q2*'s gate is returned to ground through *R3*, while *R4*, bypassed by *C5*, provides self-biasing for this transistor. The amplified audio at *Q2*'s drain is reproduced by the magnetic headphones.

**Construction.** The author's FET set is housed in a 7" x 5" x 3" aluminum box, with the tuning and regeneration controls mounted on the front panel. If you like this arrangement, begin construc-

tion by first laying out and drilling mounting holes for the tuning dial (*C1*), regeneration control (*C3*), and *L1-L2* coil form, and the circuit board, following the general arrangement shown in Fig. 2.

Then cut out a suitable sized slot through the top of the box to mount the terminal strip (*TS1*) that serves to connect the battery, headphones, and antenna to the receiver. Make sure there is enough clearance so that *TS1*'s terminals won't ground out against the chassis. Now lay the box aside temporarily.

Secure a 1"-diameter by 4"-long plastic or cardboard coil form and drill the holes called for in Fig. 3; two holes are required at each end of the *L1* and *L2* windings. Following the instructions giv-

### PARTS LIST

- B1*—6-volt lantern battery
- C1*—Midex 409-pF variable capacitor (Allied Radio 43 B 3524 or similar)
- C2*, *C5*—10- $\mu$ F, 10-volt miniature electrolytic capacitor
- C3*—50-pF variable capacitor (Hammarlund MC-50-S or similar)
- C4*—0.01- $\mu$ F paper capacitor
- L1*, *L2*—See Fig. 3
- Q1*, *Q2*—2N4360 p-channel FET (Fairchild)\*
- R1*, *R2*—22,000-ohm, 1/2-watt resistor
- R3*—470,000-ohm, 1/2-watt resistor
- R4*—10,000-ohm, 1/2-watt resistor
- RFC1*—10-mil r.f. choke (National Radio R-50 or similar)
- TS1*—5-lug terminal strip

- 1 Pair of magnetic headphones, 2000 ohms or higher
- 1—7" x 5" x 3" aluminum box (LMB TF-782 or similar)
- 1—2 1/2" x 3" perforated unclad circuit board
- 22—Push-in terminals (Vector T-28 or similar)
- Misc.—(oil form (4" long x 1" dia.), knobs (2), 1"-long 0-32 threaded spacers (2), 3/4"-long 0-32 threaded spacers (2), ground lugs (2), 6-32 x 1/4" screws (10), 6-32 nuts (2), #26 enameled wire, solder

\*Available from Glassman Electronics, 20 Hampton Rd., Massapequa, N. Y. 11758, at \$1.25 each. Minimum order is \$5; postage paid in U.S.A.

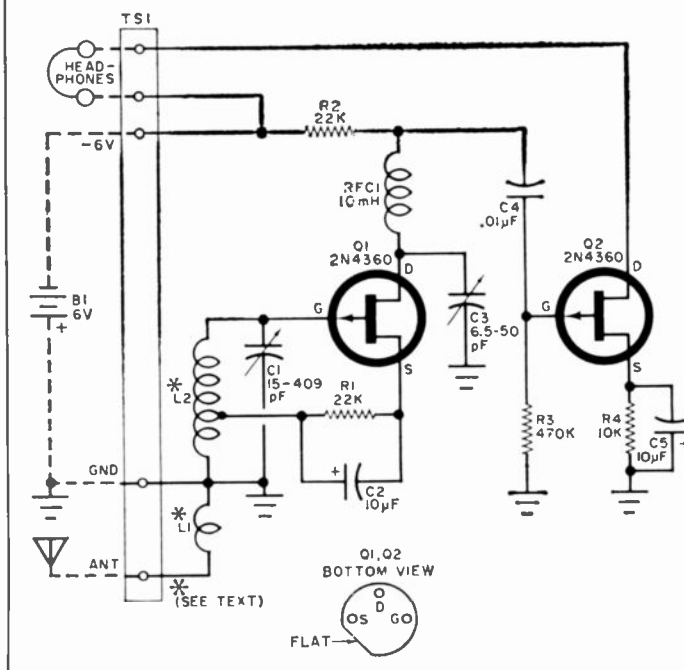


Fig. 1. This FET set schematic shows an updated version of one of the most popular radio receivers of the '30's—the regenerative receiver. Here, field-effect transistors are used to replace the once mighty vacuum tubes.

Fig. 3. To fabricate the antenna/oscillator coil (L1-L2), close-wind the indicated number of turns of  $\#26$  Formvar enameled wire on a 4" length of 1"-diameter polystyrene, phenolic or cardboard form.

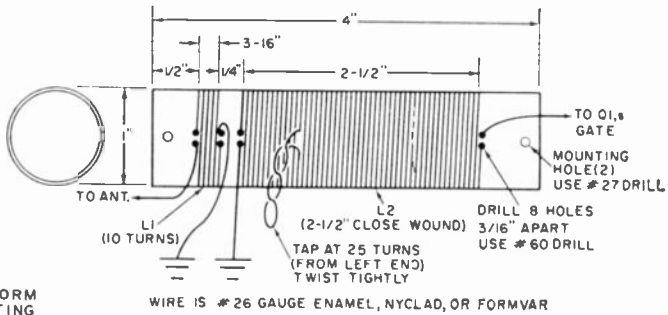


Fig. 2. Start construction by drilling holes in the aluminum box to accommodate the tuning dial shaft and regeneration control. Then drill mounting holes for the circuit board and coil form as shown here.

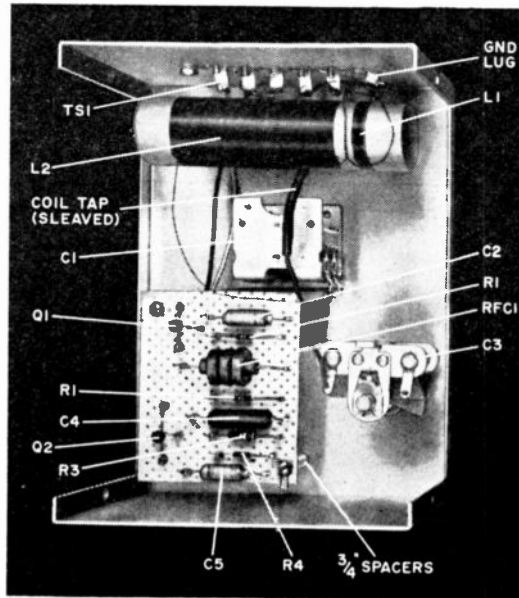


Fig. 4. The parts layout for the FET set is not critical, but the coil should be mounted at least 1 inch away from the metal box to avoid upsetting circuit Q. Mount the circuit board on  $\frac{3}{4}$ " spacers.

en in Fig. 3. wind  $L1$  and  $L2$  on the form. Thread the free end of each lead down through one hole and back up through the other to hold the wire in place. When winding  $L2$ , form a loop about an inch long and twist it together at the 25th turn from the left end; this is your coil tap. Finish winding the coil.

Now refer to Fig. 4 and install the coil in the box, using 1"-long threaded spacers to support it. Do not use any shorter spacers, since the coil must be kept at least this distance from the metal box. Mount the tuning ( $C1$ ) and regeneration ( $C3$ ) controls on the front panel and set the unit aside.

Using Fig. 4 as a guide, assemble the small parts on a  $2\frac{1}{4}$ " x 3" perforated circuit board. Flea clips can be used to

interconnect the leads. Once completed, mount the board on two diagonally-placed  $\frac{3}{4}$ " threaded spacers. Place a  $\#6$  grounding lug under the head of one of the mounting screws, and connect the common bus from the circuit board to this point.

Complete the remaining point-to-point wiring, using the schematic diagram (Fig. 1). After carefully checking your work, connect the battery (observe polarity), headphones, and antenna lead to  $TS1$ . As with any regenerative-type receiver, a good antenna and ground are a must. Use an inverted-L antenna—at least 75 feet long—placed as high as possible above the ground. The set's ground connection should be to a water-pipe.

Since no power switch is provided for the battery, you can only disconnect it by removing its leads from the terminal strip. However, if you use the recommended 6-volt lantern battery, you can get about a year's play out of the radio before having to change the battery. Of course, you can also use a regular 9-volt transistor battery if you wish, but this battery will not last nearly as long. Do *not* operate the FET set at potentials over 9 volts.

Be sure to use the recommended magnetic-type headphones and not a crystal type, since *Q2*'s drain current must return to the source through the headphones. Low-impedance headphones will not provide adequate volume.

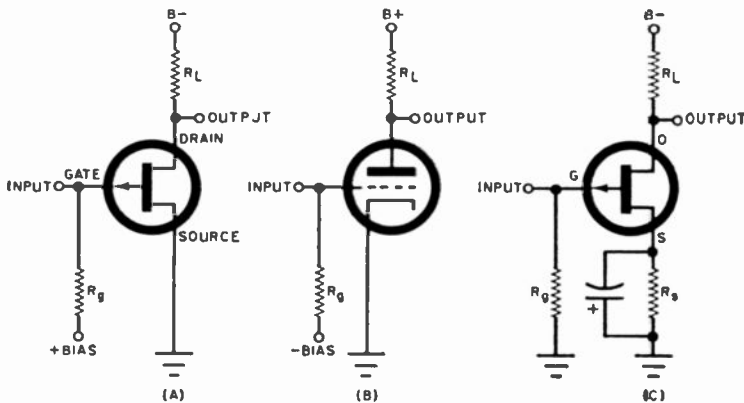
**Operation.** To tune for a station, turn the *regeneration* control fully clockwise while setting your tuning dial. Then slowly turn the control counterclockwise to reduce the amount of regeneration until

the detector quits oscillating. At that point, your station will come in. Now retune the dial slightly to peak the station.

As you tune across the band, the regeneration control will have to be readjusted slightly. On strong local stations, it will have to be turned down considerably to act as a volume control.

**Possible Modification.** After you have become well acquainted with the operation of your FET set, you may want to change *L1* to optimize it for your particular antenna, its location, and reception requirements. For example, if you are getting interference from a strong station over most of the band, remove three or four turns from *L1*. This reduces overloading while increasing the selectivity of the set. If you live in a poor signal area, you can increase the receiver gain by adding about five turns or so to *L1*, or making the antenna longer. -30-

### HOW A FET OPERATES



A field-effect transistor, variously called FET, JFET, IGFET and MOST or MOSFET, does not operate like a conventional bi-polar transistor. Rather, it controls current flow by means of an electrostatic field, and operates more like a vacuum tube—but requires no heater power. It has high-input impedance like a tube, and less circuit loading than a conventional transistor. Other advantages of the FET include lower inherent noise, and greater sensitivity to weak signals.

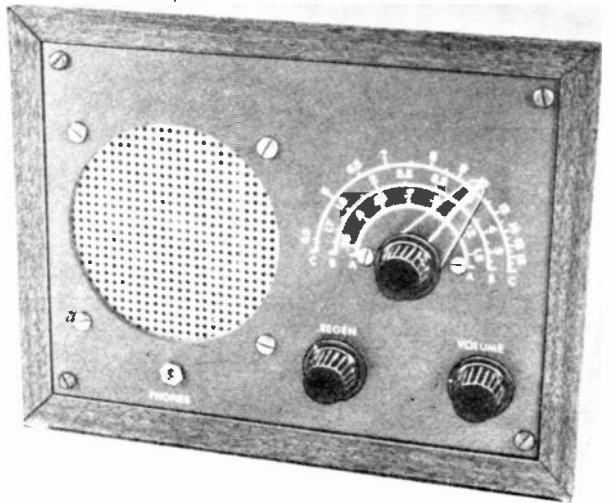
In the diagram above, observe the similarity between a p-channel FET amplifier (A) and

a comparable vacuum-tube amplifier (B). Note the difference in the polarity of the operating voltages. The vacuum tube always requires a plus (+) voltage on its plate, while the p-channel FET requires a minus (-) voltage on its drain, the corresponding electrode.

Observe, also, that the tube operates with a negative grid bias while the p-channel FET operates with a positive gate bias. To avoid the use of a separate bias supply, a self-biasing arrangement can be substituted as shown in (C). This is the scheme employed in the "FET SET" circuit.

# BUILD THE BEGINNER'S FET REGEN RECEIVER

MAKE THIS  
YOUR FIRST PROJECT  
USING  
FIELD-EFFECT TRANSISTORS



By CHARLES CARINGELLA

**P**UT THE WORLD at your fingertips with a simple all-wave receiver that packs a lot of performance in a small package! Build this FET regenerative receiver and tune in DX as well as local broadcast stations. You'll be able to listen to hams, weather broadcasts, standard time signal broadcasts, maritime telephone operators, and many, many other stations on the short-wave bands.

Simplified printed-circuit construction and nominal cost make this receiver an ideal beginner's project. Three bands can be tuned by simply changing plug-in coils—the broadcast band from 0.55 to 1.5 MHz, as well as two short-wave bands from 1.7 to 5.5 MHz and 5.5 to 18 MHz.

Highlight of the all solid-state regenerative receiver is the FET (field-effect transistor) "front end" stage. This is followed by a 5-transistor complementary-symmetry audio amplifier that delivers a room full of audio power to a built-in loudspeaker. The completed receiver measures only 8 $\frac{1}{2}$ " x 6 $\frac{1}{4}$ " x 4".

A vernier drive mechanism, with a tuning ratio of 6:1, is used for easier tuning. An ordinary 9-volt transistor radio battery provides the necessary d.c. power, so the receiver can not only be used at home but is "portable" enough to go camping, on picnics, etc. The unit will also serve as an emergency standby receiver. Since power consumption is low, battery life is quite good.

The receiver will cost about 32 dollars to build if *all* new parts are purchased individually. A savings of about 7 dollars can be realized if the complete "kit" of parts specified in the "Parts List" is purchased.

**How It Works.** The schematic diagram of the FET regenerative receiver is shown in Fig. 1. Transistor *Q1* is of the Texas Instruments 2N3819 n-channel silicon field-effect variety. This is a new low-cost epoxy FET, used as a regenerative detector, which plays a large part in making the sensitivity of this circuit rival that of some superhet communications receivers.

Pre-wound slug-tuned plug-in coils, modified slightly by the addition of a feedback winding and a miniature mounting plug, are used for each of the three bands covered. R.F. signals from the antenna are coupled to the primary winding of *L1* through capacitor *C1*. Variable capacitor *C3* tunes the receiver by resonating with the secondary winding of coil *L1*. A third winding on *L1* provides the necessary feedback for regeneration.

Potentiometer *R1* serves as the regeneration control and determines the amount of a.c. voltage that is fed back through *C2* to the feedback winding on *L1*. For reception of AM signals, *R1* is

adjusted to the point just before the stage "pops" into oscillation. This is the point of maximum sensitivity and selectivity. CW signals, as well as SSB signals, are copied by adjusting  $R1$  so the stage just barely oscillates or regenerates.

The "front end" stage employing  $Q1$  is inherently stable because of the extremely low power dissipation and the rigid mechanical layout of components on the circuit board. Many of the frequency drift problems common to equivalent vacuum-tube circuits are non-existent in this FET circuit. The author has successfully copied "ham" SSB signals with this receiver, a trick that is often hard to perform with many superhets!

The output signal developed by the regenerative detector is a low-level audio voltage. It is direct-coupled through resistor  $R4$  to audio preamplifier stage  $Q2$ , a high-gain, low-cost RCA 40395 germanium *pn*p transistor. Potentiometer  $R8$  is the volume control. Transistors  $Q3$  and  $Q4$  provide further amplification of the audio signal.

Transistors  $Q5$  and  $Q6$  operate as a push-pull complementary-symmetry Class B power amplifier. They are sold together as a matched pair and are designated as the RCA 40396. Output distortion is very low and fidelity is excellent. Over 200 milliwatts of audio power can be delivered to the speaker, more than enough to fill an average-size room with sound. D.c. stabilization is provided by the feedback path through resistor  $R17$ . The output of the audio amplifier is capacitively coupled through  $C16$  to a 3 $\frac{1}{2}$ "-diameter, 45-ohm speaker, and a miniature closed-circuit phone jack,  $J1$ , automatically disables the speaker when an earphone is used. Any impedance earphone can be employed.

Battery  $B1$  is a conventional 9-volt transistor radio battery. Since the d.c. power requirement is very modest, battery life should be quite good, with a single battery lasting for several months under normal operating and listening conditions. The idling current is a low 5 to 8 milliamperes with no signal, jumping to a high of 20 to 25 mA on audio peaks.

**Construction.** The entire receiver circuitry is constructed on a 4" x 2 $\frac{7}{8}$ " printed circuit board. The etched copper

foil side of the circuit board is shown in Fig. 2. The first step is to mount the coil socket in place with the retainer ring provided with the socket. The flat edge on the socket must face the direction indicated and the solder lugs on the socket should be on the copper foil side of the board.

Next, install variable capacitor  $C3$ . Use three 6-32 x  $\frac{3}{8}$ " screws and three  $\frac{1}{4}$ "-long spacers. The spacers must be inserted between the capacitor bracket and the circuit board to space the capacitor away from the board.

The hole template of the front panel is shown in Fig. 3. The panel thickness should be  $\frac{1}{8}$ ", and it can be fabricated from aluminum, plastic, Bakelite, or any equivalent material. Mount the speaker with four 6-32 x  $\frac{3}{8}$ " screws. At the two left-hand holes, use regular 6-32 nuts to fasten down the screws. Use 1"-long spacers that have been threaded for 6-32 screws at the remaining two locations; refer to Fig. 4 for the exact location of the spacers. Mount the vernier drive mechanism with 4-40 x  $\frac{1}{4}$ " screws and nuts. The two potentiometers and the phone jack go on last—mount them in the directions indicated in Fig. 5.

Now mount the circuit board on the front panel. (See Fig. 4.) The two circuit board mounting holes should line up with the 1" spacers, and the shaft on the variable capacitor should line up with, and fit into, the vernier drive. Attach the circuit board to the 1" spacers with two 6-32 x  $\frac{3}{8}$ " screws. Make sure the board is exactly parallel to the panel, then tighten the setscrews to lock the tuning capacitor to the vernier drive. The circuit board should now be mounted rigidly in place. Attach a knob to the shaft of the vernier drive, and turn it back and forth from one stop to the other. The vernier drive and the variable capacitor should turn smoothly. If everything checks out properly, you can remove the circuit board assembly and proceed with the wiring.

Bend the solder lugs on the coil socket over and make the connections to them as shown in Fig. 2. Keep these leads as short as possible. Flip the circuit board over and solder the components in place as shown in Fig. 6. Mount all the transistors first. Space each transistor about  $\frac{1}{4}$ " away from the circuit board, making

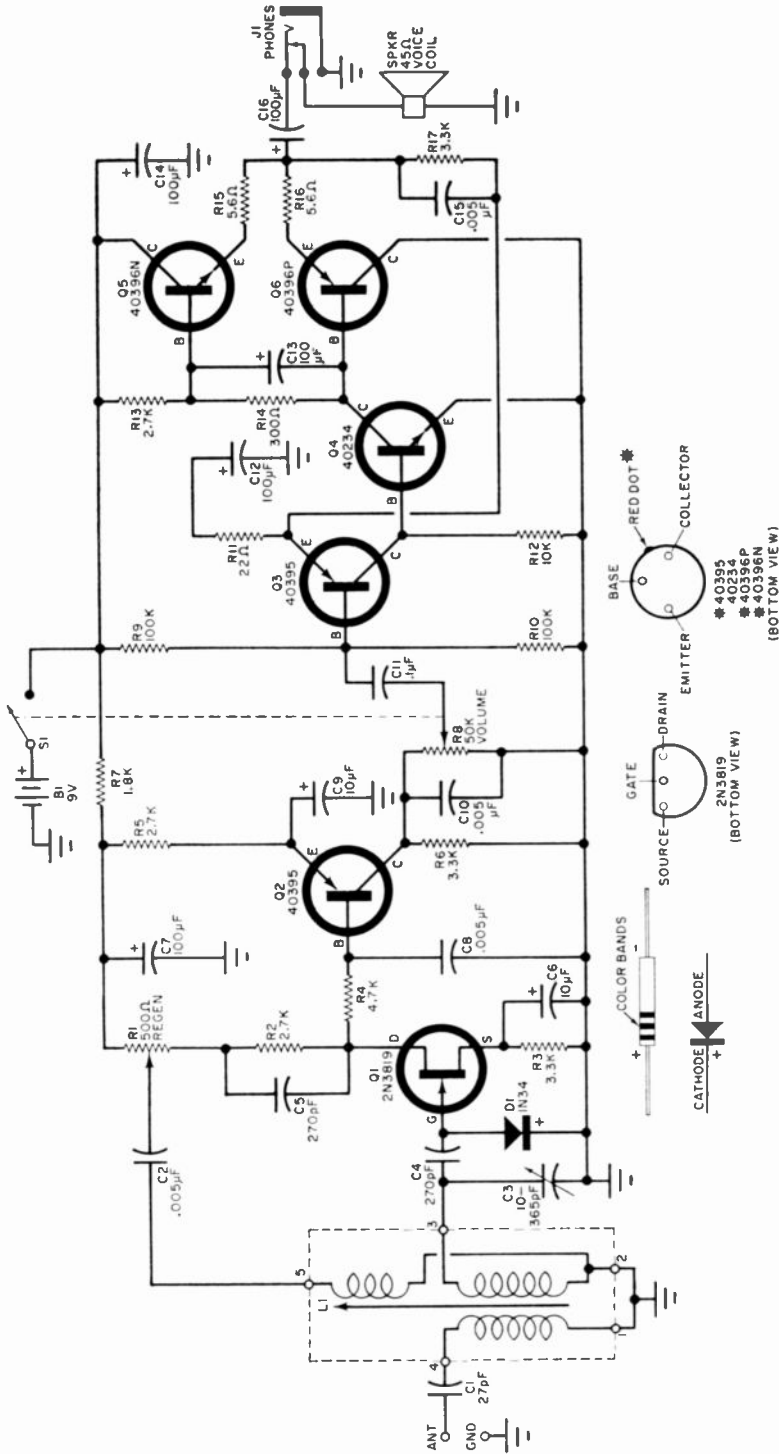
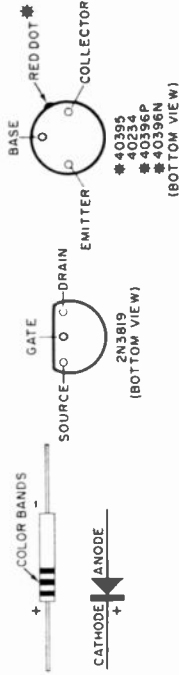


Fig. 1. Except for the number of transistors used, this circuit bears a remarkable resemblance to regenerative receivers of the 1930's. The FET is a transistor that thinks and behaves as if it were a vacuum tube. However, many of the tube problems relating to drift and instability are absent.





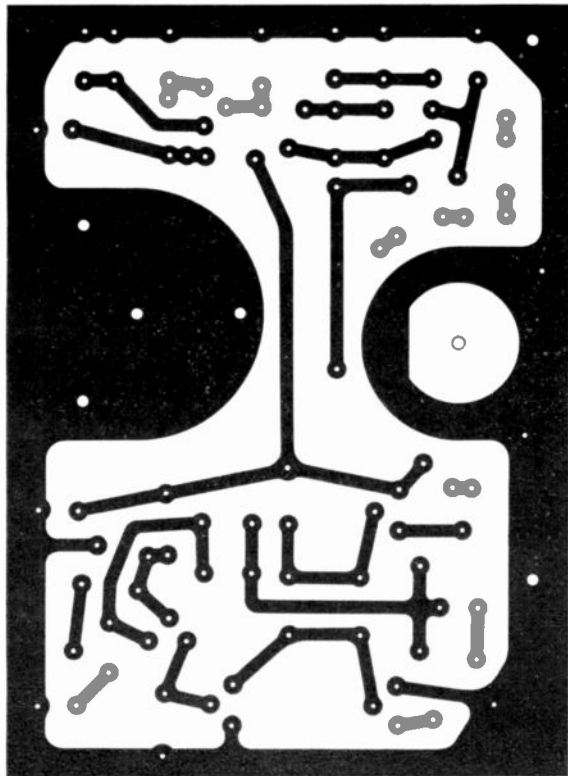
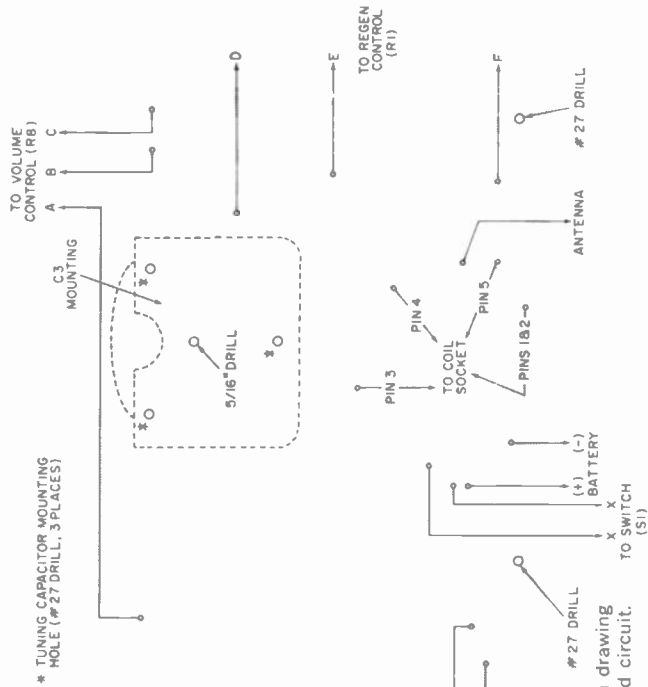


Fig. 2. "Same-size" outline of printed circuit board for readers who like to make their own. In drawing above, right, are notations on drilling of holes and making external connections to the printed circuit.



## PARTS LIST

- R1 2-volt battery  
 C1 27-pf ceramic capacitor  
 C2, C3, C4, C5, C6, C7, C8, C9, C10, C15 0.005- $\mu$ f ceramic capacitor  
 C3 100- to 505-pf variable capacitor (J. W. Miller 2111)  
 C1, C5 270-pf ceramic capacitor  
 C6, C7 10- $\mu$ f, 15-volt miniature printed circuit electrolytic capacitor  
 C7, C13, C14, C16 100- $\mu$ f, 15-volt miniature printed circuit electrolytic capacitor  
 C11 0.1- $\mu$ f 50-volt capacitor  
 D1 6V34 germanium diode  
 J1 Miniature closed circuit phone jack  
 J1 Coil for Band 1, 0.55-1.5 MHz (J. W. Miller A-5495-1); Band 2, 1.7-5.5 MHz (J. W. Miller A-5495-2); Band 3, 5.5-15 MHz (J. W. Miller C-5495-1)  
 Q1 Texas Instruments SA519 transistor  
 Q2, Q3 RC-4035X germanium pnp transistor

- Q4 RC-440234 germanium npn transistor  
 Q5 RC-440390X germanium npn transistor  
 Q6 RC-440390P germanium pnp transistor  
 R1 500-ohm linear taper potentiometer  
 R2, R3, R4, R5 2700 ohms  
 R3, R6, R17 3300 ohms  
 R4 4700 ohms  
 R7 1500 ohms  
 R8 50,000-ohm, audio taper potentiometer with 5-p.s.d. switch S1  
 R9, R10 100,000 ohms  
 R11 22 ohms  
 R12 10,000 ohms  
 R14 500 ohms  
 R15, R16 5.6 ohms  
 S1 8-pole switch (part of R8)  
 SPEAKER 7" diam. 16 $\Omega$  FM speaker with 15-ohm voice coil (Amco 5107Z15)  
 1 Printed circuit board\*

- 1 Ball-type vernier drive, 6:1 ratio (Jackson Bros. 1511/D4F)  
 3 Miniature plugs, 5-pin (Amphenol 71-58)  
 1 Miniature socket, 5-pin (Amphenol 78-55)  
 Misc. Knobs, plastic pointer, speaker grill, cabinet panel, Fabro stock clips, battery holder, battery clip, No. 28 enameled copper wire, 1 $\phi$  spacers, 4 spacers, screws, hookup wire, solder, etc.

\*Etched and drilled printed circuit board is available for \$8 postpaid from Carmigella Electronics, Inc., P. O. Box 327, Upland, Calif. 91786. A complete kit of parts (including above circuit board, pre-punched board with printed dial, plastic pointer, all components, hardware and wire (not less cabinet and battery) is available for \$24.95 postpaid. California residents should add 5% sales tax to all orders.

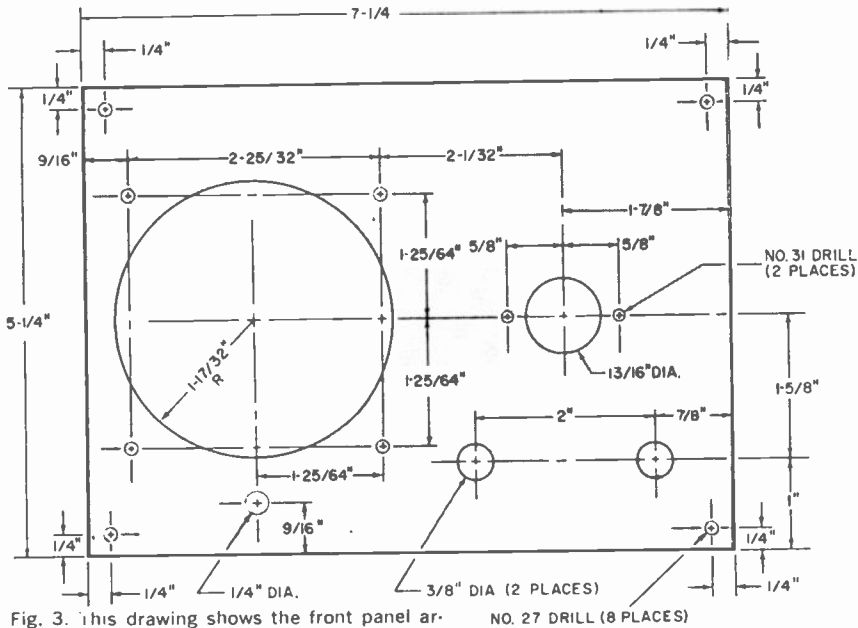
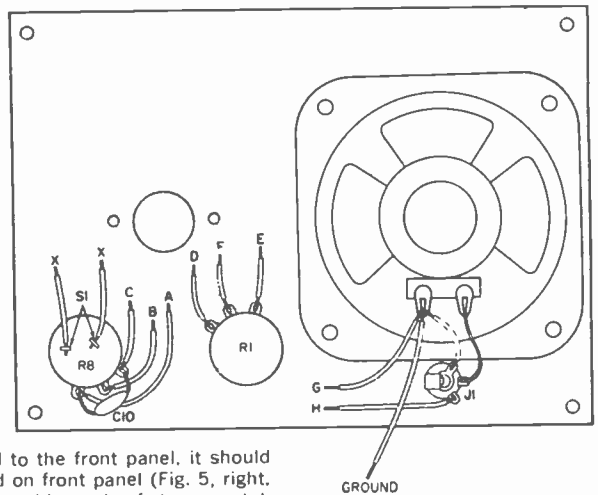
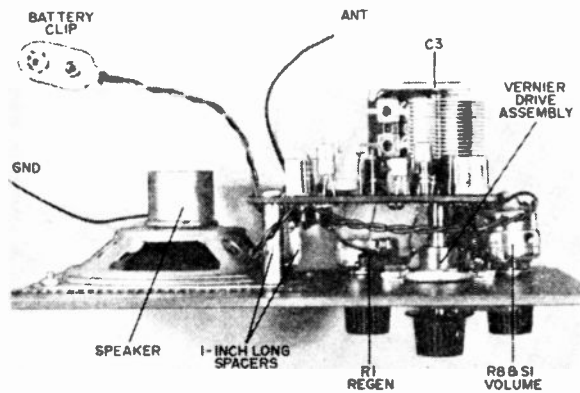


Fig. 3. This drawing shows the front panel arrangement of mounting holes in author's model.

NO. 27 DRILL (8 PLACES)



Figs. 4 and 5. When printed circuit board is attached to the front panel, it should look like Fig. 4 above. A few components are mounted on front panel (Fig. 5, right, above) before printed circuit is put in place. Be sure panel is made of strong metal.

sure that each one is oriented properly! A heat sink should be used on each transistor lead while soldering to keep from damaging the transistor.

Next, install the capacitors. They should be flush-mounted against the board. Carefully observe the polarity of the electrolytics when installing them. Capacitor *C10* is the only one not mounted on the circuit board. It is soldered directly across volume control *R8*.

Mount diode *D1* vertically on the board.

Space the body of the diode about 1/4" away from the board, and carefully observe polarity of the diode when it is mounted. As with the transistors, the leads of the diode should also be held with a heat sink while soldering.

All of the resistors are installed vertically on the board. The connection to tuning capacitor *C3* is made from the "component" side of the board (see Fig. 6). All of the remaining connecting leads are soldered to the copper foil side of the

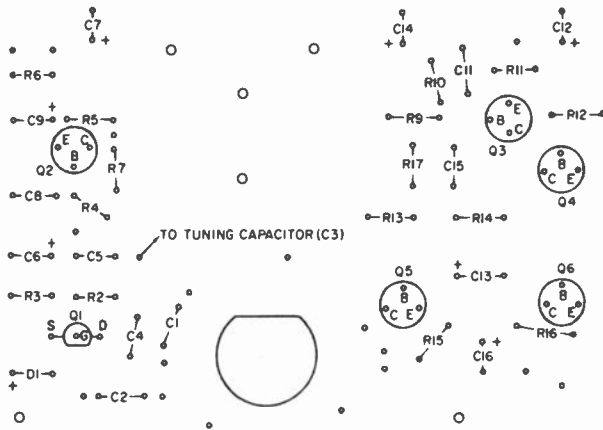


Fig. 6 Flip side of printed circuit board shown in Fig. 2. Note positions of the components, and, in particular, observe lead orientation of the various transistors. The center hole (shaft) for mounting C3 is eventually enlarged so that the shaft passes through freely without binding and C3 is rigidly supported by bolts through the 3 remaining small holes.

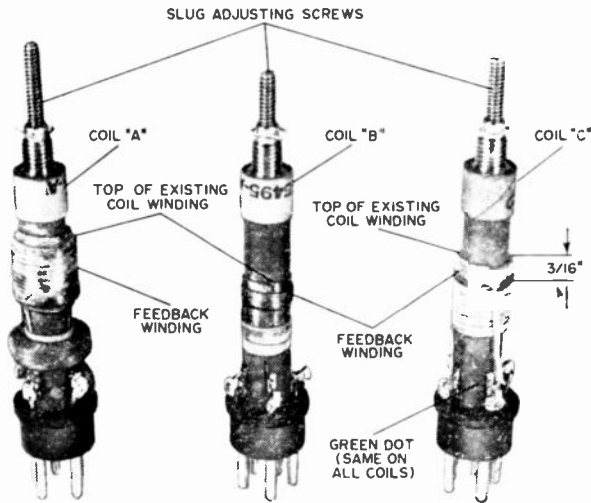


Fig. 7. Each of the plug-in coils is mounted on an Amphenol miniature 5-pin plug. Coil modification details appear in the text on the next page.

board. Flip the board over to the copper foil side (Fig. 2), and make these lead connections last. Leave these leads long; they will be trimmed to the proper length once the board is mounted in place.

Once again, mount the completed circuit board assembly on the front panel. Connect the leads from the board to the two potentiometers, the speaker, and the phone jack as illustrated in Fig. 5. Keep the leads to regeneration control *R1* as

short as possible! The lead from *J1* to the speaker lug (represented by the dotted lines) may be omitted if an aluminum panel is used. Recheck all wiring, transistors, electrolytic capacitors, and the diode polarities in accordance with Fig. 6.

**Coil Modifications.** A set of three plug-in coils will cover the frequency range from 0.55 MHz to 18 MHz. Three J. W. Miller pre-wound slug-tuned coils are used for the purpose. As furnished by the manufacturer, each coil consists of a primary winding which is connected to the external antenna and ground, and a secondary winding which is tuned by an external capacitor. A miniature 5-pin plug must be attached to each coil for "plug-in" capability. Also, a simple feedback winding must be added to each coil as shown in Fig. 7.

Heavy, tinned copper wire is used to hold the miniature plugs firmly against the bottom of each coil. The heavy wire connects the plug pins to the coil solder lugs. Solder a 1½" length of No. 18 tinned copper wire into pins 1, 2, 3 and 4 on each of the miniature plugs. Pin 5 will be left empty for the moment. The plug pins are hollow, and each lead should just barely stick out the bottom end of the pin. Make sure each connection has an adequate amount of solder within the pin, but avoid running any excess solder over the outside of the pins.

After all the pins have been soldered, test each plug in the socket on the circuit board to make sure they plug in and

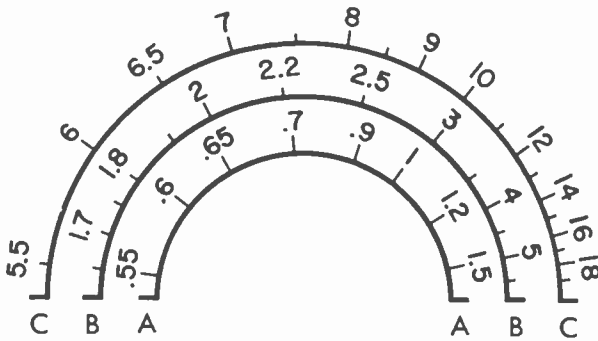


Fig. 9. If you use the coils and variable capacitor specified in the Parts List, the tuning range should be approximately 550-1500 kHz with coil "A"; 1.7-5.5 MHz with coil "B"; and 5.5-18.0 MHz with coil "C". The receiver should regenerate smoothly over this range.

out easily. If necessary, carefully trim away any excess solder. Place the plugs against each coil as shown in Fig. 7. Align the green dot on each coil between pins 2 and 3 on each plug, and attach each lead to the nearest solder lug on each coil. Run each lead through the loop on the solder lugs and cinch the leads tightly to make a rigid assembly out of the coil and plug, then solder each connection. Finally, cut off any excess leads.

Use No. 28 enameled copper wire for the feedback windings on all three coils. On each coil, start the winding by first soldering one end of the enameled copper wire to the coil solder lug which is connected to pin 2 on the miniature plug, then wind the wire as follows:

**Coil "A"**—0.55 to 1.5 MHz. With the plug pins pointed towards you, wind 30 turns close-wound across the existing top

coil, in a counterclockwise direction, starting from the bottom and winding towards the top.

**Coil "B"**—1.7 to 5.5 MHz. With the plug pins pointed towards you, wind 8 turns close-wound in a clockwise direction, starting about "10" down from the top of the existing winding, and winding towards the top.

**Coil "C"**—5.5 to 18 MHz. With the plug pins pointed towards you, wind 3 turns close-wound in a counterclockwise direction, starting about "10" down from the top of the existing winding, and winding towards the top.

Solder the end of each completed feedback winding to pin 5 of each plug. Then complete each coil assembly by coating the new feedback windings with coil dope.

A preliminary setting can be made on the tuning slug of each coil to get them in the right "ball park." Run the slug completely out of each coil by turning the adjusting screw counterclockwise until it stops. Then, for coil "A" run the slug in about 3 to 4 turns, for coil "B" run the slug in about 8 to 9 turns, and for coil "C" run the slug in about 3 to 6 turns. The coils can be more accurately aligned later.

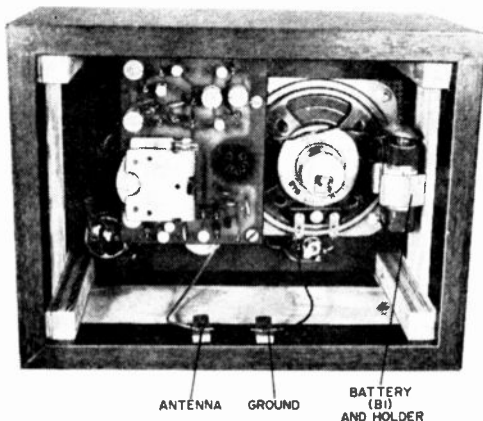
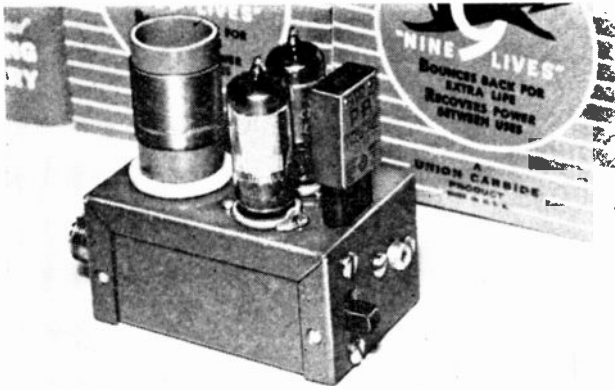


Fig. 8. Back view of the completed receiver in the cabinet designed by the author. You can either make your own cabinet or buy a ready-made metal box.

**The Cabinet.** You can construct the cabinet to suit your own taste. The author used 1/2"-thick plywood.

The cabinet can be "finished" by covering it with self-sticking shelf paper, or painting it the color of your choice. The author used an imitation wood-grain shelf paper; however, there are many types and colors to choose from. Shelf paper is readily found in grocery stores, department stores, etc.

(Continued on page 151)



# BUILD THE QRP MIDGET

By JIM WHITE, W5LET

**D**O YOU STILL get a thrill out of hamming? Or is the spirit of adventure gradually disappearing? Maybe you have been considering taking up a new hobby, like chasing butterflies, or collecting stamps. Don't do it. There is nothing like switching to low power—very low power—to restore the thrill to hamming.

If you have done all of your hamming on a "store-bought" rig, maybe you should try your hand at building a transmitter—one that is really portable, with no power lines to worry about. The *QRP Midget* is a 2-tube, battery-powered transmitter that you can hold in the palm of your hand. It will work on 80-, 40-, or 20-meter CW. It can be built for less than \$10 and, when connected to a good antenna, will give a good account of itself.

**How It Works.** The circuit uses two 3S4 tubes in parallel as a crystal oscillator. The filaments are wired in series so that a 6-volt battery can be used for the filament supply. By using plug-in coils, band-changing is as simple as plugging and unplugging a tube. The coils are tuned to resonance in each band by a single variable capacitor.

In addition to the 6-volt battery, two 45-volt B batteries are wired in series to provide 90 volts for the plates and screens of the tubes. The key is connected in series with the B-minus lead to the batteries. A small coil, *L2*, couples the r.f. in the plate circuit to the antenna.

**Construction.** Since the *QRP Midget* is very small, the arrangement of parts is important. A good look at the photo-

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TO THE DAYS OF OLD  
WITH  
2.5 WATTS INPUT

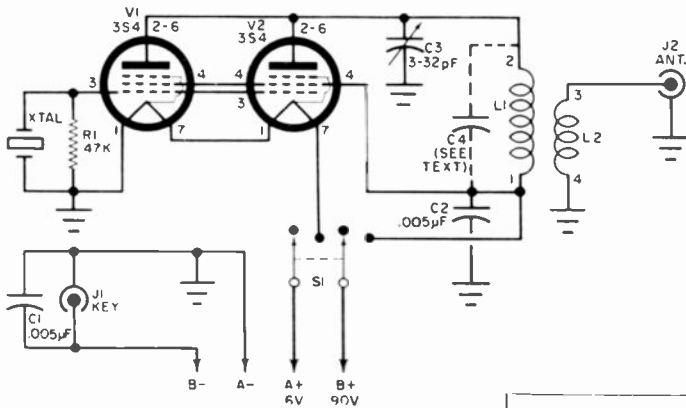
graphs will show you just where each part is located.

After all of the necessary holes are drilled and punched, install the crystal socket. Then wire *R1* across its terminals. Leave enough excess lead wire to reach pin 3 of *V1* and the ground connection of *J1*. Now install the three tube sockets, phono (*J1*) and coax (*J2*) connectors, and variable capacitor *C3*.

Following the circuit diagram, carefully wire the balance of the transmitter. All wiring, with the exception of the leads to the batteries, is done with No. 20 solid hookup wire. The battery leads are made of 18" lengths of No. 20 stranded hookup wire; it is a good idea to use different colored wire for these four leads to lessen the possibility of making a mistake when connecting them to the batteries.

The last three parts to be mounted are *S1*, *C1*, and *C2*. The two capacitors are wired across *J1* and the 4-prong coil socket, respectively. The four battery leads are connected to the switch, the ground connection of *J1*, and the "hot" side of *J1*.

**Winding The Coils.** On each of the coil forms, there are two separate windings, *L1* and *L2*, of No. 24 enameled wire. They are separated from each other by a



Rockbound transmitter for 80, 40, and 20 meters is small enough to fit into your glove compartment, complete with batteries. Note that pin 5 on 3S4, connected to screen grid and filament center tap, is not used, and is not shown here. Key plugged into J1 transmits transmitter on and off for CW operation. Don't let the low power fool you non-hams—you must have a license to put this unit on the air.

### PARTS LIST

- C1, C2—0.005- $\mu$ F, 1000-volt disc ceramic capacitor
- C3—3-32 pF midget variable capacitor (E.F. Johnson 100-130 or similar)
- C4—50-pF silver mica capacitor
- J1—Phono connector, female
- J2—Coax connector, female
- L1, L2—See text
- R1—47,000-ohm, 1/2-watt resistor
- S1—D.p.s.t. slide switch
- V1, V2—3S4 tube
- 3—Coil forms (J. Millen 45004)
- 1—Crystal socket (National CS-6)
- 1—Coil socket (Amphenol 49RSS4)
- Misc.—6-volt battery, 45-volt battery (2), tube sockets (3), wire, solder, nuts, bolts, etc.

distance of 1". For 80 meters,  $L1$  consists of 31 turns, close-wound, and  $L2$  is 8 turns, close-wound. The 40-meter coil has 21 turns on  $L1$  and 7 turns on  $L2$ , both close-wound.

The 20-meter coil has 12 turns on  $L1$ . This coil is wound so that the winding takes up about 1 inch, with the turns spaced equally to occupy this space. Coil  $L2$  on the 20-meter form consists of 3 turns, close-wound.

When you wind the 80-meter coil, be sure and solder  $C4$  in place as you solder the two wires from  $L1$  to the pins. This capacitor is mounted inside the coil form.

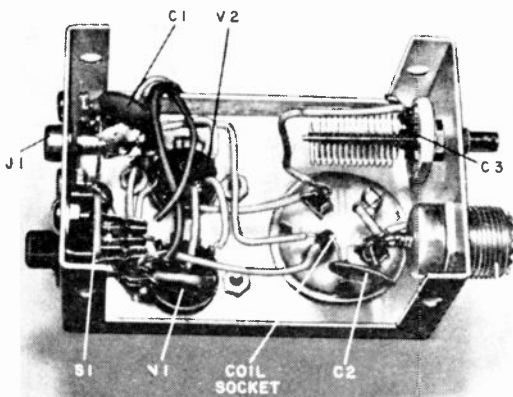
**Going On The Air.** Connect a key to  $J1$  and a good antenna for the band you intend to work to  $J2$ . With the power switch in the "off" position, insert the

two 3S4's into their sockets. Plug a crystal into the crystal socket and a coil into the coil socket (they must be for the same band). Now, using a field strength meter, or a receiver S-meter, turn the transmitter on, press the key, and slowly rotate variable capacitor  $C3$  until you get an indication that the *QRP Midget* is oscillating.

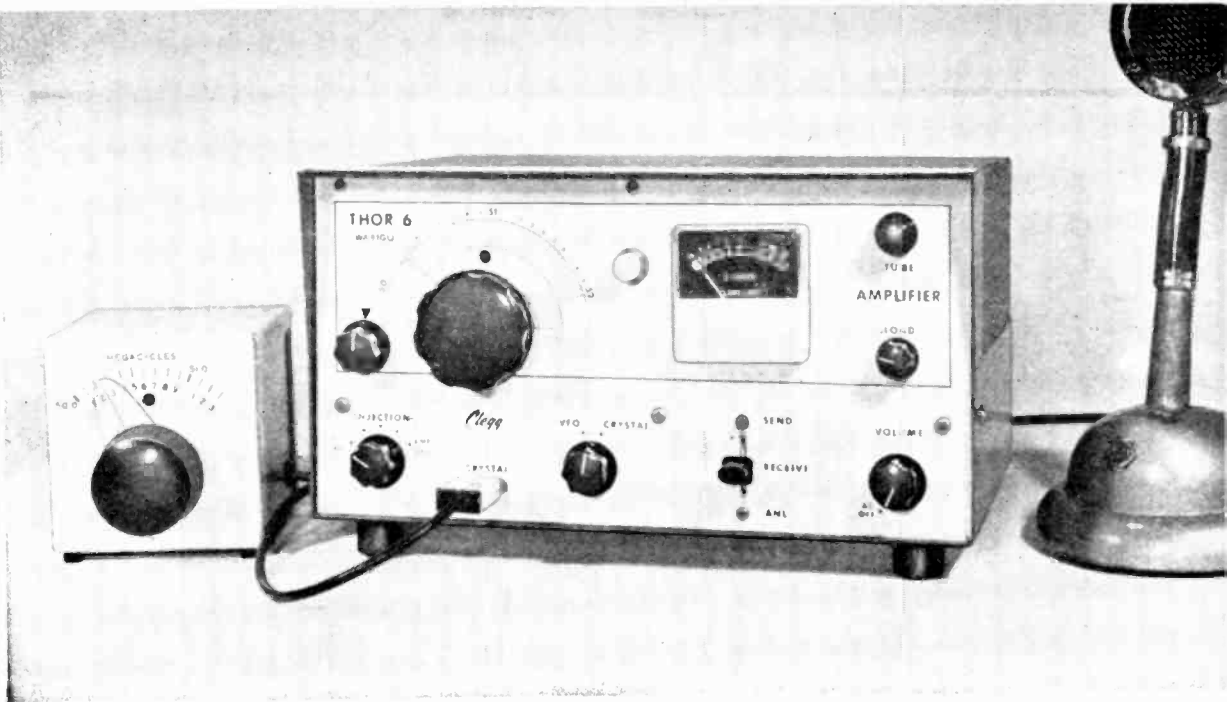
Tune  $C3$  to the peak reading. If you peak it too much, the keying may be erratic. Adjust  $C3$  for the best output consistent with good keying.

Keep in mind that you must have a good antenna when you use the *QRP Midget*. A makeshift antenna simply will not do the job with such low power. Put some time and energy into the antenna, and it will pay dividends. Also, the author has found that a few of the crystals for 20 meters are a little sluggish and do not oscillate very well; you might have to try several before you get a good one.

If you want to measure the input to the *QRP Midget*, just put a milliammeter in series with the B-plus lead. The input should be about 2½ watts.



Neatness counts; proper parts location and lead dress are important for clean operation. Keep the leads short. Terminal strip to accommodate battery leads can be mounted on the other half of the box.



## BUILD THE INCREDIBLE VFO

... A SIMPLE, PRACTICAL, INEXPENSIVE  
VFO THAT REALLY WORKS

By R. L. WINKLEPLECK, WA9IGU

**I**F YOU ARE A HAM, you know that the only substitute for an unlimited supply of transmitter crystals is a stable variable-frequency oscillator (VFO). But you also know that VFO's are sometimes unstable, and minute changes of coil dimensions due to heat produced from nearby vacuum tubes and resistors, or changes in the electrode voltages of the vacuum tube oscillator, *can* and *do* cause the drift.

You can build a relatively stable *passive* VFO using a couple of capacitors and an inductor—a VFO in which there are no tubes or resistors to heat up, and no power supply or transistors to contend with. You don't have to lay a finger on your transmitter circuitry, either. You simply put a few parts together in a metal box, remove the transmitter crystal, and plug the VFO right into the crystal socket.

Why isn't everybody using this incredible VFO? The reasons are simple. Hams tend to distrust passive circuits that appear to offer something for nothing and, furthermore, external passive VFO's don't work with all transmitters. The transmitter's oscillator must be capable of sustaining oscillation by itself. A passive VFO merely determines the frequency of oscillation and is not an oscillator circuit in itself.

**When It Can Be Used.** If your transmitter employs any variation of the basic grid-plate oscillator shown in Fig. 1, you're in! Observe that there's an r.f. choke in the cathode of the oscillator tube, and that the crystal is connected between grid and ground. Note also that a feedback path is provided from cathode to grid via a capacitance divider.

Other circuit variations, such as a resistor across the crystal socket or in the cathode lead, or a coupling capacitor in

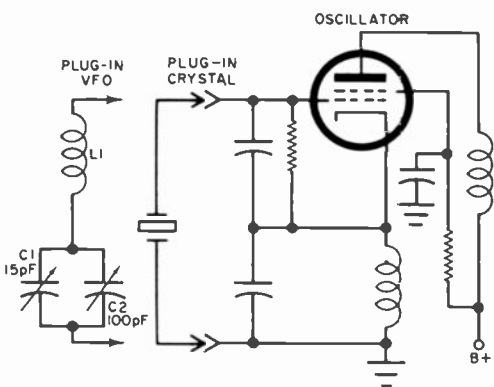


Fig. 1. To convert this crystal-controlled oscillator to a series-tuned Colpitts VFO, simply replace the crystal with the L-C combination shown.

the grid circuit, are acceptable. For, once you remove the crystal and connect the "Incredible VFO" in its place, you will have a series-tuned Colpitts oscillator that will work like a charm in any frequency range permitted by the series L-C combination.

**Pro's And Con's.** Before deciding on a passive VFO, consider all of its features—good and bad. Obviously, it's cheap,

simple, and easy to build. And as stated previously, it requires no tubes or transistors, and no power supply. If well built, and if the oscillator voltage is stable, it will exhibit very little drift. Differences in plate voltage will usually swing the frequency a bit, however. Use of the "Incredible VFO" does not require that you modify your rig, and it can be replaced with your original crystal at a moment's notice.

If your construction is sloppy, the

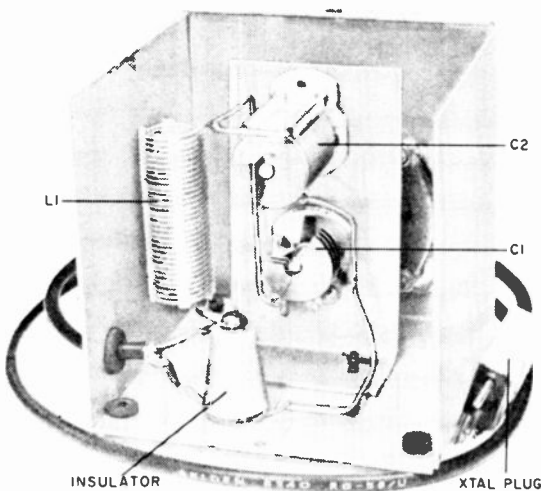


Fig. 2. The tuning capacitors are premounted on a heavy aluminum subpanel which is then secured to the base of the enclosure. The insulator floats the ungrounded cable lead from coil to xtal plug.

unit's performance will be sloppy. To a degree, this VFO is susceptible to body capacitance, and you must not touch the connecting cable or plug while on the air or your frequency will shift. And if you place the VFO too close to the transmitter, temperature changes could produce a significant frequency drift.

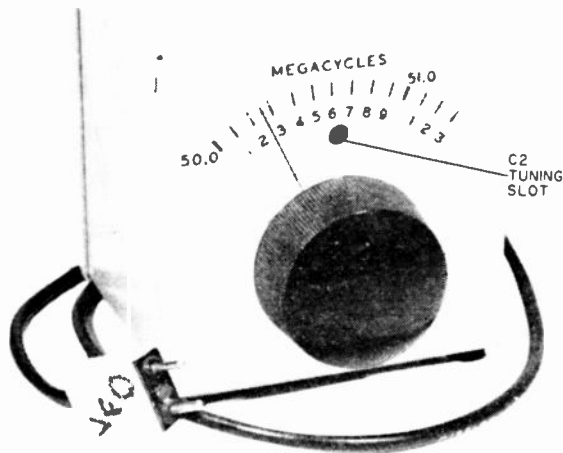
**Construction.** You can build a passive VFO for any transmitter frequency you want. Appropriate inductance and capacitance values for frequencies in the amateur bands, from 1.75 to 220 MHz, are given in Chapter 2 of the *Radio Amateur's Handbook*.

If, for instance, you work on six meters and want to replace your 8-MHz crystal with a passive VFO, you will need a 2"



length of B&W Miniductor coil = 3007 for L1. Unwind about half a turn from each end of the coil to serve as connecting leads. The coil length given does not include the leads.

Two capacitors in parallel cover the entire 2-MHz frequency band. The larger capacitor, C2, is variable to 100 pF and determines the tuning range of the band. It is screwdriver-adjusted through a hole in the front panel. The smaller capacitor, C1, is variable to 15 pF and



Alignment of the VFO is a simple matter, and requires no special test equipment. All you need is a receiver to monitor the VFO signal while you adjust capacitor C2 until the signal is heard.

tunes in the desired frequencies. It is equipped with a vernier dial for ease of calibration and tuning. The capacitors and the coil are connected as shown in Fig. 2.

Both capacitors should be of high quality and of rugged construction to insure frequency stability. They are both mounted on a heavy aluminum subpanel, and the entire assembly is housed in a 4" x 4" x 4" aluminum box.

Use heavy pieces of wire—No. 12 or larger—to join the capacitors together. Connect the coil between the high side of the capacitors and the top of a 1" porcelain insulator. Affix solder lugs at both extremes of the insulator before mounting.

Strip one end of a short piece of RG-

58/U cable and solder the center conductor to the lug on the high side of the insulator along with the coil terminal. The shield strands of the cable go to the ground lug under the insulator, together with the common (ground) lead from the capacitors. Be sure there is a good ground to the chassis.

The coax cable is run through a grommeted hole in one side of the case, and the free end is terminated with a suitable crystal holder that will mate with your particular crystal socket. Be sure to mark the pin with the ground shield, as well as the grounded side of the crystal socket on your transmitter. Always connect ground to ground.

**Alignment.** The alignment of the VFO can be a little tricky, but if you proceed slowly and carefully, you should have no trouble at all. Plug the VFO into the crystal socket of your transmitter; then fire up the transmitter and allow it to warm up with plate voltage applied to the oscillator only.

Set the VFO's main tuning dial (C1) near its center of rotation. Turn on your receiver and set it to a frequency in the middle of the VFO's expected operating range. Through the access hole, tune C2—very slowly—until the receiver picks up the VFO signal. Alternately tune C1 and C2 for the strongest signal.

Put a dummy load across your transmitter's antenna output and set the transmitter to "transmit." If the transmitter loads properly, fine. If it does not, you are probably working on a frequency outside of the transmitter tuning range, and you must retune C2 to operate in the correct frequency range.

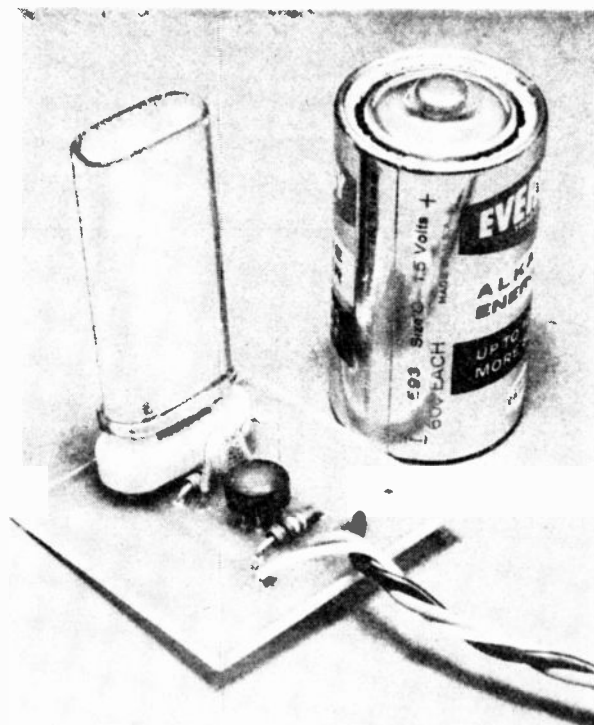
After you find the point where the transmitter loads properly, and you can pick up the signal, mark the receiver-indicated frequency on the VFO dial as your first calibration point. Continue tuning the band, resetting C1 to a different spot as you go along, and calibrating the VFO dial with the new frequency. Do not disturb the setting of C2 after its initial adjustment.

If your transmitter exhibits an undue amount of drift, it is probably due to poor power supply regulation. You can correct this condition by adding the necessary circuitry to regulate your power supply.

# L'IL RICHIE

SIMPLE, STABLE,  
HARMONIC-RICH  
CRYSTAL OSCILLATOR  
IS BUILT AROUND  
A LOW-COST  
INTEGRATED CIRCUIT

By **DON LANCASTER**



L'il Richie is a small one—it's shown here alongside a conventional "C" cell—but the crystal is a 100-kHz bar and is larger than most crystals.

**T**AKE ONE low-cost integrated circuit, two resistors, one capacitor, and one crystal—combine properly—turn on the power, and you can generate crystal-controlled sine or square waves at any frequency between 100 kHz and 3 MHz, and, with slight modification, the 3- to 10-MHz range. Uses of the "L'il Richie" are as varied as the user's imagination.

Amateur radio operators will find the harmonic-rich output useful as 100-kHz or 1-MHz crystal calibrators. As a bonus,

the addition of an output tank circuit creates a flea-power transmitter for field days, antenna testing, and hidden-transmitter hunts.

For AM servicing, just insert a 455-kHz crystal, and you have an i.f. alignment generator. Switch to 500-, 1000-, or 1500-kHz crystals, and you have a handy signal generator for dial calibration, tracking adjustments, or antenna and r.f. stage tuning.

For TV or FM work, plug in the need-

ed crystal—3.58, 4.5, or 10.7 MHz—and you have a marker or signal generator all set to go. And, finally, the advanced experimenter can use the "L'il Richie" as a stable, crystal-controlled reference clock for electronic counting circuits.

**How it Works.** The two independent gates in *IC1* (Fig. 1) are biased in their class A region using resistors *R1* and *R2*. These two gates are cascaded with *C1* to form a two-stage, RC-coupled r.f. amplifier. Feedback from output to input via *XTAL* produces the desired oscillation, in the form of a square wave very nearly equal to the crystal's series-resonant frequency.

## PARTS LIST

*C1*—1000-pF disc ceramic capacitor—see text  
*IC1*— $\mu$ L914 epoxy micrologic dual gate (Fairchild)\*

*R1, R2*—10,000-ohm,  $\frac{1}{2}$ -watt carbon resistor  
*XTAL*—Series resonant, first-overtone crystal, 100 kHz to 3MHz with *C1* as listed; to 10.7 MHz with selected value for *C1*

Misc.—1 $\frac{1}{2}$ " x 1 $\frac{1}{8}$ " single-sided PC board,\*\* socket to fit *XTAL* with mounting screw, solder terminals (3), solder

\*Data sheet and distributor list are available from Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, Calif.

\*\*Complete kit, including printed circuit board, but less crystal and socket, is available from Southwest Technical Products Corp., Box 16297, San Antonio, Texas 78216, for \$1.75, postpaid in the U.S.A.

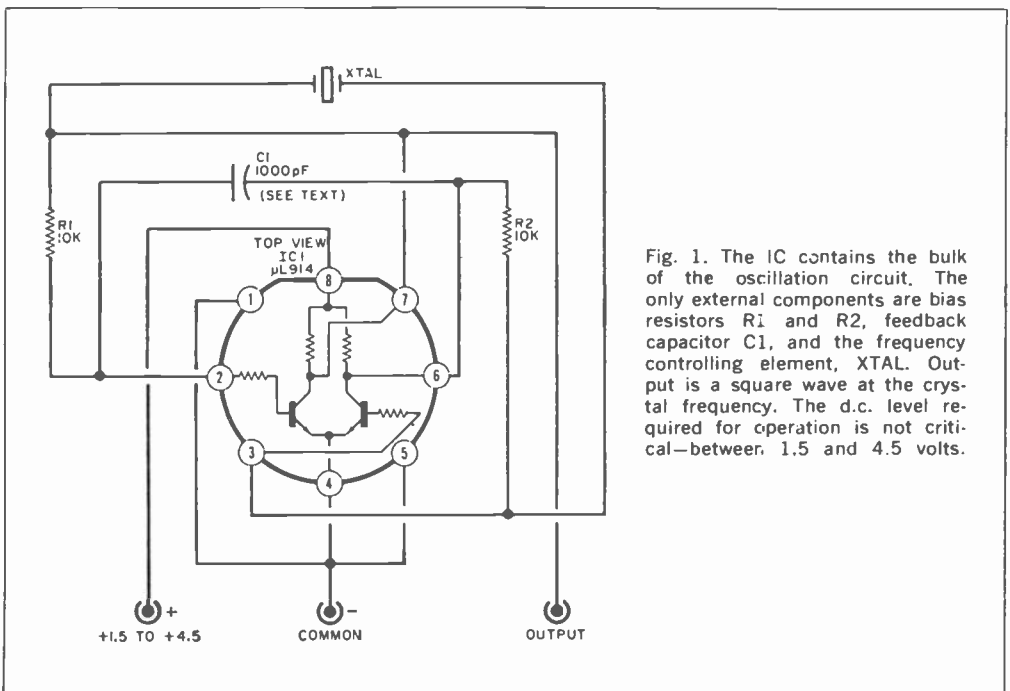


Fig. 1. The IC contains the bulk of the oscillation circuit. The only external components are bias resistors *R1* and *R2*, feedback capacitor *C1*, and the frequency controlling element, *XTAL*. Output is a square wave at the crystal frequency. The d.c. level required for operation is not critical—between 1.5 and 4.5 volts.

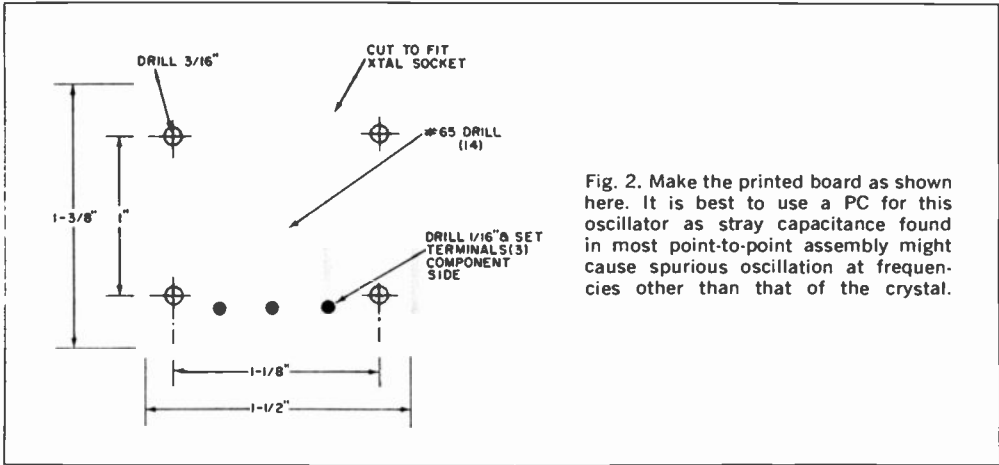


Fig. 2. Make the printed board as shown here. It is best to use a PC for this oscillator as stray capacitance found in most point-to-point assembly might cause spurious oscillation at frequencies other than that of the crystal.

The entire circuit requires only five low-cost parts and can be powered by any convenient supply from a single penlight cell (1.5 volts) up to 4.5 volts d.c.

**Construction.** Any neat construction technique can be used for this circuit, but long leads or sloppy construction can produce a device whose frequency may not entirely depend upon the crystal used. A complete kit, including the printed circuit board, is available from the source indicated in the Parts List, but if

you want to do your own PC layout work, just follow Figs. 2 and 3.

Note that IC1 is mounted with the positive power lead centered on the flat of its epoxy case (pin 8). And be sure that the crystal holder pins and the crystal socket match, as some older crystal holders have different pin diameters and spacings.

After assembly and inspection, insert a crystal of below 3 MHz, and perform an initial checkout using 3 volts from two flashlight cells. If you're planning on using crystals from 3 to 10 MHz, you'll have to experiment to get the value of C1 just right to suit your particular crystal's drive requirements. Higher frequency generators will require values of from 20 to 100 pF.

Some capacitor tinkering is required at these higher frequencies and a generator tailored in this manner will most likely work best with one particular crystal, and over a more limited power supply range. You might like to try a trimmer, or padder, for C1 if you're planning high-frequency operation with multiple crystals. A 0.01- $\mu$ F power supply bypass capacitor might also be required. A trimmer will let you "pull" the crystal slightly to bring it into exact calibration with Station WWV on 5 or 10 MHz.

Occasionally, older surplus crystals or one with an unusual cut may take off on the second or third harmonic instead of the fundamental. Usually, a bit of ca-

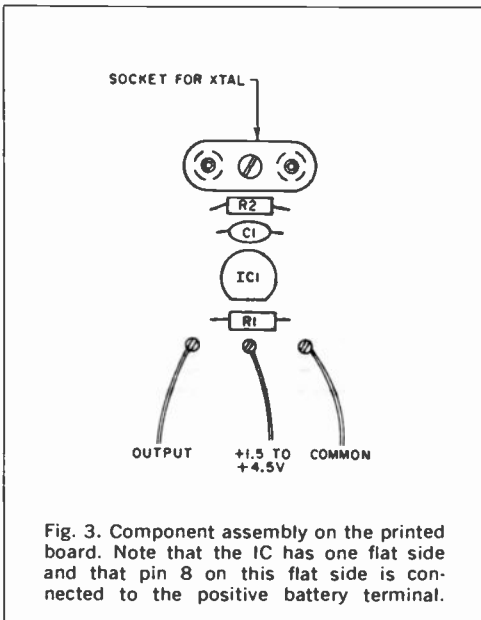


Fig. 3. Component assembly on the printed board. Note that the IC has one flat side and that pin 8 on this flat side is connected to the positive battery terminal.

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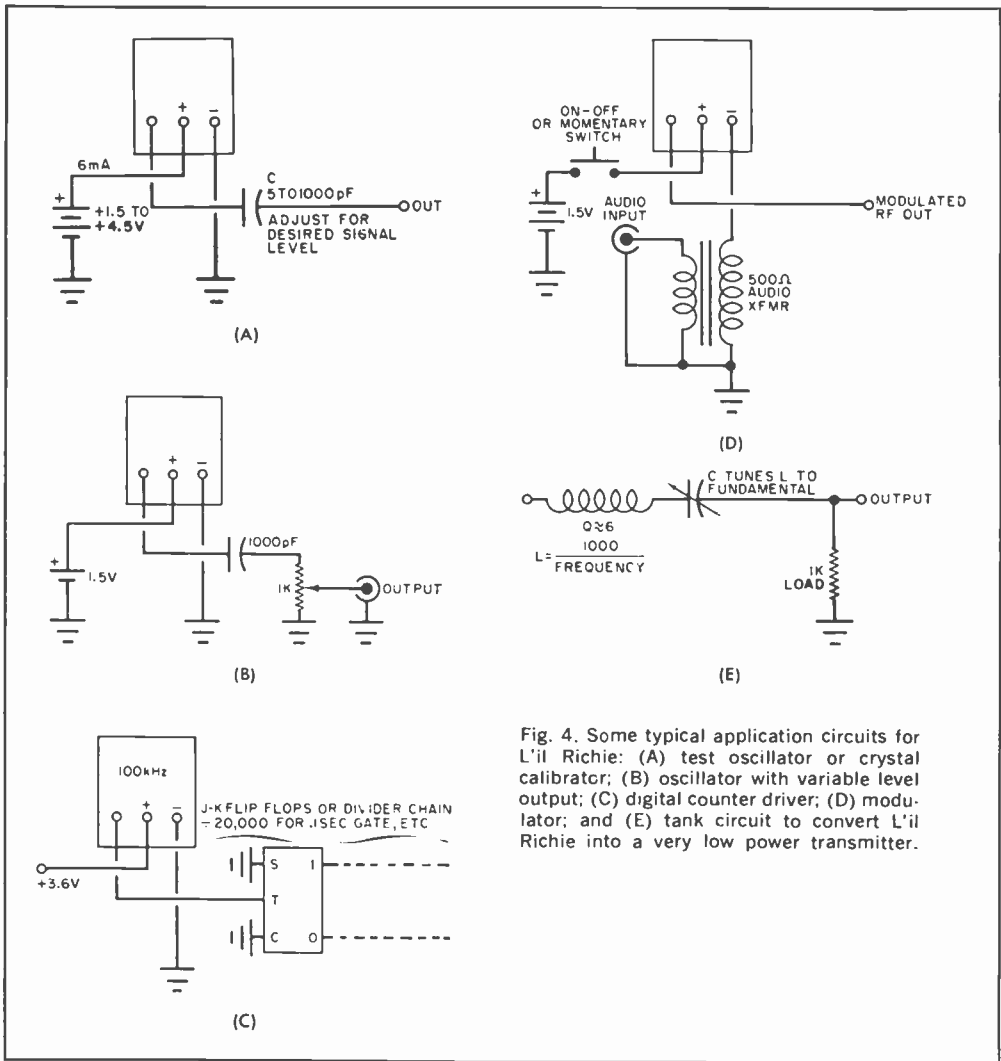


Fig. 4. Some typical application circuits for L'il Richie: (A) test oscillator or crystal calibrator; (B) oscillator with variable level output; (C) digital counter driver; (D) modulator; and (E) tank circuit to convert L'il Richie into a very low power transmitter.

capacitance shunting resistor  $R_2$  will settle things down. Values will be in the 50- to 200-pF range.

**Operating Hints.** Figure 4 shows some circuits you might like to try. In the test oscillator or crystal calibrator in Fig. 4(A), an output capacitor ( $C$ ) is selected to get the desired signal level. If you want a continuous output level adjustment range, use the circuit shown in Fig. 4(B). The digital clock and divider connection is shown in Fig. 4(C); a coupling capacitor is not required here.

On-off switching, keying, or audio modulation are added with the circuit in Fig. 4(D). Or, if you want a sinusoidal output instead of a square wave, just add a series-resonant tank circuit to the output, tuned to the crystal frequency, as shown in Fig. 4(E).

The generator's output voltage will be slightly less than the supply voltage. Expect around 1.2 volts peak-to-peak with penlight cell operation, and perhaps 4 volts for a 4.5-volt supply. Total circuit drain is less than 6 mA with the higher supply voltage.

# Getting The Most From Your CB Rig

AN IMPORTANT NOTE  
ON TUNING YOUR TRANSMITTER

By DANIEL MEYER, KMT2967

**E**VERY CB USER is entitled to get the maximum legally permitted power output from his transceiver. As long as the average input power is 5 watts or under, or the average output power is 4 watts or less, the FCC has no complaints. The most common methods of achieving optimum CB results, such as proper antenna matching, microphone techniques, etc., are well covered in the instruction manuals and have been detailed in many magazine articles. However, there is one subject on which much misinformation abounds yet is a vital point if you want to get maximum CB operating results within the legal limits. This is the matter of transmitter alignment.

**Transmitter Alignment.** Practically all of the instruction manuals supplied with CB equipment describe the transmitter final amplifier adjustments required in order to obtain maximum r.f. output. Usually these manuals recommend the use of a 52-ohm dummy load and adjustment of the final tank circuit for maximum meter reading (built-in metering, or power output metering). This method assumes that maximum r.f. output is the principal criterion in achieving best CB coverage. This might be true if the CB rig were being used for code

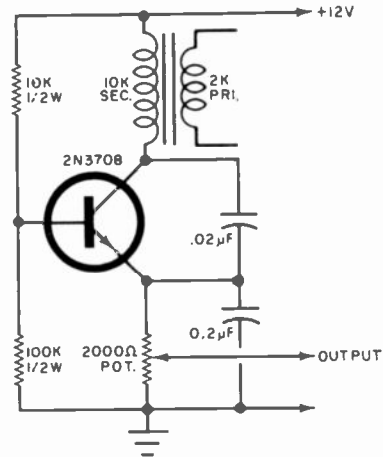


Fig. 1. This simple single-tone audio oscillator can be jury-rigged to provide a signal to modulate your CB rig. Tap the output to the hot side of the mike input. The transformer is a miniature component used for transistor interstage coupling.

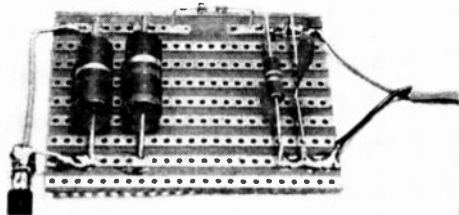
transmissions, but it is completely wrong with voice modulated transmitters.

Maximum CB coverage results when the received signal is demodulated at a distant point. Primarily, we are inter-

TRANSCEIVERS	METHOD OF ALIGNMENT			
	Tuned for Maximum RF		Tuned for Maximum Modulation	
	RF Output (W)	Det. Audio (V)	RF Output (W)	Det. Audio (V)
(1) Tube CB	3.75	3.5	3.5	4.0
(2) Transistor CB	3.5	3.25	3.25	3.8
(3) Tube CB	4.25 <sup>†</sup>	2.0	3.0	4.0
(4) Transistor CB	3.25	3.0	3.0	3.5
(5) Tube CB	2.5	2.75	2.25	3.25

<sup>†</sup>Illegally modified.

Table 1. Here are the results of tuning up five different CB rigs for maximum detected modulation rather than maximum r.f. output. All five transceivers got out better after the "modulation" tuneup.



POPULAR ELECTRONICS lab-tested the author's method with results that proved "modulation" tune-up was best. This is a Veroboard (wiring side up) hookup assembled in 10 minutes. Coax input is to the left, leads to the scope or VTVM to the right.

ested in getting the maximum amount of demodulated audio power at the receiver. Obviously, to obtain this maximum demodulated audio, we should tune the transmitter for maximum modulation rather than maximum r.f. output.

The received signal level depends on the amount of audio detected and not on the amount of carrier present. Actually, the less r.f. power needed to accomplish the job, the better the received signal.\* Manufacturers do not suggest transmitter alignment for maximum modulation because this requires test equipment and is not as simple as aligning for maximum r.f. output.

**How It Is Done.** To align your CB rig for maximum modulation, you need an audio oscillator. If you cannot borrow one, you can construct a very simple transistorized oscillator as shown in Fig. 1. The audio frequency is not critical and any frequency between 400-2000 hertz will do.

You will also need a dummy load-detector circuit similar to the one shown in Fig. 2. This circuit can be put into a small metal box or simply soldered together at the end of a short piece of coax cable. The output of your dummy load-detector circuit can be connected to an oscilloscope, a VTVM, or even a good multimeter.

The audio oscillator is connected to your microphone input. It is not necessary to disconnect the microphone; simply clip the output of the audio oscillator to the mike connector—or even to an input grid circuit under the chassis, whichever is handier.

\*See "Mule Box," POPULAR ELECTRONICS, March 1967, page 45.

To align the transmitter, key the transmitter and adjust the output of the oscillator for a clean sine wave as displayed on your oscilloscope. Do not increase the output of the oscillator past the point where the waveform is clipped, flattened or distorted. If you're using a multimeter or VTVM, the distortion point can be determined as that point where no further increase in output is obtained as the oscillator level is increased. The output signal (with the circuit shown) will generally be on the order of 2-6 volts r.m.s. The exact voltage depends upon the diode and the meter loading but is not important in aligning the transmitter.

Watch the scope, or meter, and adjust the final amplifier tuning and loading for maximum output. Adjust the controls in much the same way as you adjust those designed to tune up for maximum r.f. output. However, you will find that in

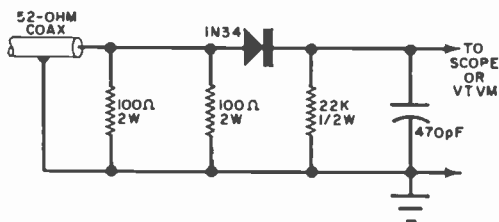


Fig. 2. To demodulate your CB output, you will need this circuit. Use a scope or VTVM to measure the output voltage—a VOM loads down the circuit.

tuning for maximum modulation the adjustments are much sharper and more critical. The two adjustments (in a usual pi-network) will interact.

It is recommended that you align your CB rig using an oscilloscope. The scope will also show if your rig produces distortion, which would result in reduced intelligibility and waste power output in audio harmonics.

**Results.** How much you can expect to gain by this method of alignment will depend on the particular CB rig you are using. Several examples of CB rigs aligned by the author are included in Table 1. In some cases, the alignment made for maximum r.f. output happened to result in something near the correct setting for maximum modulation. In other cases, the alignment made for maximum modulation resulted in something near the correct setting for maximum r.f. output. (Continued on page 150)



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# CHAPTER 5

## LAB & TEST EQUIPMENT PROJECTS

We are particularly pleased with the "mix" of projects described in this chapter of the Spring 1968 **ELECTRONIC EXPERIMENTER'S HANDBOOK**. The number and variety of test equipment projects is in keeping with the trend toward more home workshop design and construction of "individualized" testing gear. Readers should particularly note the two projects by James Randall embodying field-effect transistors in useful applications.

The audio waveform generator ideas (pages 110 and 118) are both useful and somewhat unusual, while the frequency meter (127) is an audio lab project that has been requested by **HANDBOOK** readers. And a topnotch home workshop in which a lot of solid-state experimentation is done should find Charles Rakes' transistor and diode tester of considerable interest.

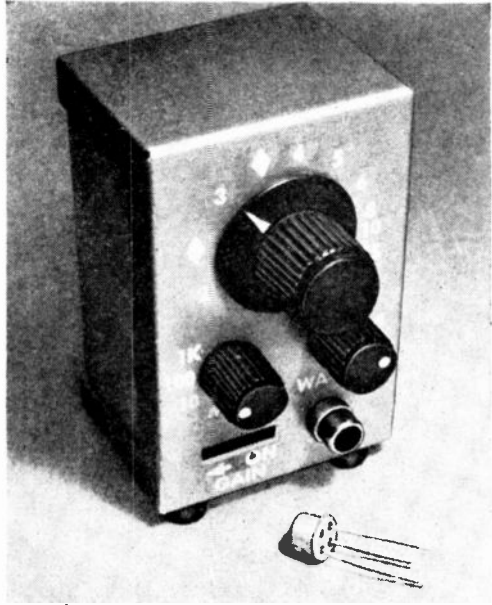
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# BUILD MULTI-WAVEFORM GENERATOR

SIMPLIFY YOUR  
HI-FI TESTING THROUGH  
THE USE OF  
THIS CONTINUOUS-COVERAGE  
LOW-COST GENERATOR

By MELVIN CHAN



**S**ERIOUS AUDIOPHILES with a good working knowledge of electronics are aware of the many types of test signal waveforms that can be used to check out audio amplifiers. Some signals, unlike sine waves, can perform a number of tests at one time. One of these signals is the square wave. This waveform will check out amplifier frequency response while simultaneously indicating any high- or low-frequency inadequacies, phase shift, and any ringing present in the system.

Some audio engineers prefer to use a sawtooth signal, instead of a square wave, to perform these tests, while others feel that a "spike" waveform is best. The use of these waveforms has been discussed in technical journals serving the hi-fi field. The simple, low-cost (under \$10) multiple waveform generator described in this article can deliver a square, sawtooth or spike waveform test signal, at any fundamental frequency between about 20 and 20,000 Hz.

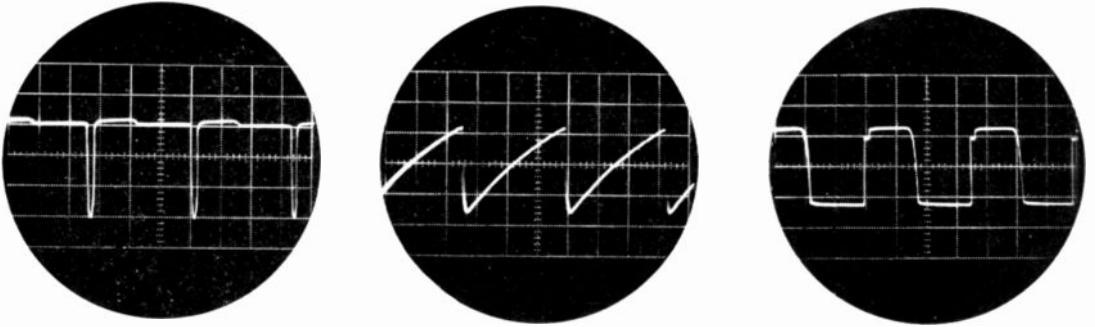
**How It Works.** The circuit for the test set is shown in Fig. 1. Transistor *Q1* is a unijunction unit operating as a relaxation oscillator. The frequency of oscillation is determined by front panel potentiometer *R2*, in conjunction with a

charging capacitor (*C1*, *C2*, or *C3*) selected by switch *S1*. During oscillation, a sawtooth waveform will appear at the emitter of *Q1*, and a negative-going spike will appear at *B2* of *Q1*. The sawtooth and spike waveforms are directly fed to waveform selector switch *S2*, and on to emitter follower *Q3*.

The sawtooth signal is also fed, through *R4*, to the base of transistor *Q2*.

## PARTS LIST

*B1*—9-volt battery  
*C1*—0.02- $\mu$ F capacitor  
*C2*—0.2- $\mu$ F capacitor  
*C3*—2.2- $\mu$ F electrolytic capacitor  
*C4*, *C5*—30- $\mu$ F, 6-volt electrolytic capacitor  
*C6*—0.47- $\mu$ F capacitor  
*J1*—Phono jack  
*Q1*—2N2646 unijunction transistor  
*Q2*, *Q3*—2N2712 transistor  
*R1*—1500-ohm, 1/2-watt resistor  
*R2*—25,000-ohm linear potentiometer  
*R3*—2000-ohm, 1/2-watt resistor  
*R4*, *R5*—10,000-ohm, 1/2-watt resistor  
*R6*—50,000-ohm miniature potentiometer (Lafayette 99 R 6145 or similar)  
*R7*, *R8*—100,000-ohm, 1/2-watt resistor  
*R9*—5000-ohm potentiometer (with *S3*)  
*S1*, *S2*—2-pole, 5-position switch  
*S3*—S.p.s.t. switch (part of *R9*)  
Misc.—Small box (Premier 1001 or Bud CU-3001-A), printed circuit board, knobs, hardware, etc.



The pulse (left), sawtooth (center) and square wave (right) waveforms as seen on an oscilloscope. The little step on the leading edge of the square wave will vary dependent on the transistor used for Q2.

This transistor is biased by  $R6$  so that it conducts only during a small portion of the sawtooth waveform. This produces a square wave at the collector of  $Q2$ . Transistor  $Q3$  is an emitter follower which accepts the signal selected by  $S2$  and supplies it, at relatively low impedance, through capacitor  $C6$ , to output jack  $J1$ .

**Construction.** Layout of the printed board is shown in Figs. 2 and 3, while Fig. 4 illustrates the method of mounting used by the author. The printed board is secured to the bottom of the case with three 2-56, 1/2"-long bolts, using nuts

to space the board far enough away from the case to preclude any possibility of shorting components. Figure 4 also illustrates one method of mounting the battery.

After mounting frequency control potentiometer  $R2$ , multiplier switch  $S1$ , waveform selector switch  $S2$ , and output jack  $J1$ , the printed board can be wired to these components as shown in Fig. 3. Looking at the rear of control  $R2$  (as mounted), the left-hand terminal goes to the PC board (near  $R3$ ), and the center and right-hand terminals are connected together. One lead from this

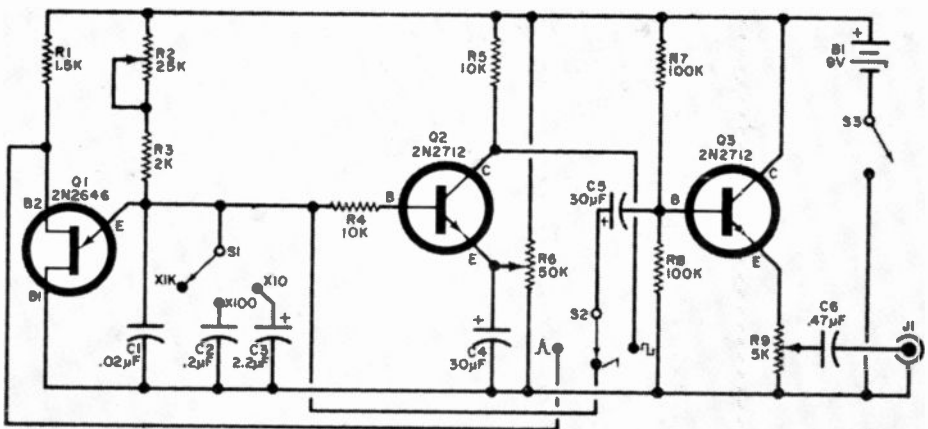


Fig. 1. As transistor Q1 oscillates, a pulse is generated at base-2 and a sawtooth waveform appears at the emitter. The sawtooth signal also produces a square wave via Q2. Signal choice is made by S2

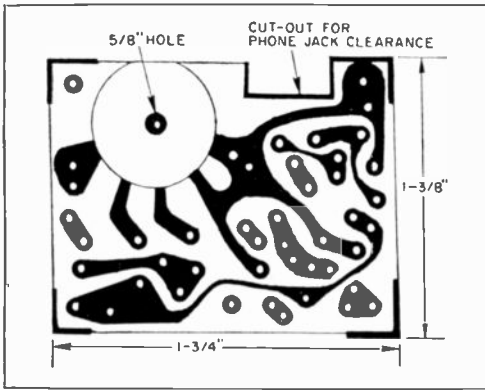


Fig. 2. Actual-size printed board. Potentiometer R9 (with S3 attached) is a printed circuit type (Lafayette 99 R 6019) and solders directly into board.

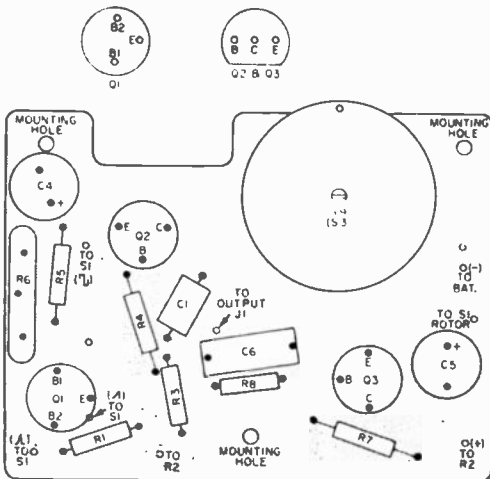


Fig. 3. Transistors Q2 and Q3 have in-line leads, although the PC board shows a triangular arrangement, so that other transistor types may be used. Drawing is oversize to show parts layout clearly.

pair goes to the PC board (near C5) and the other goes directly to the positive terminal of battery B1. The power switch (S3) is located in the negative lead of the battery.

**Calibration.** Connect an oscilloscope to the output jack, place S2 in the pulse setting, turn the generator on, and you should see a pulse-type signal on the scope. Switch S2 to the sawtooth position, and there should be a sawtooth waveform on the scope. Frequency of the

waveforms is dependent on the setting of R2 and S1.

When these waveforms are present, switch S2 to the square-wave position, and adjust R6 until a symmetrical square wave is obtained. Since this unit was not designed to rival precision instruments, there will probably be some discrepancy



Fig. 4. In the author's unit, the battery is mounted on the rear cover so that, when the two sections are joined, it will not mechanically interfere with R2, S1, S2, or components mounted on printed board.

in the calibration scale for each range. However, as shown in the photo on page 110, exact scale markings are broad.

To calibrate the unit, a reasonably accurate audio generator as well as an oscilloscope is required. Start with the x10 range. Set S1 to x10 and S2 to square-wave output. Connect the external audio generator to the scope and set it for 20 Hz. Adjust the scope sync control until it locks and displays only one 20-Hz waveform. Now, without touching the scope,

(Continued on page 140)



BUILD

# MULTIPURPOSE

# FET

# SIGNAL

# TRACER

IT'S SO SENSITIVE  
YOU CAN TRACE  
A SIGNAL  
ALL THE WAY UP TO  
THE RECEIVER INPUT

HERE'S a honey of a signal tracer you can build for less than the cost of an ordinary commercial unit, and yet is so versatile you can use it as a millivoltmeter, output meter, microphone preamplifier, auxiliary audio amplifier for tests and experiments, tape recorder monitor and, of course, as a sensitive and accurate signal tracer for testing and trouble-shooting audio- and radio-frequency circuits.

The advanced circuitry, featuring a field-effect transistor (FET) to achieve high input impedance and prevent circuit loading, includes a high-gain transistor preamplifier and a packaged imported audio amplifier that provide so much gain you can trace a signal right up to the very input of a receiver with a demodulator probe. Test results can be monitored visually on a panel voltmeter, externally on a scope, or aurally on a built-in speaker or optional headphones.

By **JAMES RANDALL**

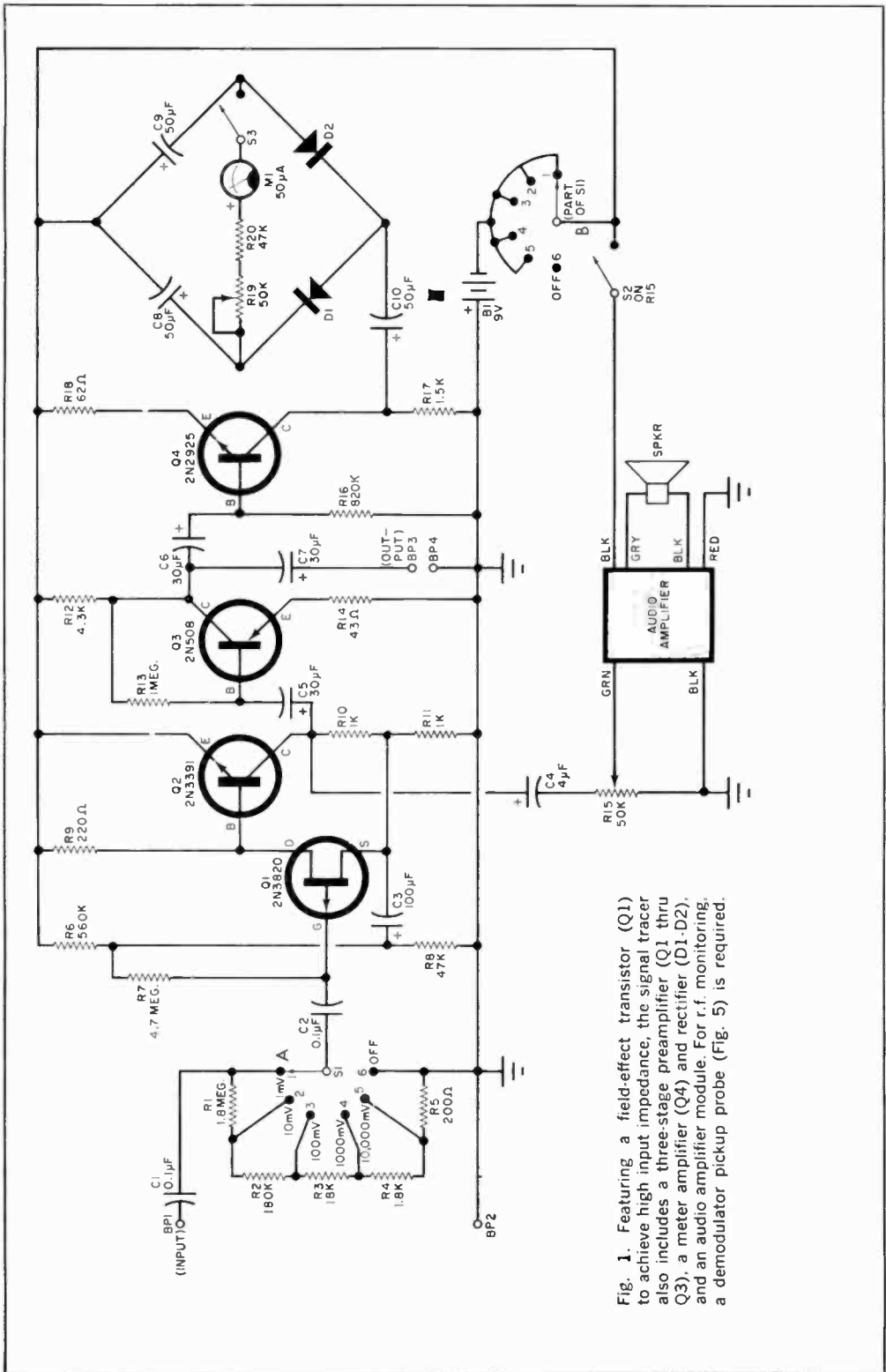


Fig. 1. Featuring a field-effect transistor (Q1) to achieve high input impedance, the signal tracer also includes a three-stage preamplifier (Q1 thru Q3), a meter amplifier (Q4) and rectifier (D1-D2), and an audio amplifier module. For r.f. monitoring, a demodulator pickup probe (Fig. 5) is required.

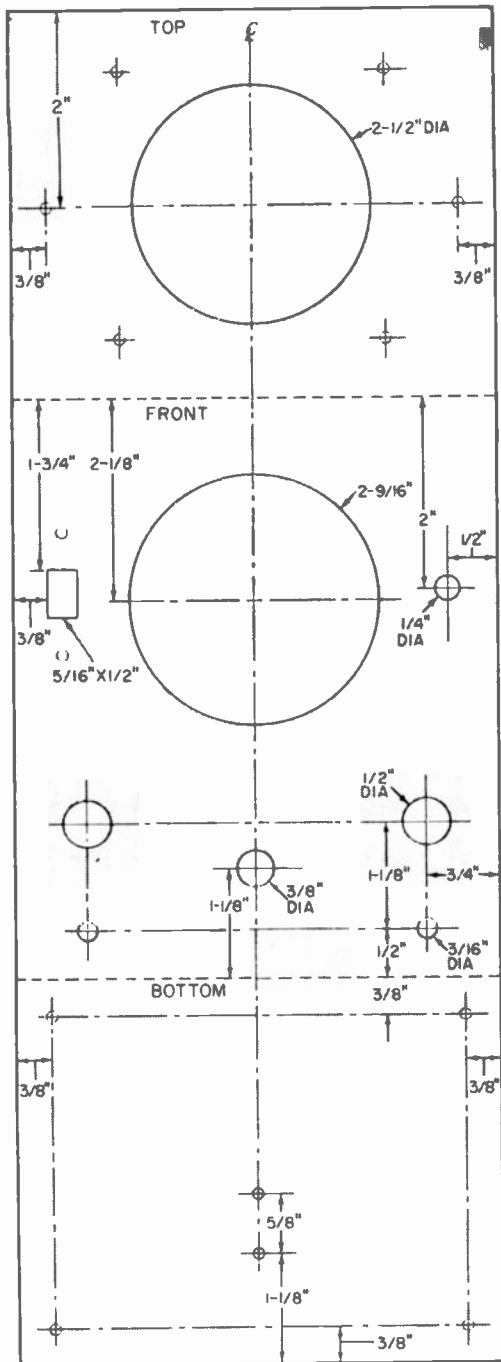


Fig. 2. If you use the recommended-size utility cabinet, you can follow these dimensions when you lay out the cabinet. Compare your speaker and meter sizes with the respective cutouts before punching any holes.

## SPECIFICATIONS

Input Impedance	2 megohms
Voltage Range	100 $\mu$ V to 10 volts
Preamplifier	
Voltage Gain	200
Audio Amplifier	
Output Power	100 milliwatts
Power Requirements	9-volt battery

## PARTS LIST

- B1—9 volt transistor battery  
 BP1, BP2, BP3, BP4—5-way binding post  
 C1, C2—0.1- $\mu$ F, 100-volt capacitor  
 C3—100- $\mu$ F, 6-WVDC, miniature electrolytic capacitor  
 C4—4- $\mu$ F, 12-WVDC, miniature electrolytic capacitor  
 C5, C6, C7—30- $\mu$ F, 12-WVDC, miniature electrolytic capacitor  
 C8, C9, C10—50- $\mu$ F, 6-WVDC, miniature electrolytic capacitor  
 D1, D2—1N60 germanium diode  
 M1—3" meter, 0-50  $\mu$ A (Lafayette 99 C 5042 or similar)  
 Q1—2N3820 field effect transistor  
 Q2—2N3391 transistor  
 Q3—2N508 transistor  
 Q4—2N2925 transistor  
 R1—1.8 megohms,  $\pm 5\%$   
 R2—180,000 ohms,  $\pm 5\%$   
 R3—18,000 ohms,  $\pm 5\%$   
 R4—1800 ohms,  $\pm 5\%$   
 R5—200 ohms,  $\pm 5\%$   
 R6—560,000 ohms  
 R7—4.7 megohms  
 R8—47,000 ohms  
 R9—220 ohms,  $\pm 5\%$   
 R10, R11—1000 ohms,  $\pm 5\%$   
 R12—4300 ohms  
 R13—1 megohm  
 R14—43 ohms  
 R15—50,000-ohm potentiometer (with switch S2)  
 R16—820,000 ohms  
 R17—1500 ohms  
 R18—62 ohms  
 R19—50,000-ohm potentiometer  
 R20—47,000 ohms see text  
 S1—2-pole, 6-position miniature switch  
 S2—S.p.s.t. switch (on R15)  
 S3—S.p.d.t. slide switch  
 T—100-mW, 4-transistor, imported audio amplifier (Lafayette 99 C 9042 or similar)  
 U—6" x 5" x 4" utility cabinet  
 Misc.—Rubber feet (4), 1/4" long  $\approx 6$  spacers (2), handle, grill cloth, pointer knob for M, circuit board, wire, solder, battery clip, etc.  
 Accessories—Oscilloscope demodulator probe (1); oscilloscope direct probe (1)

all resistors  
1/2-watt

## USING THE SIGNAL TRACER

To signal-trace the r.f. and i.f. stages of a receiver, use a demodulator probe at the input binding posts. Set the dial of the receiver under test to a local station, or apply a signal at the receiver input using a signal generator. Then turn the receiver on.

For aural signal-tracing turn on the signal tracer, set its sensitivity control to 1 mV, and advance the volume control as necessary for comfortable listening. Starting at the receiver antenna coil, touch the probe tip in turn to the input and output of each stage in the receiver through the audio section. When you lose the signal, the difficulty lies in the stage just preceding the last test point. You can get an indication of the gain of each stage by the amount the sensitivity and gain controls must be reduced to maintain equal volume.

For visual monitoring, the audio amplifier can be turned off and the signal voltage read on the panel millivoltmeter, or on a scope connected at the output binding posts. You can also monitor the incoming signal at these binding posts with a pair of headphones.

To use the signal tracer as an audio amplifier for a microphone, tape recorder, phonograph, etc., connect the source to the input terminals with a shielded cable or direct probe, and use either the internal speaker or external remote speaker for listening.

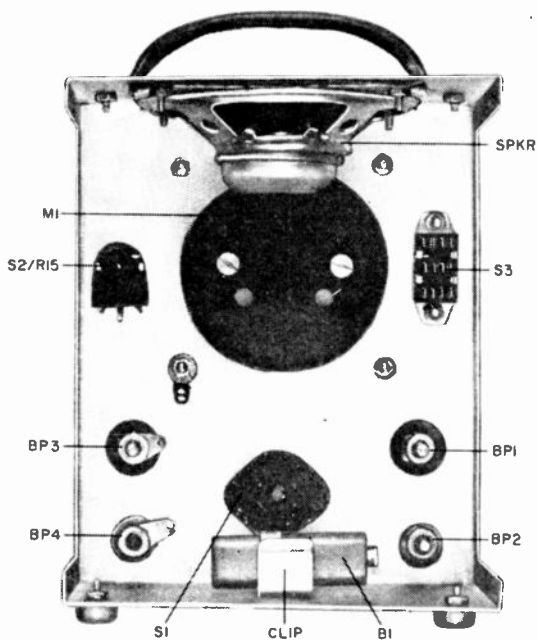
**Circuit Description.** The signal tracer (Fig. 1) consists of a step attenuator ( $R1$  through  $R5$ ), a three-stage preamplifier ( $Q1$  through  $Q3$ ), a meter amplifier ( $Q4$ ) and bridge, and a packaged audio amplifier and speaker.

An input signal is attenuated as necessary by the setting of  $S1$  before it is applied, through  $C2$ , to the gate of FET  $Q1$ , biased by  $R7$ . The amplified output at  $Q1$ 's drain is direct-coupled to the base of  $Q2$ , biased by the drop across  $R9$ . The output at the collector is fed through  $C5$  to the base of  $Q3$ , biased by  $R13$ , and to the audio amplifier module through  $C4$  and gain control  $R15$ .

A signal at  $Q3$ 's collector can be monitored at OUTPUT binding posts  $BP3$  and  $BP4$ , across coupling capacitor  $C7$ , and is also fed through  $C6$  to the base of  $Q4$ , biased by  $R16$ . The amplified output at the collector is applied through  $C10$  to the bridge rectifier and the meter ( $M1$ ) circuit for measurement.

The entire unit is powered by a 9-volt transistor battery, controlled by  $S1$  and  $S2$ . Switch  $S3$  serves to disconnect  $M1$  from the circuit when the meter is not in use. Potentiometer  $R19$ , in series with limiting resistor  $R20$ , permits easy calibration of the meter.

Fig. 3. After you have laid out the cabinet, and drilled or punched out the necessary mounting holes, secure the carrying handle and then install the speaker, meter, and other components shown.



Since a 50- $\mu$ A meter must be used for  $M1$ , its scale has to be replaced with that of a 1-mA meter, or recalibrated for 1-mV full scale. The dial can be calibrated simultaneously with the unit after assembly.

**Construction.** Lay out and drill the holes in the metal cabinet according to the dimensions given in Fig. 2. If you



plan to use a larger cabinet or a different voltmeter, be sure to make the necessary changes in the dimensions before proceeding with the construction.

After drilling and cutting the holes, deburr them using a fine file, and then spray on a coat or two of light gray

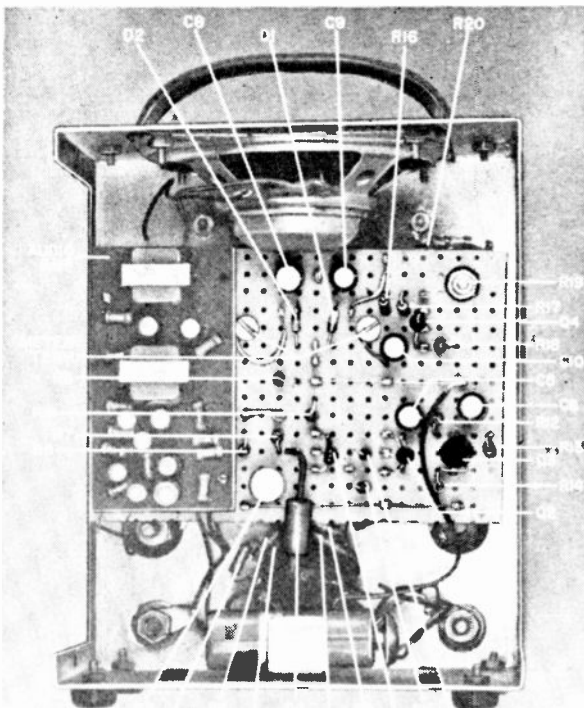


Fig. 4. Layout is not critical but do not dress the input and output leads near each other, to prevent feedback. You can rearrange the parts as you wish for improved appearance. Resistors R1 through R5 are mounted directly on S1.

paint and allow it to dry thoroughly. Label all controls and binding posts with decal lettering, then seal the lettering with a few coats of clear plastic spray or clear lacquer.

Refer to Fig. 3 and install the handle, speaker and grille, rubber feet, battery clip, voltmeter, binding posts and switches as shown. Before you install switch S1, it must be prewired and assembled with

the attenuator resistors (R1 through R5) in accordance with Fig. 1. Observe, also, that S2 is mounted on potentiometer R15.

Mount the audio amplifier module on one side of a 4 $\frac{3}{4}$ " x 3" perforated circuit board (see Fig. 4), isolating the amplifier with  $\frac{1}{2}$ "-long standoff spacers. Assemble the circuit board following any convenient layout. The one shown can be used as a guide. Keep all leads as short as possible, and avoid crossing input and output circuits to insure against oscillation.

Potentiometer C19 and capacitors C4 and C7 are mounted on the underside of the circuit board. The easiest way to handle this mounting problem is to connect one end of each capacitor to the board before it is mounted, and connect the other end after the circuit board is in place. *Be sure to observe all capacitor and diode polarities.*

Using the terminal screws that come with the meter, secure the circuit board to the back of the meter housing with  $\frac{1}{4}$ " spacers between the two surfaces to isolate the board from the meter. Complete the rest of the point-to-point wiring, following the schematic (Fig. 1). Now install the battery.

Check the unit for overall operation by applying a signal at the input and observing the meter deflection, or try monitoring the signal at the loudspeaker with all controls on.

**Calibration.** To calibrate the signal tracer, flip meter switch S3 to its *on* position, turn off the audio switch on the GAIN control, and set the SENSITIVITY switch to 1 mV.

Apply a 1-kHz, 1-mV signal to the INPUT jacks, and adjust potentiometer R19 for full-scale deflection. If the meter pegs, or if full-scale deflection is obtained with R19 set to maximum resistance, increase the value of R20 as necessary to obtain 1-mV full-scale deflection with R19 at mid-range. If, on the other hand, full-scale deflection cannot be achieved with R19 at mid-range, reduce the value of R20 as necessary. Lock or seal the calibration pot (R19) without disturbing its setting.

If precision resistors were used for R1 through R5, the calibration for the  
(Continued on page 152)

# SIGNAL - POWERED SIGNAL SQUARER

THIS INEXPENSIVE ADDITION TO A SINE-WAVE GENERATOR  
 PRODUCES FAST RISE-TIME  
 SQUARE WAVES OF THE SAME FREQUENCY

By **LESLIE SOLOMON**, Technical Editor

**M**OST EXPERIMENTERS either have, or have access to, conventional audio frequency sine-wave generators. However, there may come a time when you are finishing some project and the instructions call for the use of a square-wave signal—but you don't have a square-wave generator! After being hit this way a couple of times, the author decided to either buy a composite sine/square wave generator, or cook up some circuit that could be used with an existing sine-wave source. The result is shown in the diagram below.

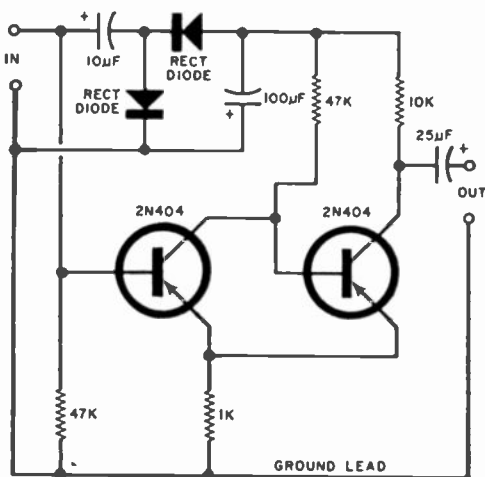
The circuit is a conventional two-transistor Schmitt trigger having a built-in

power supply with both signal and a.c. power derived from the output signal of the audio generator. Operation of the Schmitt trigger is such that the frequency of the output square wave is the same as the frequency of the incoming sine wave. Unlike a bistable multivibrator, commonly used in squaring circuits, the Schmitt circuit does not divide the frequency by two. Also, rise time is excellent.

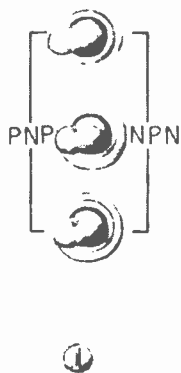
Input signal requirements are rather broad. The circuit will accept almost any source of a.c. between 50 and 15,000 Hz, with a voltage level between 0.5 and 10 volts r.m.s. Output signal level is a function of input signal level.

Component values are not critical and may vary broadly from those shown in the schematic. If *npn* transistors are used, reverse the polarity of the rectifier diodes and the electrolytic capacitors. In fact, a little experimentation with various values of resistors and capacitors will teach you a lot about Schmitt trigger operation. The rectifier diodes can be any type, of almost any voltage or current ratings, that you happen to have on hand.

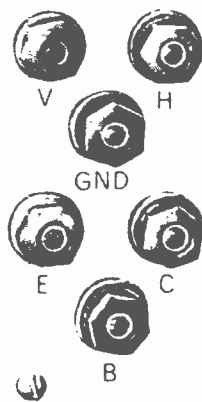
Mounting is up to the builder. Several units have been made, ranging from small PC boards that can be directly plugged into the output jacks of the sine-wave generator to perforated board projects that are mounted within the generator and provided with separate output terminals.



The incoming sine waves play a dual role: they trigger the Schmitt circuit and supply d.c. power.



MAX. CURRENT ADV.



## BREAKDOWN REVERSE VOLTAGE TRANSISTOR AND DIODE TESTER

**F**OR EACH different transistor parameter, there is a test procedure that can be set up and followed in order to predict a transistor's ability to live up to its specifications. While there are many different specifications for a transistor, not all of them must be up to par in any one application. For most applications, it is usually sufficient to know that a transistor will work in a given circuit, without being too concerned about the transistor's capabilities in excess of the circuit's requirements. Quite often you can take advantage of the commercially accepted tolerance of ratings by going through a batch of less expensive transistors and selecting those that will work in your circuit.

For example, if a transistor is rated to withstand a reverse voltage across the collector and base elements of, say, 100 volts, you wouldn't care whether or not the transistor breaks down at 75 volts when the most voltage it will see in a

NONDESTRUCTIVE  
"ONE-SHOT"  
SCOPE TECHNIQUE  
USED TO  
REVEAL SEVERAL  
CHARACTERISTICS  
AT ONCE

By **CHARLES D. RAKES**

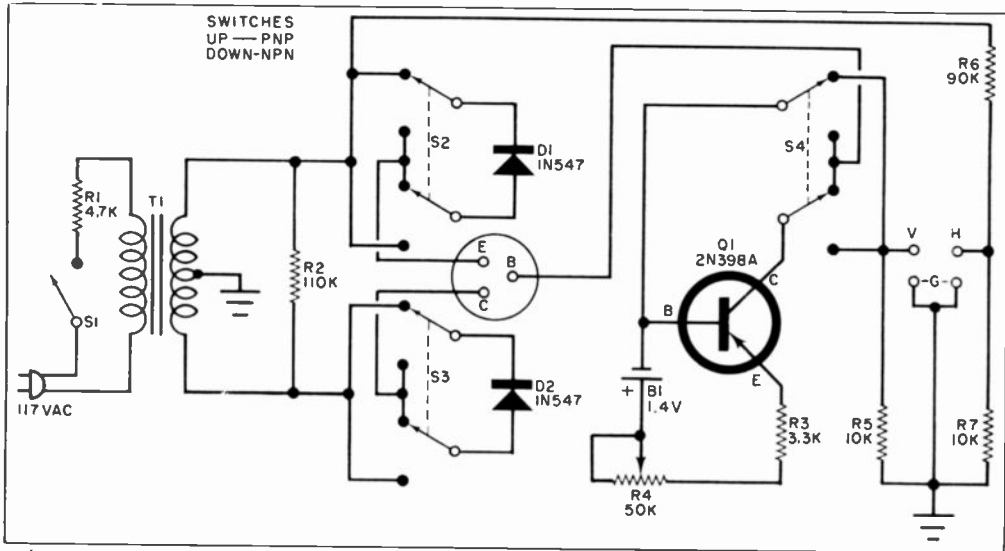


Fig. 1. Reverse voltage is applied alternately across the emitter-base junction of the transistor under test by the combined action of diodes D1 and D2 on the a.c. voltage from the transformer. Transistor Q1 acts as a current limiter. Potentiometer R4 can be adjusted to limit maximum current flow to a predetermined value. Zener diodes and other diodes as well as neon lamps can be checked out with this adapter. Output voltages are fed to an oscilloscope for interpretation.

given circuit does not exceed 9 volts. But you wouldn't want to put this transistor into a 90-volt circuit. By the same token, if the transistor checked out at 120 volts, there's no reason why you couldn't insert this component into a 110-volt circuit.

Many fine, inexpensive transistor testers are available that can predict gain and leakage, but none of them can tell you anything about the figure for reverse breakdown voltage. One way to check reverse breakdown voltage is to gradually apply an increasing amount of voltage until the transistor breaks down. Once you do that, you will know what the breakdown voltage is, and you will also have to junk the transistor. It's like testing a fuse to find out how much current it will take to make it pop. There is no trick to a destructive-type test and there is a point of no return that most of us would object to. The way to avoid destruction of solid-state components even in the presence of potentials in excess of the breakdown voltage is to limit the amount of current to prevent thermal runaway.

If you have an oscilloscope, you can take a page out of a transistor manufacturer's notebook; and if you build the simple, low-cost circuit presented here,

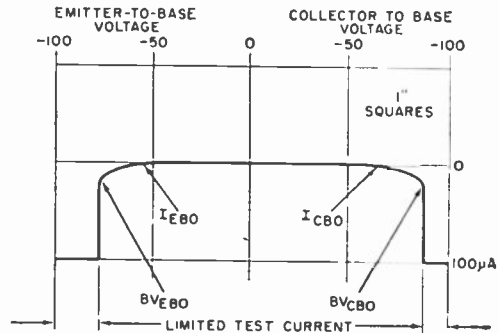


Fig. 2. Trace obtained when testing a good transistor can be analyzed as follows: left portion of curve shows what happens when reverse voltage is applied across emitter-base junction; right side indicates collector-base junction characteristics. Trace also shows cutoff and reverse current.

you can perform a non-destructive test to check both emitter-to-base reverse breakdown voltage, and collector-to-base reverse breakdown voltage. With this circuit, you will also be able to determine emitter cutoff current and collector cutoff current. All four of these parameters can be ascertained from a single scope trace, in a "one-shot" type of test. The procedure is rapid and lends itself to mass production techniques.

As a sort of bonus feature, this same

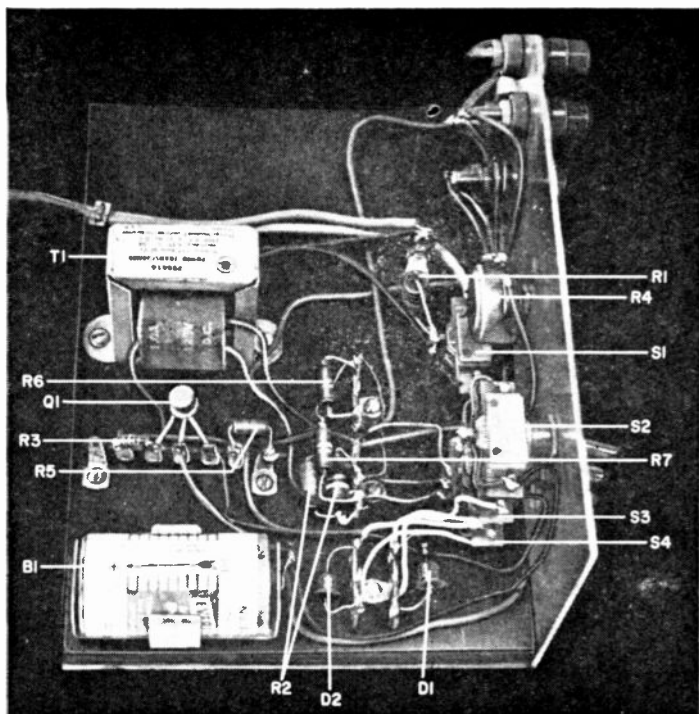


Fig. 3. Layout of components is not critical. Two resistors are shown connected in parallel to obtain proper value for R2. A 3-gang d.p.d.t. switch can be used instead of separate switches for S2, S3, and S4. Observe polarity of B1, D1 and D2.

#### PARTS LIST

*B1*—1.4-volt mercury battery  
*D1, D2*—1N547 diode  
*Q1*—2N398A transistor  
*R1*—4700-ohm, 2-watt resistor  
*R2*—110,000-ohm, 4-watt resistor—see text  
*R3*—3300-ohm, 1/2-watt resistor  
*R4*—50,000-ohm potentiometer  
*R5*—10,000-ohm, 1/2-watt resistor  
*R6*—90,000-ohm, 1/2-watt resistor  
*R7*—10,000-ohm, 1/2-watt resistor  
*S1*—S.p.s.t. switch  
*S2, S3, S4*—D.p.d.t. switch  
*T1*—Power transformer: primary, 117 volts; secondary, 250 volts with center tap (Stancor PSS416, or similar)  
*Misc.*—Terminal strips, binding posts, chassis, hardware, etc.

test procedure will let you determine the zener voltage of zener diodes, the reverse breakdown voltage for low-peak-inverse-voltage diodes, and both the firing and holding voltages of neon lamps.

**How It Works.** With this test circuit, units under test are subjected to a maximum reverse voltage of about 100 volts. The "maximum-current" range is adjustable from approximately 20  $\mu$ A to 500  $\mu$ A. The amount of maximum current that

can be safely passed through the transistor under test depends upon the power that can be safely dissipated in the tested unit. If a large number of units are to be checked, the voltage and current limits can be grease-penciled on the oscilloscope screen for a quick go-no-go selection.

As shown in Fig. 1, switches S2, S3, and S4 are in the PNP position, and the anodes of diodes D1 and D2 are connected to the emitter and collector test jacks respectively. The base test jack is returned to ground through current sampling resistor R5.

The voltage developed across R5 is fed to the vertical input of the scope through test jacks marked V and G. The scope's horizontal sweep is controlled by the voltage that appears across the 10 to 1 voltage divider resistors R6 and R7 and which is fed out through the terminals marked H and G.

**Emitter-To-Base Reverse Voltage.** When the top of T1 goes negative with respect to ground, D1 conducts, and sends the emitter voltage (with respect to base) of the transistor under test in the nega-

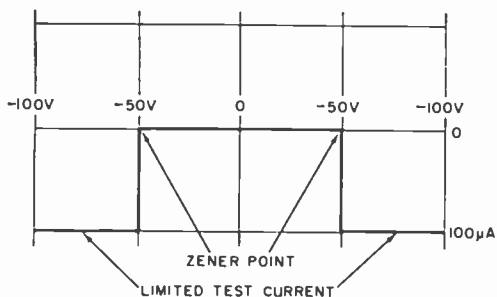


Fig. 4. Typical scope trace of good zener diode is shown here. Right half reveals same information as left half, and is actually redundant. Single-sided patterns can be just as easily obtained. See text.

tive direction and causes a downward deflection of the scope's trace when this voltage breaks through the emitter base junction. Keep in mind that this potential across the emitter and base is reverse voltage. Also, the voltage at the top end of  $R6$  and  $R7$  at this time is negative with respect to ground. As the voltage swings in the negative direction, the scope's spot travels from the center of the screen towards the left to display a horizontal trace.

The action of the scope's trace can be understood by an examination of Fig. 2. Note that as the negative horizontal voltage increases the reverse voltage across the emitter and base is also increasing, and at about 75 volts the curve drops sharply—this is the point of voltage breakdown.

During the time that the emitter-to-base-junction is subjected to this reverse voltage,  $D2$  blocks the collector current

### REVERSE VOLTAGE AND CURRENT CUTOFF PARAMETERS

$BV_{CB0}$ : Collector-to-base d.c. breakdown reverse voltage with the emitter circuit open. Collector current ( $I_c$ ) should be specified.

$BV_{EB0}$ : Emitter-to-base d.c. breakdown reverse voltage with the collector circuit open. Emitter current ( $I_e$ ) should be specified.

$I_{CB0}$ : Collector d.c. current cutoff when the collector junction is reverse-biased with the emitter circuit open. Collector base voltage ( $V_{CB}$ ) should be specified.

$I_{EB0}$ : Emitter d.c. current cutoff when the emitter junction is reverse-biased with the collector circuit open. Emitter base voltage ( $V_{EB}$ ) should be specified.

of the transistor under test and leaves the collector in an essentially open-circuited condition. This open-circuit condition satisfies one of the requirements for determining the specification for reverse voltage breakdown.

During the time that the applied voltage is in excess of the breakdown voltage, current is limited to prevent destruction of the component under test by the action of circuit  $Q1$ ,  $R3$ ,  $R4$ , and  $B1$ . Potentiometer  $R4$  can be adjusted to increase or decrease the maximum current.

As the voltage across the secondary of  $T1$  swings back to zero, the spot on the screen retraces its path, and returns to its central point on the zero reference line.

**Collector-To-Base Reverse Voltage.** When the polarity of the a.c. voltage across  $T1$  reverses, a positive voltage appears across  $R6$  and  $R7$  and pulls the spot horizontally from the center of the screen to the right. The positive voltage on the cathode of  $D1$  also blocks the emitter current of the transistor under test, effectively opening the emitter circuit. The negative voltage on the anode of  $D2$  now completes the collector-to-base circuit through  $Q1$ . The trace on the right side of the scope indicates the collector-to-base reverse voltage breakdown. Here again the requirement for the third element in a transistor to be open-circuited when checking for reverse voltage breakdown is satisfied.

The same action takes place for an  $npn$  type of transistor except that the polarity of the reverse voltage is reversed and the deflection of the trace will be upward. Of course, switches  $S2$ ,  $S3$ , and  $S4$  are simultaneously flipped to the  $NPN$  position.

While the vertical deflection of the scope's beam is a function of the voltage drop across  $R5$ , the extent of this voltage drop depends upon the current through  $R5$ , the collector-to-base of  $Q1$  and the transistor under test. If the vertical input of the scope is calibrated for 1 volt per inch, a 1-inch high trace represents  $100 \mu A$  of current ( $100 \mu A \times 10,000 \Omega = 1 \text{ volt}$ ).

The tilt on the left side of the trace (Fig. 2) shows emitter-to-base reverse

(Continued on page 140)

# THE "R.F. SNIFFER"



**N**O HAM OR CB'ER should be without some type of r.f. signal indicator for trouble-shooting and operating transmitters, r.f. amplifiers, and oscillators. A simple r.f. field strength meter fits the bill nicely. This device is almost as versatile in r.f. circuits as a multimeter is in d.c. and low-frequency a.c. circuits. Furthermore, it is easier to use and it is more compact than most multimeters.

For versatility, few field strength meters that cost up to \$15 have an advantage over the inexpensive unit described here. The tiny "Sniffer" can "tell" you when your transmitter is on-the-air simply by "sniffing" (sampling) your transmitted carrier. Off-the-air tuning of low power transmitters is simplified when the "Sniffer" is used as a dummy load antenna. Also, this versatile little test instrument can "sense" when an oscillator is working correctly, and it can respond to electromagnetic radiation coming from r.f. circuits within its pick-up field.

**The Circuit.** The "R.F. Sniffer" circuit shown in Fig. 1 is a voltage doubler type of detector, formed by capacitors  $C1$  and  $C2$  and diodes  $D1$  and  $D2$ . This type of circuit provides almost twice as much sensitivity as would be obtained from a single-diode detector.

BUILD A FIELD STRENGTH METER FOR LESS THAN \$6

By J. C. GILLESPIE

Resistors  $R1$  and  $R2$  and capacitor  $C3$  form a filter network which tends to smooth the rectified voltage to the meter to provide a steady pointer deflection. Unless the meter circuit is calibrated to yield a specific reading at a set distance from a circuit of known power, the reading obtained will be only of a relative nature. However, this circuit is typical of the type used with commercially available test equipment, such as voltmeters, oscilloscopes, and field strength meters.

**Construction.** Almost any type of chassis construction can be employed, but keep component leads as short as possible. If you prefer a printed circuit board layout, you can make your own by using Fig. 2 as a guide. Parts placement, however, is not critical.

Be careful to observe the proper polarity when connecting  $D1$ ,  $D2$ , and the meter into the circuit. Since the "Sniffer" is to be used at r.f. frequencies, select

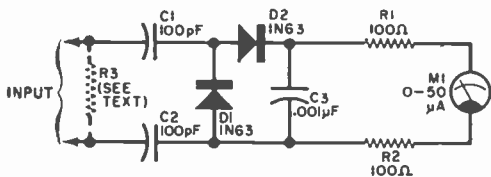


Fig. 1. Values shown for C1, C2 and C3 are for frequencies up to about 3 MHz. For higher frequencies, smaller value capacitors are required.

### PARTS LIST

C1, C2—100-pF disc capacitor  
 C3—0.001- $\mu$ F disc capacitor  
 D1, D2—1N63 point-contact diode  
 M1—0-50  $\mu$ A meter  
 R1, R2—100-ohm,  $\frac{1}{2}$ -watt resistor  
 R3—52- or 75-ohm, 1-watt carbon composition resistor—see text  
 Misc.—Printed circuit or perforated phenolic board, five-way binding posts or metal spacers, (2) solder, hardware, etc.

point-contact type diodes for D1 and D2. In applications where the frequency is higher than about 3 MHz, the values for C1, C2 and C3 should be considerably smaller than shown in Fig. 1.

Fasten five-way binding posts, or a pair of 1"-long threaded metal spacers as shown in Fig. 3, to the "Sniffer" to serve as input terminals.

**Applications.** A 6" length of hookup wire, when connected to either of the input terminals, acts as an antenna which should produce a good r.f. voltage indication on the meter. Simply set the "Sniffer" near an r.f. amplifier or a trans-

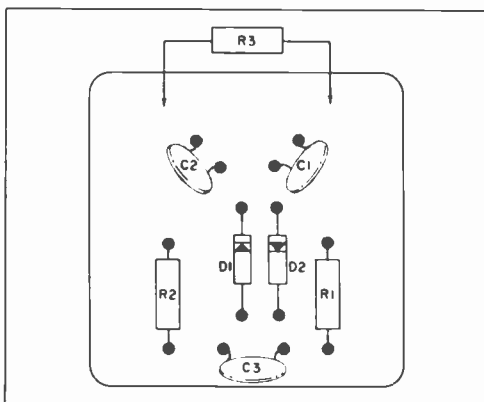


Fig. 2. Component side of actual-size printed circuit board with "see-through" view of foil side.

mitter antenna to obtain a reading. In order to prevent loading and other interactions, do not place the "Sniffer" closer to the test circuit than is necessary to obtain useful meter readings.

If you want the "Sniffer" to indicate the presence of electromagnetic radiation, bend a 6" length of wire to form a loop, and connect the ends to the inputs of the "Sniffer." This setup is used in much the same manner as you would dip a grid dip meter into a test circuit. In the case of miniaturized circuits where dipping can be difficult, make a smaller loop, but use twisted-pair wire.

For dummy load antenna operation, solder a 52- or 75-ohm carbon composi-

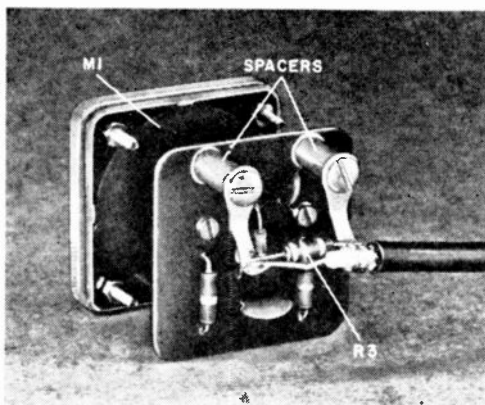


Fig. 3. Mount foil side of printed circuit board facing meter. Photo shows how coaxial cable and R3 are connected for dummy load antenna operation.

tion resistor (R3) across the "Sniffer's" input terminals as shown in Fig. 3. (The characteristic impedance of the transmission line will determine the value of the resistor needed.) Then connect the center conductor to the input terminal adjacent to C1 and the shield of the transmission line to the other input terminal. For use with transmitters capable of more than 1 watt of output power, connect two resistors in series, but wire the transmission line across only one of the resistors; the modification will safely withstand two watts of power.

If you are a ham, CB operator, hobbyist, or technician, you'll soon find the "R.F. Sniffer" indispensable for quick checks of r.f. equipment. Its light weight and small size make it convenient for mobile use.





# VOM + FET = TVM

**W**OULD YOU USE an ordinary low-input impedance VOM (volt-ohm-milliammeter) to make essential voltage measurements in high-impedance circuits while your VTVM (vacuum-tube voltmeter) was sitting idly on your workbench? Of course not. But what do you do if you don't have a VTVM? You can step up the input impedance of your VOM by interposing a suitable device between the circuit under test and the VOM. Such a device—a FET VOM-to-TVM converter—can be built for about \$10.00.

So long as your present VOM has a 0-50 to 0-100  $\mu$ A d.c. full-scale range, it can be made to exhibit an input impedance on the order of 10 megohms even on low d.c. voltage ranges with the aid of this converter. If you want to measure a.c., you can achieve an input resistance of about 1 megohm by simply using a rectifier probe with the converter.

Battery operation of the converter and the VOM make the combination into a portable "VTVM" independent of a 117-volt power line—an advantage most VTVM's do not have.

BUILD SIMPLE ADAPTER  
TO MAKE YOUR VOM  
ACT LIKE A  
\$200 TRANSISTORIZED  
VOLTMETER

By **JAMES RANDALL**

**How It Works.** Figure 1 shows the circuit diagram for the converter. Resistors  $R1$  through  $R4$  comprise a 10-megohm voltage divider used for range selection. The N-channel field-effect transistor (FET),  $Q1$ , in a source-follower configuration isolated by  $R5$ , acts like a high-impedance to low-impedance matching device, and also forms one leg of a bridge circuit.

The other legs of the bridge are made up of source resistor  $R6$ , potentiometer  $R9$ , and resistors  $R8$  and  $R10$ . Potentiometer  $R9$  zero-sets the meter (balances the bridge) to compensate for the current through  $R6$  and  $Q1$  when no voltage is applied to the test probes.

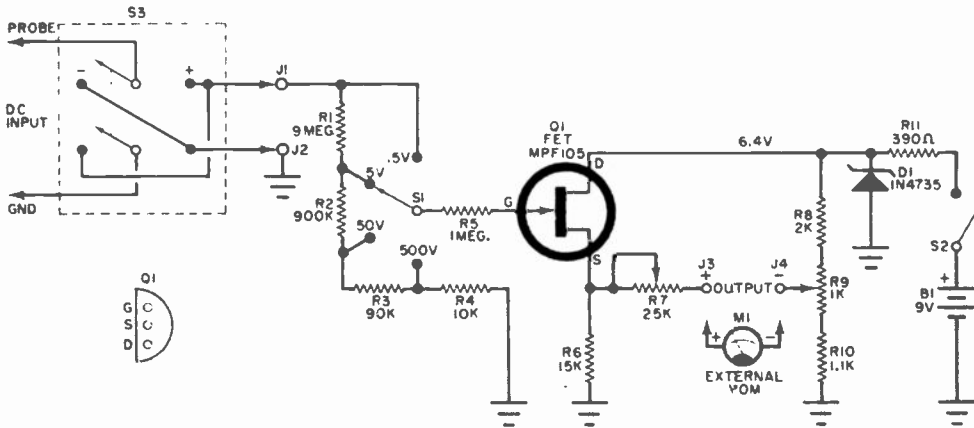


Fig. 1. High-impedance characteristic of field effect transistor permits 10-megohm voltage divider to come between the circuit under test and a VOM. Divider sets up 4 voltage ranges from 0.5 volt to 500 volts.

Operating power is supplied by *B1*, and stabilized by zener diode *D1*, to maintain calibration accuracy for a longer period during the life of the battery. Battery end voltage in this instance is about 6 volts.

To measure a.c. voltages with any d.c. instrument, it is first necessary to convert the a.c. into d.c., which is then measured by the instrument. A suitable circuit for making this conversion is shown in Fig. 2.

The r.m.s. values of a.c. voltages from power line frequencies to r.f. can be measured by using this circuit ahead of the voltage divider in the FET converter. The limit of the maximum voltage which can be measured is determined primarily by *D2*, which is used as the rectifier. Input coupling capacitor *C1* can have a 400-volt rating or higher, as desired. Resistors *R12* and *R13* should be precision 1% types, or selected from 5% resistors to obtain accurate values.

### PARTS LIST

- B1*—9-volt battery
- C1*—0.05- $\mu$ F, 600-volt capacitor
- D1*—6.2-volt,  $\frac{1}{2}$ -watt zener diode
- D2*—1N4003 diode, or similar
- J1, J2, J3, J4*—Input and output jacks or binding posts
- Q1*—Motorola MPF105 field-effect transistor
- R1*—9 megohms,  $\pm 5\%$
- R2*—900,000 ohms,  $\pm 5\%$
- R3*—90,000 ohms,  $\pm 5\%$
- R4*—10,000 ohms,  $\pm 5\%$
- R5*—1 megohm,  $\pm 20\%$
- R6*—15,000 ohms,  $\pm 5\%$
- R7*—25,000-ohm miniature potentiometer
- R8*—2000 ohms,  $\pm 5\%$
- R9*—1000-ohm miniature potentiometer
- R10*—1100 ohms,  $\pm 5\%$
- R11*—390 ohms,  $\pm 10\%$
- R12*—270,000 ohms,  $\pm 1\%$
- R13*—680,000 ohms,  $\pm 1\%$
- S1*—Single-pole, 5-position, non-shorting rotary switch
- S2*—S.p.s.t. slide switch
- S3*—D.p.d.t. slide switch—optional
- 1—3" x 4" x 5" utility cabinet—see text
- 1—2 $\frac{1}{2}$ " x 2 $\frac{1}{2}$ " perforated circuit board—see text
- Misc.—Rubber feet (4), cabinet handle, battery clip, knobs, wire, solder, "L"-brackets (2)

**Construction.** You have a number of choices in constructing the FET VOM-to-TVM converter. The unit can be built in the form of a probe, or built as a plug-in unit, or as a bench-type accessory and housed in a small utility cabinet. The choice is a matter of convenience, and depends essentially on the availability of the necessary miniature components as well as on the particular VOM with which it will be used. For example, if you can get a miniature selector switch—not over one-half inch in diameter—for *S1*, as well as miniature po-

(Continued on page 148)

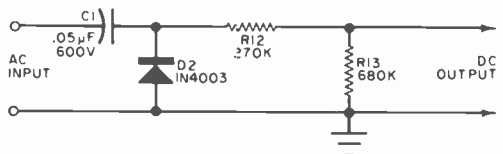
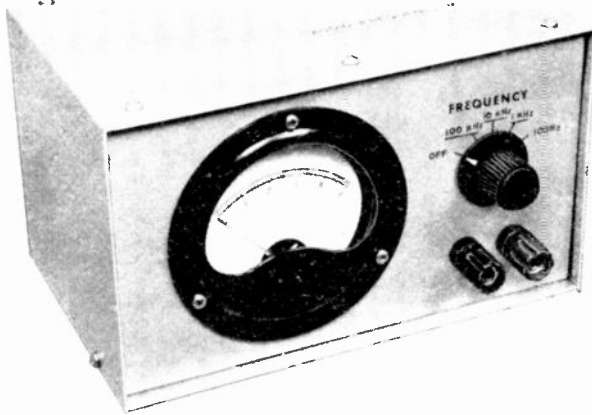


Fig. 2. This simple rectifier probe can be assembled to measure a.c. voltages. The probe's impedance (about 1 megohm) varies inversely with frequency.



# BUILD THE ELECTRONIC FREQUENCY METER

... AN DEAL INSTRUMENT  
FOR THE ACCURATE MEASUREMENT  
OF AUDIO AND ULTRASONIC FREQUENCIES

By WALT HENRY

**H**ERE'S AN ACCURATE, low-cost electronic frequency meter that's sure to delight the hearts of engineers, technicians, and experimenters alike. Direct reading, the instrument measures the frequency of audio and ultrasonic voltages from 100 hertz to 100 kHz, over wide ranges of input signal levels, and displays the frequency count on a front panel meter.

To measure an unknown frequency, you simply connect the signal source to the instrument's binding posts, rotate the frequency switch to the desired range, and presto! You read off the frequency from an expanded scale meter. Nothing could be simpler.

Fully transistorized and battery-operated, the audio frequency meter counts sine waves, square waves, or pulses. You can build it for less than \$30!

**How It Works.** The circuit (Fig. 1) consists essentially of a two-stage, high-gain squaring amplifier ( $Q1$  and  $Q2$ ), a regenerative switch ( $Q3$  and  $Q4$ ), a

single-stage meter amplifier/driver ( $Q5$ ), and a millimeter ( $M1$ ).

An input signal at binding posts  $BP1$  and  $BP2$  is limited by diodes  $D1$  and  $D2$  before it is applied to the base of  $Q1$ , the first squaring amplifier. The limiter operates at signal levels between 0.5 volt peak-to-peak (0.17 volt, r.m.s.) and 85 volts peak-to-peak (30 volts, r.m.s.), thereby protecting the amplifier in the presence of large input signals, eliminating any need for an input level control.

Transistor  $Q1$  is biased by  $R5$  bypassed by  $C3$ , and its high-gain characteristics alternately drive  $Q2$  into saturation and cutoff, even with relatively low input signals. Thus, the waveform at the collector of  $Q2$  is essentially a square wave.

The square wave is then differentiated by the combination of resistor  $R13$  and capacitor  $C4$ ,  $C5$ ,  $C6$ , or  $C7$ , depending on the frequency range selected. The differentiator output is a series of alternately positive and negative spiked pulses that are applied across  $D3$  to trigger the multivibrator ( $Q3$  and  $Q4$ ). The purpose of diode  $D3$  is to remove the negative portion of the pulses, so that only the positive spikes appear at  $Q3$ 's base.

In the absence of a trigger pulse, transistors  $Q3$  and  $Q4$  are in the saturated on state, and their output current biases  $Q5$  to off. When a trigger pulse arrives, however,  $Q3$  and  $Q4$  are turned off, the reverse bias on  $Q5$  is removed, and current flows from  $Q5$ 's collector through the meter. Once off,  $Q3$  and  $Q4$  remain off until the timing capacitor ( $C8$ ,  $C9$ ,  $C10$ , or  $C11$ ) charges through its timing resistor ( $R9$ ,  $R10$ ,  $R11$  or  $R12$ ) to turn on  $Q4$  again.

As  $Q4$  turns on, its collector current flows through the base of  $Q3$  and is amplified by this transistor. Amplification of  $Q4$ 's base current results in a further increase in collector current. Thus, a very fast regenerative switching action takes place as  $Q3$  and  $Q4$  turn on to discharge the timing capacitor and ready the circuit for the arrival of the next trigger pulse.

The current to the meter consists of a series of pulses at the collector of  $Q5$ . Pulse width will be constant on each range, but the higher the input frequency, the more pulses appear in a given time, and the average current is increased. The inertia of the meter move-

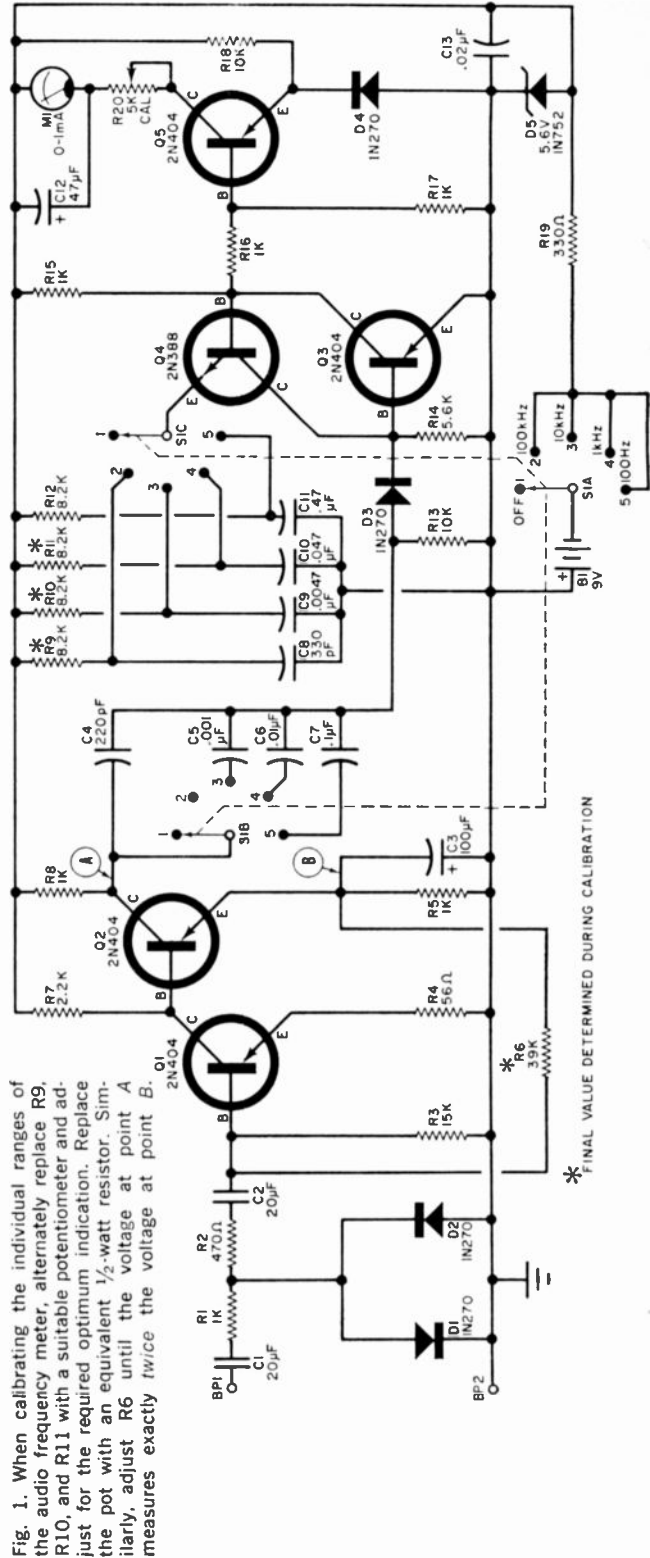


Fig. 1. When calibrating the individual ranges of the audio frequency meter, alternately replace  $R9$ ,  $R10$ , and  $R11$  with a suitable potentiometer and adjust for the required optimum indication. Replace the pot with an equivalent  $\frac{1}{2}$ -watt resistor. Similarly, adjust  $R6$  until the voltage at point A measures exactly twice the voltage at point B.

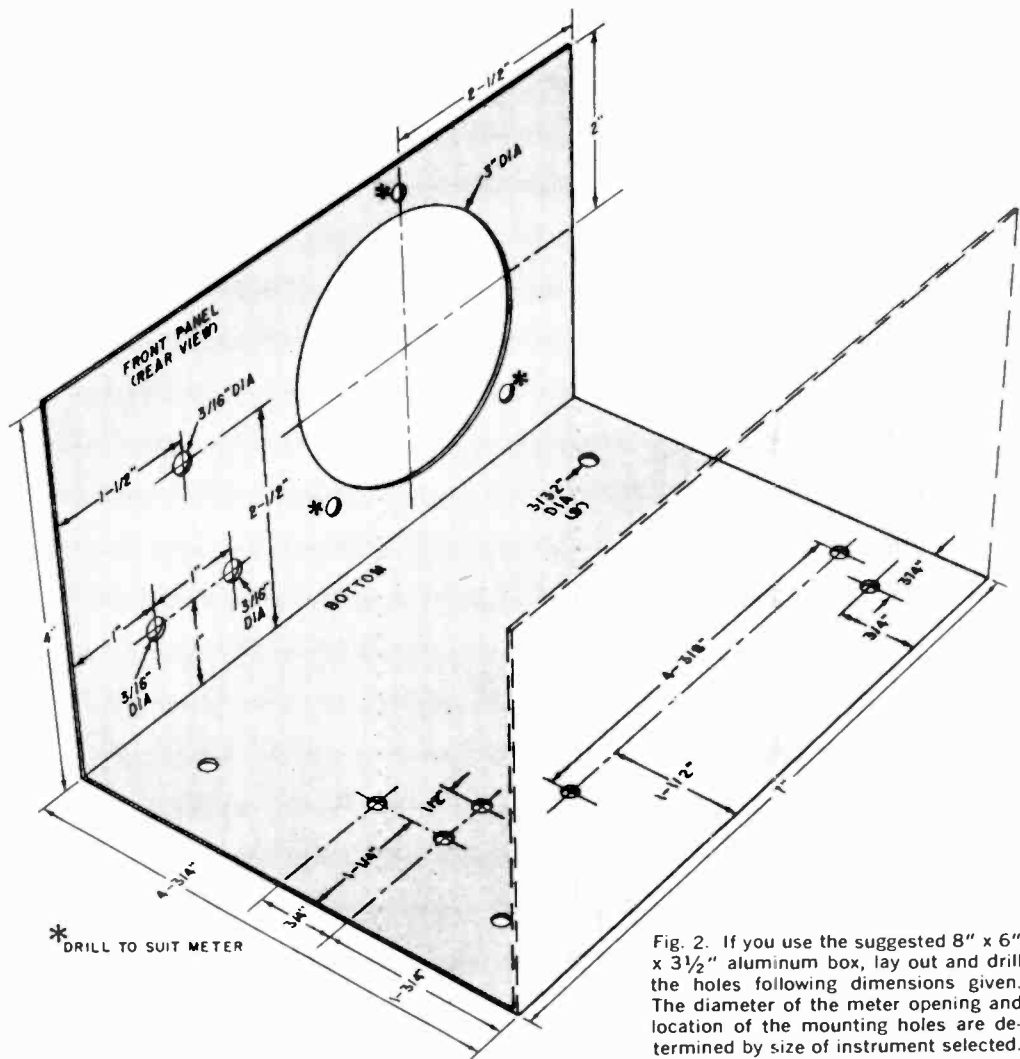


Fig. 2. If you use the suggested 8" x 6" x 3 1/2" aluminum box, lay out and drill the holes following dimensions given. The diameter of the meter opening and location of the mounting holes are determined by size of instrument selected.

### PARTS LIST

B1—9-volt battery  
 BP1, BP2—5-way binding post  
 C1, C2—20- $\mu$ F, 50-volt non-polarized electrolytic capacitor (Cornell-Dublier BRNP 20-30, or similar)  
 C3—100- $\mu$ F, 10-volt electrolytic capacitor  
 C4—220-pF mica capacitor  
 C5—0.001- $\mu$ F, 100-volt disc ceramic capacitor  
 C6—0.01- $\mu$ F, 100-volt disc ceramic capacitor  
 C7—0.1- $\mu$ F, 100-volt mica capacitor  
 C8—330-pF, 100-volt mica capacitor  
 C9—0.0047- $\mu$ F, 100-volt mica capacitor  
 C10—0.047- $\mu$ F, 100-volt tubular capacitor  
 C11—0.47- $\mu$ F, 100-volt tubular capacitor  
 C12—47- $\mu$ F (or 50- $\mu$ F), 10-volt electrolytic capacitor  
 C13—0.02- $\mu$ F, 100-volt disc ceramic capacitor  
 D1, D2, D3, D4—1N270 diode  
 D5—Zener diode, 5.6 volts (1N752A or 1N3513 or equivalent)

M1—0.1 mA milliammeter  
 Q1, Q2, Q3, Q5—2N404 transistor  
 Q4—2N388 transistor  
 R1, R5, R8, R15, R16, R17—1000 ohms  
 R2—470 ohms  
 R3—15,000 ohms  
 R4—56 ohms  
 R6—39,000 ohms—see text  
 R7—2200 ohms  
 R9, R10, R11, R12—8200 ohms—see text  
 R13, R18—10,000 ohms  
 R14—5600 ohms  
 R19—330 ohms  
 R20—5000-ohm potentiometer (Bourns 3067-S, or similar)  
 S1—5-position, 3-pole rotary switch (Mullory 13251, or similar)  
 T—8" x 6" x 3 1/2" aluminum box  
 Misc.—4-pin terminal strips (3), 4 3/4" x 2 3/4" perforated phenolic board, flea clips, battery holder, wire, solder, etc.

All resistors  
 1/2 watt,  
 $\pm 10\%$

ment and the filtering action of *C12* cause the meter pointer to move smoothly rather than oscillate with the pulses. Potentiometer *R20* sets the basic calibration of the instrument.

Zener diode *D5* regulates the supply voltage so that an aging battery, for example, will not cause any abrupt change in the calibration of the instrument.

**Construction.** The ideal size enclosure for the radio frequency meter is an 8" x 6" x 3½" aluminum box. The meter, range switch, and input binding posts are mounted on the front panel, which can be laid out and drilled as shown in Fig. 2. The layout for the bottom plate shows mounting holes for four rubber feet, the battery holder, two terminal strips, and the phenolic circuit board which mounts the small parts.

A three-lug terminal strip, mounted on the range switch (see Fig. 3), serves as

potentiometers to achieve greater flexibility of adjustment during calibration. If you do use potentiometers, mount them on the circuit board instead of on the switch. Incidentally, the switch has five positions, although only four of these are used for range selection. The first position is your power on-off control.

Capacitor *C12* is mounted directly across the meter terminals; be sure to observe polarity. Except for input capacitor *C1*, coupling capacitor *C2*, resistors *R1* and *R2*, and diodes *D1* and *D2*—which are mounted on terminal strips—all other parts are assembled on a 4-¾" x 2-¾" perforated phenolic circuit board. Do not solder *R6* permanently in place at this time, since its value may have to be changed during calibration. Note that sockets are not required for mounting the transistors, although they were used in the author's model of the unit. Also, other high-gain, fast-switching transis-

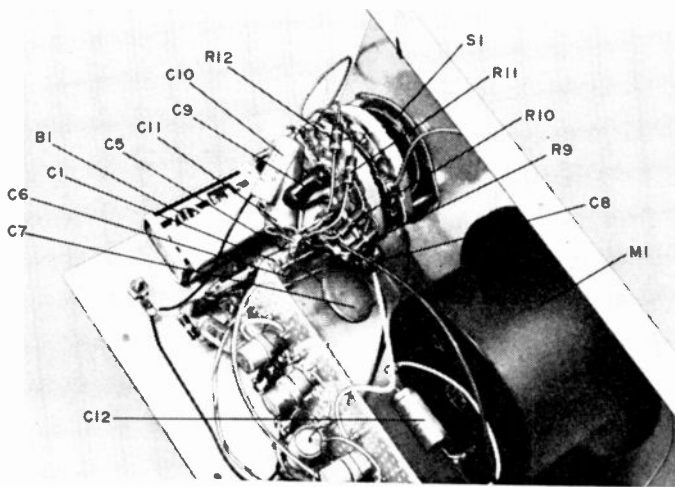


Fig. 3. The frequency-determining components can be assembled on the back of the switch, and the entire assembly mounted on the front panel.

connecting terminals for the timing resistors (*R9*, *R10*, *R11*, and *R12*) and capacitors (*C8*, *C9*, *C10*, and *C11*) as well as for the differentiator network capacitors (*C5*, *C6*, and *C7*), all of which are mounted on the back of the switch. However, the timing resistors should not be permanently connected to the switch until their final value has been determined during calibration.

A convenient, though more expensive, alternative is to replace the timing resistors with miniature-type 15,000-ohm

resistors can be substituted for the types indicated.

After assembly, the board is mounted vertically on the chassis as shown in Fig. 4. But be sure to keep it at least a half-inch away from the back panel or other metal surfaces in order to minimize stray capacitance.

While, in general, the circuit layout is not critical, it is important that you isolate the leads to the amplifier input from those going to the meter, to prevent cross-coupling. Also, run ground leads

from the various points in the circuit to a single ground lug on the chassis. The lug can be secured under one of the screws.

**Checkout And Calibration.** After you have carefully checked all your wiring, insert the battery in its holder and turn the range switch to the 100-kHz position. The meter pointer should suddenly deflect up-scale and then settle down back to zero. With the positive lead of

be employed as a 60-Hz signal source.

The meter should give a reading when the test signal is applied to the binding posts. Adjust *R20* for a reading of exactly 0.6 on the dial. Thus, the range setting (100 Hz) times the meter reading (0.6) gives 60 Hz, the input frequency.

To calibrate the 1-kHz, 10-kHz, and 100-kHz ranges, you'll need an audio oscillator. However, to obtain an accurate calibration on each range, it will be necessary for you to adjust the value of the

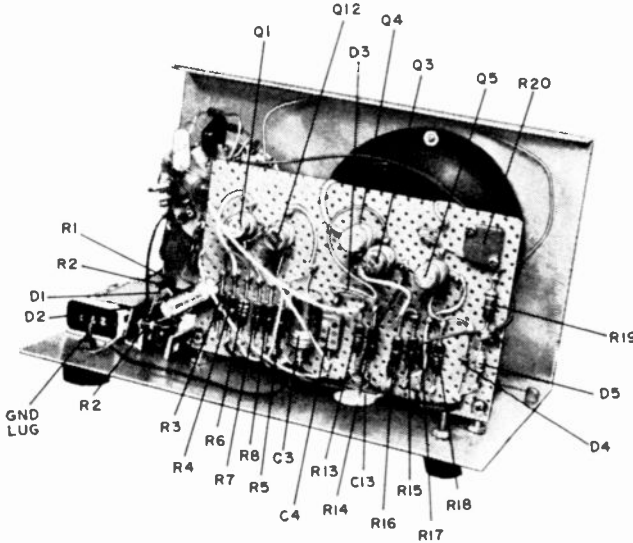


Fig. 4. When mounting the circuit board, position it at least  $\frac{1}{2}$ " above bottom plate and away from back panel, to minimize stray capacitance.

your voltmeter at ground (chassis), measure the voltages at the emitter and collector of transistor *Q2*. Ideally, the voltage at the collector should be twice the voltage at the emitter, although in practice this ratio is difficult to achieve.

If this voltage ratio cannot be achieved, within reasonable limits, alternately lower and raise the value of *R6* as necessary. Once the final resistance value has been determined, solder this resistor in place permanently.

Now set the range switch to the 100-Hz position and connect a 60-Hz signal across the input binding posts. An accurately calibrated audio signal generator can be used as the signal source, but the signal amplitude should be at least 1 volt peak-to-peak (0.4 volt r.m.s.). A 6- or 12-volt filament transformer connected to the a.c. power line can also

timing resistor for each range. Thus, *R9* is adjusted for the 100-kHz range calibration, *R10* for the 10-kHz range, and *R11* for the 1-kHz range. If potentiometers are used in place of resistors, calibration will be quite simple.

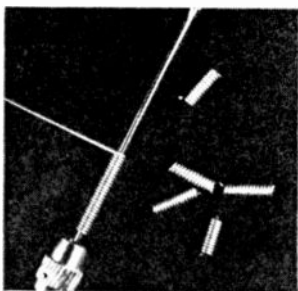
**Operation.** To operate the audio frequency meter, simply connect the signal whose frequency is to be measured to the input binding posts. *Caution:* Since the input capacitor, *C1*, is rated at 30 volts, do not apply higher level signals to the instrument.

Turn the range switch clockwise from *off* until you get a meter reading between 0.1 and 1.0. The exact signal frequency is determined by multiplying the reading indicated by the setting of the range switch. After use, turn off the instrument to save the battery.

# THE BEST OF TIPS & TECHNIQUES

## MAKE YOUR OWN WIRE PIGTAILS TO SIMPLIFY COMPONENT REPLACEMENT

If you don't have a supply of the commercially available pigtails ("Kwikette") made by Sprague, you can whip up a few of your own, minus the solder (the commercial units are coated with solder). A pigtail serves as a small coupler between the lead of an original component being replaced and the replacement component lead. To make one, you



simply wind a short length of 22-AWG bare wire around a sewing needle or another stiff piece of wire of appropriate diameter. Make it loose enough to fit over the component leads easily. When replacing a

component on a printed circuit board, leave as much of the original component's leads as possible on the board. Solder the pigtail in place, but do not allow the old leads to shift their position if they become momentarily desoldered. If possible, heat-sink the old component leads with a pair of pliers when applying heat.

—Louis H. Phelps

## FIBER OPTICS CAN PUT LIGHT WHERE YOU WANT IT—EVEN AROUND CORNERS

Use a soldering gun on a component you cannot see, and more harm than good can come of your work, especially if the component is a transistor which is easily damaged by heat.

There are plastic fiber optic light guides available that will light your way with a pencil-thin beam of light so that you can work in the tightest and most poorly lit areas of a chassis. When light is focused on one end of a light guide, it is transmitted

to the other end with very little loss in intensity, even if the guide is bent in a circle. A small penlight flashlight can be used as a light source, and an alligator clip can be taped to the light guide so that you don't have to hold the guide while you're working. One source of fiber optic light guides is Edmund Scientific Co., Barrington, N.J.; they cost about 65 cents a foot.

—E. S. Connors



## EYE SCREWS SUPPORT BREADBOARD COMPONENTS

When breadboarding, use an assortment of ordinary eye screws of the type available in 5 & 10 and hardware stores to mount your potentiometers, switches, phone jacks, binding posts, etc., as shown in the accompanying photo. Determine, by trial, the right size eye screw for the component being mounted.

If necessary, open up the screw eye a bit with a pair of pliers. Then, after planning your layout, insert the screw far enough into the breadboard to support the component that is being mounted.

—Art Trauffer



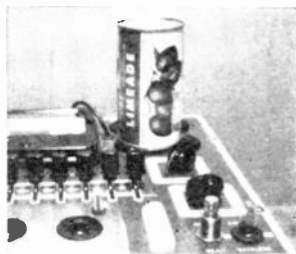
## PLIERS MAKE SHORT-ORDER WORK OF STRIPPING INSULATION FROM WIRE IN A PINCH

Trying to wiggle a pair of diagonal cutters into a tight area to strip the insulation from a wire while at the same time trying to avoid damaging nearby components can be a frustrating experience. Here's a tried-and-true method for stripping plastic or shellacked-cotton insulations from solid wires (it seems to be a flop on stranded wires). You simply crush the insulation in the jaws of a pair of pliers. Then you can easily snip away the split insulation from the undamaged wire. Incidentally, this technique is one way of dealing with stubborn "space age" Teflon insulation.

—Winston Tharp

## TIN CAN OVEN KEEPS TUBE TESTER HONEST

You can improve the reliability of your tube tester with a tin can oven that simulates the living and working conditions of a vacuum tube. Line the inside of the can—beer, frozen juice, etc.—with asbestos and, after inserting the tube in the tester, place the can over the tube. Allow a few minutes for the tube to warm up before testing.

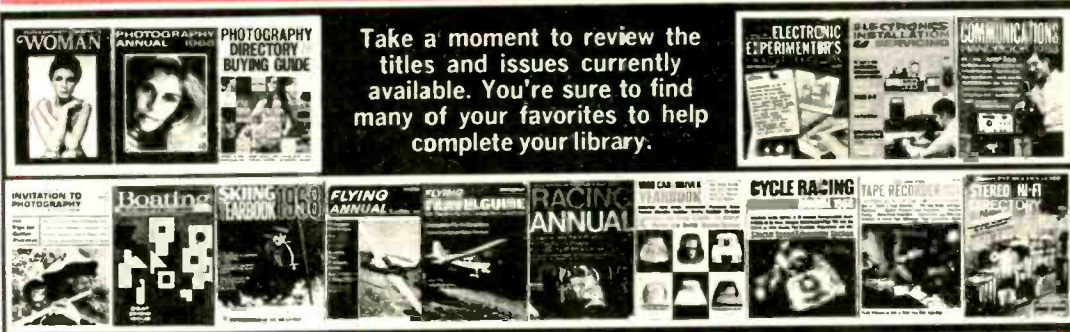


—H. R. Rosenblatt



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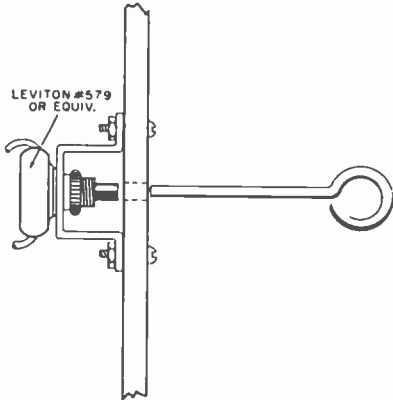
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## SECRET SWITCH SAFEGUARDS YOUR EQUIPMENT

When you're not around, a hidden switch can stop inquisitive people from playing with your radio, TV, etc. Drill a hole in the front panel of the unit you want safeguarded. Mount a push-type switch on a U-bracket, and screw the bracket to the rear of the panel so that the switch is in line with the hole. Then connect the switch to one side of the power cord (leave the regular on-off switch in the circuit). When you want to dis-

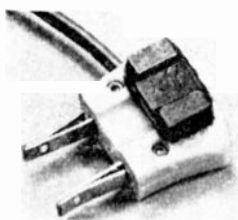


connect the power, insert a metal or plastic rod in the hole and press. To restore the power, press again. The rod is the key to your lock, so bend one end of it into a closed loop and carry it around on your key chain.

—Carl Dunant

## MAGNET CURES "LINE CORDITIS"

Like most electronics enthusiasts, you probably have your fair share of power cords that consistently and obstinately unwrap themselves from around



your electronic equipment when you are moving it from one place to another, and try to trip you up. You can cure this "line corditis" with a small but powerful magnet. Glue the magnet to the cord

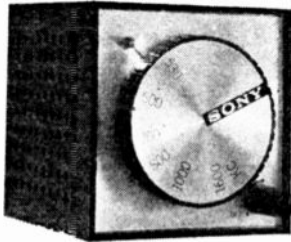
plug as shown in the photo. If your equipment cabinet is made of aluminum or other nonmagnetic material, bolt or glue a small sheet of steel to it. Wrap the line cord securely around the unit and place the magnet against the steel plate.

—D. E. Hausman

## PIPSQUEAK IN SIZE BUT MITE-T-LITE

A combination pilot light and dial light assembly for battery-powered equipment can be made with a short length of plastic tubing and a miniature lamp such as the Sylvania

ML-202A Mite-T-Lite. First coat the leads of the lamp with lacquer to insulate them; slot the tubing and slip it over the lamp. Then drill a hole to fit the covered lamp in line with the dial position indicator mark. Use a drop of cement to hold the assembly in place. Since the



lamp operates at between 1 and 2 volts, if a 1-volt source isn't available, connect a resistor that drops all but 1 volt in series with the on/off switch and lamp (about 330 ohms for a 6-volt battery). The Mite-T-Lite doesn't add appreciably to current drain (15.5 mA); and for its size (0.176" long and 0.055" in diameter), it gives off a surprisingly bright light.

—William S. Gohl

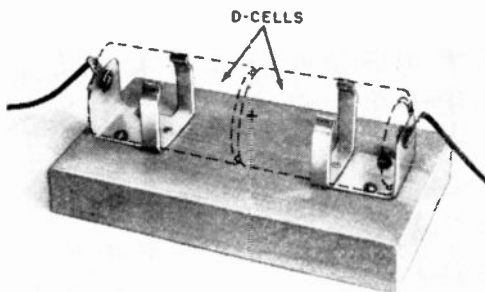
## WEATHER STRIPPING PROVIDES FEET FOR PROJECTS BY THE YARD

Foam rubber weather stripping, the type used around doors and windows to prevent drafts, can be transformed into excellent and inexpensive rubber feet for your projects. The strips are usually backed with an adhesive that will stick to just about any clean surface, so there's no need to drill holes in the cabinet. Use a sharp knife or a pair of scissors to cut the strips into small rectangular or square pieces as required. Strip away the protective backing, and stick the pieces to the bottom of the cabinet. (With some types of weather stripping, it is necessary to use a reducing solution to make the pieces stick.)

—Jean Heroux

## TWO-FOR-THE-PRICE-OF-ONE BATTERY HOLDER

The next time you need two D-cell battery holders and find that you have only one on hand, cut the holder in half and mount the two halves on a piece of wood, or on your



chassis, spaced just far enough apart to accept both cells. Use a fine-tooth hacksaw blade to cut through the center clips of the holder.

—Art Trauffer

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## PRETTY IT UP WITH SPRAY PAINT

How about that last project? It didn't look so hot in that transparent plastic box, did it?



But it might have looked a lot better if the box had been painted. Next time, spray the *inside* of the plastic box (before mounting the components) with one of those plastic paints which come in a spray can. Special paints are available in a wide variety of colors that

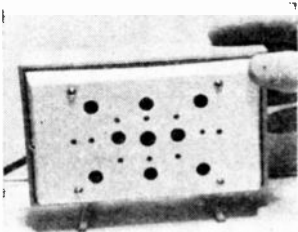
will adhere to plastic. Painting the *inside* of the box hides all those scratches you might get on the outside, and prevents loss of coloration from handling the project.

—William S. Gohl

## CLOCK CASE BAFFLES SMALL SPEAKER

If you have an old electric clock that won't tell you the right time, you might give it a second chance to work for you. Remove the clock parts and use the cabinet to house an extra speaker for your transistor radio or to make a handy test speaker in your workshop. Drill a few holes in the case to allow the sound to come through. You can paint or decorate the case to cover the original clock markings and to make it fit in with your room decor.

—Homer L. Davidson

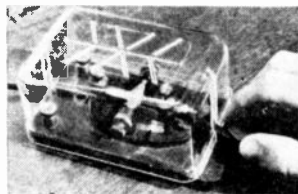


## KEEP YOUR CW KEY CLEAN WITH A "DUST COVER"

Here's a handy way to prevent dust from "bugging" your key and to reduce the danger of shocks where high voltage is present.

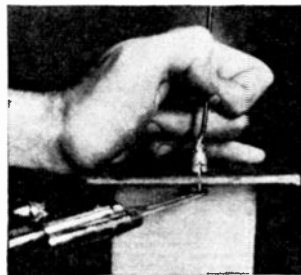
Take a common plastic food container that measures about 2½" deep by 3" in diameter, and cut openings in it to clear the key, the shorting lever—if any—and connecting cable. Then place the container over the key. The resulting "dust cover" can also house a click filter, if you use one. Plastic food containers are available from most dime stores for about 29 cents.

—Stephen Stone W1NFSU



## UPSIDE-DOWN SOLDERING TECHNIQUE KEEPS PLUG TIPS CLEAN

One way to prevent short circuits between the inner conductor and the shield of an audio cable and to keep solder from building up in the phono plug's tip is to pre-tin the inside of the tip, and hold the plug upside down when you apply the heat. You can do all this with the aid of a piece of scrap phenolic



board or thin piece of wood. Drill a ¼"-diameter hole in the board to hold the plug. Feed the solder into the plug's tip and apply heat to the end of the tip only. Allow a little solder to flow into the tip,

then insert the inner conductor of the lead. The lead should be prepared and tinned beforehand. Do not use any more heat than needed to just melt the solder. Solder the cable shield to the outer conductor in the usual manner.

—D. Peterson

## CONVERT PHONO MOTOR INTO COOLING FAN

Heat build-up is perhaps the most troublesome problem in electronic equipment. Solid-state devices must operate "cool" to prevent thermal runaway in transistors and large heat sinks may be inadequate. Wherever heat build-up may be a potential cause of trouble, a fan or blower should be used. If you have an old phonograph or tape recorder motor you might consider using it as a "fan." The only other thing you need is a suitable fan blade (see page 149 of the Lafayette Radio Electronics 1968 catalog for sizes). Slide the blade onto the motor shaft, tighten the blade setscrew, and mount the assembly where needed. A single fan of this type should provide adequate cooling for almost any electronic device in your home or workshop.

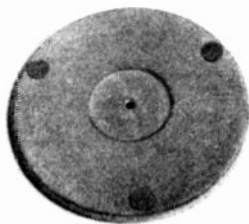
—Joe Riedel

## SELF-STICK FELT PROTECTORS CUSHION DEFLOCKED TURNTABLES

A worn and rough turntable is bad news to a record. Rather than glue on a new felt cover, or pull out the flocking kit, you can pick up a package of small, circular felt pads at your hardware store and stick them on the turntable as shown. Use as many pads as you want, in a circular arrangement.

They hold the record away from the turntable, act as a cushion, and reduce dust pick-up considerably.

—Carl Dunant

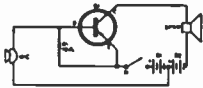
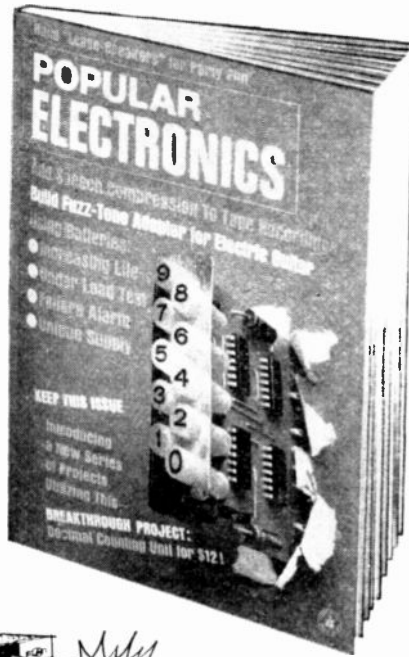


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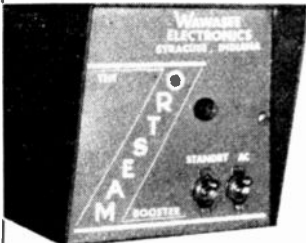
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## FIRING RANGE TIMER

(Continued from page 34)

conduct readily. When  $Q1$  conducts in this manner, the voltage across  $C1$  appears across  $D1$  and  $D2$ , overcomes the forward bias on  $Q2$  and "shuts" it off. It takes about  $\frac{1}{2}$  second to discharge  $C1$  enough to allow the forward bias on  $Q2$  to take command and turn  $Q2$  on again, to repeat the cycle.

During the time when  $Q2$  is off, the emitter of  $Q3$  sees enough positive voltage to go to work and generate an audible tone.

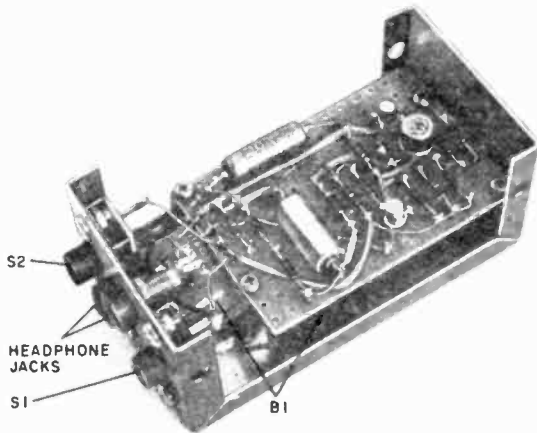
The frequency of oscillator  $Q3$  and thus the pitch of the emitted tone, is a function of the values chosen for components  $C2$  and  $R8$ . In this application, the output is an 800-hertz note which is picked up by the headphone.

**Construction.** The timer is built in a  $4" \times 2\frac{1}{8}" \times 1\frac{1}{2}"$  metal box. Power and timing switches  $S1$  and  $S2$ , as well as the headphone tip jacks, can be mounted on one end of the case. The remaining parts, except the batteries, must be wired on a  $1\frac{7}{8}" \times 3" \times \frac{1}{16}"$  perforated phenolic board as shown in Fig. 2, and the sub-assembly mounted inside the case on four  $\frac{3}{4}"$ -long stand-off spacers.

The two 9-volt batteries are connected

### PARTS LIST

- $B1$ —9-volt battery (2)
- $C1$ —150- $\mu F$  tantalum electrolytic capacitor
- $C2$ —0.1- $\mu F$ , 100-volt Mylar capacitor
- $D1, D2$ —1N914 diode
- $Q1, Q3$ —2N2646 unijunction transistor (General Electric)
- $Q2$ —7.155 transistor (General Electric)
- $R1, R2$ —180,000 ohms—see text
- $R3$ —22 ohms
- $R4$ —470 ohms
- $R5$ —27,000 ohms
- $R6$ —4700 ohms
- $R7$ —1800 ohms
- $R8$ —15,000 ohms
- $R9$ —100 ohms
- $R10$ —330 ohms
- $S1, S2$ —S.p.s.t. slide switch
- 1— $4" \times 2\frac{1}{8}" \times 1\frac{1}{2}"$  gray hammer-ton aluminum box
- 1— $1\frac{7}{8}" \times 3" \times 1/16"$  circuit board, 0.180" hole spacing plain
- 1—1500-ohm single headphone with leads ( Allied Radio 86 U 686 or similar)
- 40—Push-in terminals for circuit board (Victor T18 or T28, 100 in package)
- Misc.—Phone tip jacks (2), battery terminals (2), pieces of round  $\frac{1}{4}"$  brass rod  $\frac{3}{4}"$ -long tapped for 6-32 screws (4)



The two series-connected 9-volt batteries comprising B1 are tucked away under the circuit board. The headphone jacks and switches are panel-mounted.

in series and tucked away under the circuit board. To insure optimum timing accuracy, use a high-quality tantalum electrolytic capacitor for C1. Also, although 180,000-ohm resistors are specified for R1 and R2, it is preferable to use Trimpot or similar miniature potentiometers initially, since the value may have to be changed during calibration.

If you use the low-cost headphone suggested and would like to install it in a pair of earmuffs, drill a hole in the bottom of one earmuff, and fish the phone tips and cord through the hole. The single headphone snaps into the earmuff and fits snugly in place.

**Calibration.** For precision timing, it is usually necessary to calibrate the timer against a standard such as a stopwatch or clock with a sweep-second hand. To adjust the timing, substitute for R1 and R2 precision printed-circuit-type potentiometers having resistances of about 250,000 ohms. With switch S2 set to 20 seconds, adjust R2 for a precise 20-second interval. Then, with S2 set to 10 seconds, adjust R1 for this interval.

After you measure each potentiometer's resistance setting, you can replace the potentiometers with fixed resistors having the measured values. Should you desire any other timing intervals, just change the values of R1 and R2 accordingly.

-30-

# BUCK-TEN BAGS

## SILICON DIODES

	1	12	20	40	50	100	240
PIV	AMP	AMP	AMP	AMP	AMP	AMP	AMP
50			.25	.50	.55		1.50
100	.12	.25	.35	.75	.80		2.00
200	.15	.30	.50	1.00	1.05	1.50	2.50
400	.18	.35	.70	1.25	1.30		3.00
500	.20	.50	.90	1.50	1.60	2.00	4.00
600	.24	.65	1.00	1.75	1.90		4.40
800	.30	.75	1.30	2.00			5.00
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## **MULTI-WAVEFORM GENERATOR**

*(Continued from page 112)*

remove the audio generator from the vertical input, and apply the output from *J1* to the scope. Rotate *R2* until exactly one waveform is displayed. This position of *R2* can then be pencil-marked as the "2" position.

Repeat the above procedure for as many dial markings as desired. Then proceed to the other multiplier scales, and make sure that the calibration points are reasonably accurate for the higher frequencies. In the event of serious mis-tracking, select the multiplier range that is most accurate, and use it as a reference. Then either select, or trim, the capacitor values (*C1*, *C2*, or *C3*) until a reasonable accuracy is obtained.

If desired, the lower end can be reduced down to 2 Hz if a good-quality 20- $\mu$ F capacitor is used for *C3*. If this is done, the value of *C4* will have to be increased in order to produce a good square wave.

-30-

## **TRANSISTOR/DIODE TESTER**

*(Continued from page 122)*

current while the tilt on the right side shows collector-to-base reverse current. In this idealized trace, reverse current becomes evident at about -60 to -70 volts, and increases gradually until the breakdown voltage point is reached. The breakdown point is also commonly referred to as the zener point.

(Note that the  $\text{O}$  to -50 volts per inch along the horizontal scale represents the inverse voltage across the transistor under test when the scope's horizontal input sensitivity (through the test circuit) is calibrated at 50 volts per inch. The voltage across the horizontal input has a linear relationship and is in step with the inverse voltage applied to the test transistor.)

**Construction.** Parts placement and layout is not critical. In Fig. 3, the test circuit is shown breadboarded on an 8½" x 6" piece of ¾" plywood. The front panel



is an 8½" x 4½" piece of 16-gauge aluminum. More compact construction can be obtained by using a 6" x 5" x 4" aluminum utility box. Ground only those points shown in the schematic (Fig. 1). Use spaghetti to insulate transistor *Q1*'s leads.

A 2N398A transistor was chosen for *Q1* because of its high collector-to-base reverse breakdown voltage rating. The transistor used in the project is rated at -105 volts, but actually checked out at -150 volts.

Although individual switches are used for *S2*, *S3* and *S4*, you can substitute a suitable two-position rotary switch or stacked slide switch. The binding posts for the test transistor's connections and for the connections to the oscilloscope can be of any design. You may find it more convenient to add another ground post, or eliminate the terminals altogether and connect the leads that go to the scope directly to the circuit.

All parts used in the tester are standard. If you have any difficulty in locating a 110,000-ohm, 4-watt resistor for *R2*, you can connect two 220,000-ohm, 2-watt resistors in parallel.

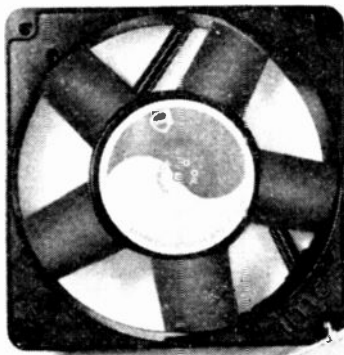
**Zener Diode Test.** The curve shown for the zener diode (Fig. 4) can be obtained by connecting a jumper between the emitter and collector terminals (*E* and *C*) of the test circuit, and connecting the zener diode between one of these terminals and the base terminal (*B*). The cathode lead of the diode goes to ground, and the switches are in the *PNP* position. If you reverse the diode's connections, and flip the switches over to the *NPN* position, the trace will go upward instead of downward. The test can be made either way.

If you do not use the jumper and connect only one side of the diode either to the emitter or the collector terminal, the left half or the right half of the trace will be obtained. Both halves of the trace contain the same information.

**Neon Lamp Test.** If a good neon lamp is connected between the base and collector test points, the curve shown in Fig. 5 will be displayed. Reading this curve is more or less self-explanatory. Here *S2*, *S3*, and *S4* were set to the *PNP* position.

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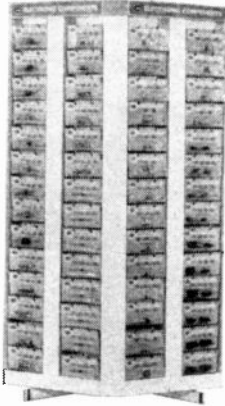
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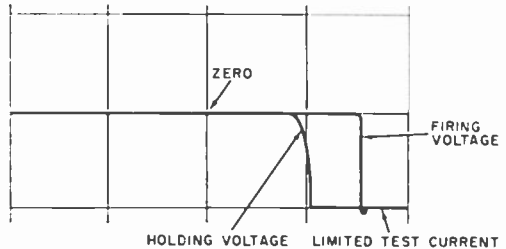


Fig. 5. Firing and holding voltage of a neon lamp can be predicted. If the scope's horizontal sweep is calibrated at 50 volts per inch, the neon lamp depicted here ignites at about 75 volts and stays lit until the potential drops to about 50 volts.

pends upon how accurately you calibrate the oscilloscope. Once the oscilloscope is correctly calibrated, no further scope adjustments are required.

**Scope Calibration.** To adjust vertical sensitivity, apply a 1-volt peak-to-peak a.c. signal directly to the scope's vertical input, and adjust the vertical gain for a 1"-high pattern. This is all there is to the vertical calibration for a deflection of 100 microamperes per inch.

Horizontal sensitivity can be calibrated by applying a 5-volt peak-to-peak a.c. signal directly to the horizontal input terminals and adjusting the horizontal gain for a 1"-long trace. Because of the 10-to-1 voltage divider network in the test circuit, actual horizontal sensitivity will be 50 volts per inch. ~~50~~

**"PRINCESS CINDERELLA"**

(Continued from page 72)

structure is a prime requisite for best possible performance. Either 3/4"-thick fir plywood or light pine shelving (sold as 1" x 10" clear pine board) can be used for the top, bottom, and sides, although pine is specified in the Bill of Materials.

The port and speaker locations and the dimensions are fairly critical. Locate the holes for the speakers exactly as shown in Fig. 1. The hole size for the port will be determined by the outer diameter of the hard cardboard mailing tube you choose for the port duct. This mailing tube should be 2 1/2" long and should preferably have an inner diame-

ter of 2". The outer diameter is only important in that it will guide you in cutting out the right-size hole.

After the three holes are cut, insert the mailing tube into the port hole and dress it flush with the front of the speaker board so that some of the cardboard duct extends inside the enclosure. Glue the tube in place and, when dry, apply a coat of flat black paint to the front of the board, inside the cardboard duct, and inside the speaker cutouts.

**Assembly.** Set the speaker board  $\frac{3}{8}$ " back from the front edge of the enclosure's bottom board and glue and nail these two pieces together. Do the same for the top and both sides. Then sand and stain or paint all exterior surfaces—except the speaker board. When the paint or stain dries, mount the speakers over their respective cutouts and wire them according to Fig. 2.

Nail or screw  $\frac{1}{2}$ " x  $\frac{3}{4}$ " pine cleats  $\frac{3}{4}$ " in from the rear edge of the enclosure as shown in the illustrations. Now staple or tack a 2"-thick layer of cotton batting or other suitable acoustic damping material to the sides and rear wall of the enclosure near the woofer. Also staple a 2"-thick curtain of cotton batting to the inside top of the enclosure and arrange this curtain so that it drapes over the woofer but is clear of the inside mouth of the port duct.

Attach the grille cloth to the front of the speaker board and miter-cut four

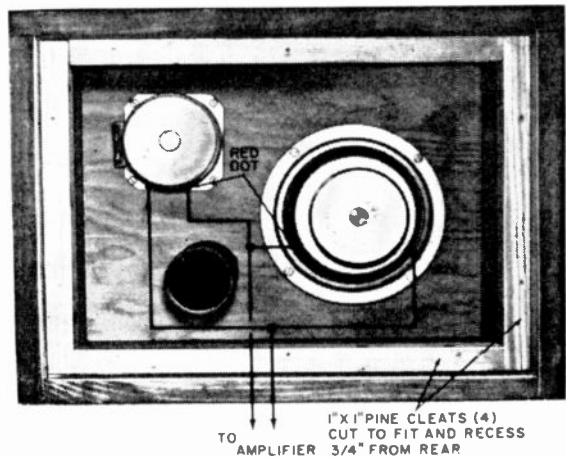


Fig. 2. Pine cleats hold rear board of enclosure in place. Proper speaker phasing is obtained only when red dots on speakers are wired common to each other.

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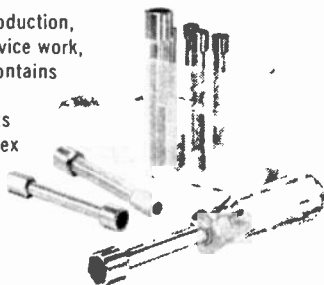
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pieces of  $1\frac{1}{2}$ "-quarter-round molding to neatly frame the front of the enclosure and to hide the ragged edges of the grille cloth.

Finally, screw the rear board of the enclosure in place and connect the speaker wires to the 4- or 8-ohm output of your amplifier. You'll note that this is a small system which gives a special feeling of "presence," particularly in the reproduction of music from small instrumental groups. You can increase the bass output from your amplifier without adversely affecting the system (doubling). The end result will be a sound that is much *bigger* than would seem possible considering the physical size of the new "Princess Cinderella" enclosure.

**Construction Variations.** In place of the usual grille cloth, the author used an expanded aluminum grille on the front of the "Princess Cinderella" enclosure. For maximum attractiveness, the grille should be backed by a black cloth of open weave to hide the speakers.

Various readers of the original "Cinderella" article have asked whether the choice of enclosure material is of importance to the performance of the system. Apparently, what these readers had in mind was the possibility of using one of the new, very hard, "pressed" boards for the enclosure walls. You can use any material for the "Cinderella" systems, provided that it is inflexible, and that the enclosure can be sealed so there are no air leaks in the corners or wrap-around which fits the front and back of the enclosure.

-30-

## BATTERY CHARGER/TESTER

(Continued from page 30)

given for *R11* through *R15* are for use with a 0 to 1 mA meter. Different voltage ranges can be set up, and different meters accommodated just by using resistors of proper values.

The values of the resistors and potentiometers *R1* through *R10* are a function of the battery voltage, charge rate, and source voltage. For example, if you want to charge a 9-volt transistor battery, and the source is 12 volts d.c., about 3

volts would have to be dropped by the resistor or potentiometer in the circuit. At 10 mA, about 300 ohms is needed. For 1½-volt batteries, about 10½ volts have to be dropped by the resistor in the circuit and its value would be on the order of 1050 ohms to obtain a 10-mA charging current. (It's Ohm's law at work.)

If two 1½-volt cells are placed in parallel for charging, as is possible with Stations A and B, and each cell is to receive 10 mA of current, 20 mA will have to flow through the appropriate resistor and the required value will be about 525 ohms.

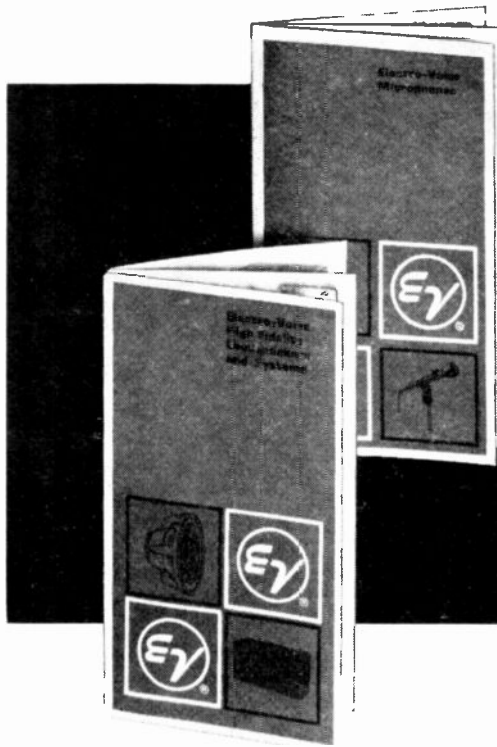
Actual values needed to obtain a specified charging current vary from battery to battery, depending upon their internal resistance. Nominal values for the potentiometers are 1000 to 2000 ohms. The fixed resistors for trickle-charge purposes can be replaced with variable controls, or eliminated completely. You can set up any of the stations to provide a trickle charge just by adjusting the appropriate potentiometer. If you eliminate the fixed resistors, switches S3 through S7 can be s.p.s.t. types. Resistance values for trickle-charge purposes are considerably higher. To establish a 2 mA rate instead of 10 mA, approximately 5 times more resistance is needed.

Each station, except possibly A and B, may have a different set of values for the trickle-charge resistors and charge potentiometers. Of course, you have to avoid exceeding the wattage rating of the resistors and potentiometers. Determine the wattage to be dissipated simply by multiplying the voltage drop by the current and multiply by a factor of 2 to give yourself a margin of safety. About 2 to 4 watts is more than adequate for most applications.

**Battery Testing.** Batteries should be tested under load conditions. End life of batteries depends upon the equipment in use. For example, if a 9-volt battery is used in a transistor radio that can operate on 6 volts, the battery voltage can drop to 6 volts and still be considered adequate. On the other hand, the same battery, at 6 volts, with the same load, will be inadequate if the radio cuts out at 7 volts.

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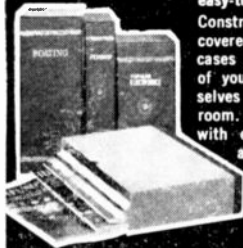
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cally meaningless. While some conclusions can be made if the voltage is too high or very low, significant conditions can best be determined by actual charge and discharge behavior. You can check for high internal cell resistance and save yourself the job of charging a "dud."

To do this, first apply a 10-mA load and observe the voltage of the cell. Then apply a 10-mA charge and observe the cell's voltage again. With a high resistance "dud," the voltage will go to zero or very near to it with as little as a 10-mA load and will jump to an excessive value on charge. If you get these test results, discard the battery.

**Battery Charging.** Battery manufacturers supply Load Voltage/Current Discharge curves in their manuals. A typical set of curves is shown in Fig. 3. These can be used as a guide to get started, but you will soon develop an intuitive approach based on your own experience. A good safe rule of thumb is to charge at the same rate that the cell was discharged.

In general, carbon-zinc dry cells which have been in service over six months will not respond well to recharging. Mercury and alkaline batteries display better recharging characteristics than the carbon-zinc units, and of course, nickel-cadmium cells are best.

Don't let a battery get into a completely discharged condition prior to charging, and don't overcharge. All types of cells are susceptible to destruction from overcharging. Check the total ampere/hour capability of each battery.

As very little shelf life can be expected, recharged batteries should be put into use immediately or kept on a trickle charge.

-50-



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## VOM + FET = TVM

(Continued from page 126)

tentiometers for  $R_7$  and  $R_9$ , then all of the components can be put in a probe case no bigger than 1" x 1" x 7".

However, the simplest, and most economical approach is to use a 3" x 4" x 5" utility cabinet in which standard components can be assembled with plenty of

room to spare. Such a box will provide room for a polarity reversing switch (*S3*) enabling you to measure either positive or negative voltages without physically reversing the input leads. But while this feature is handy to have, it is not really necessary.

You can duplicate the author's model by following the general layout which is shown in the photographs. Then you can mount the range switch, *S1*, the balance control, *R9*, the polarity reversing switch (optional), and the input and output jacks on the panel.

Divider resistors *R1* through *R4* are mounted directly on the range selector switch (*S1*), which has an *off* position. However, you may find it more convenient to

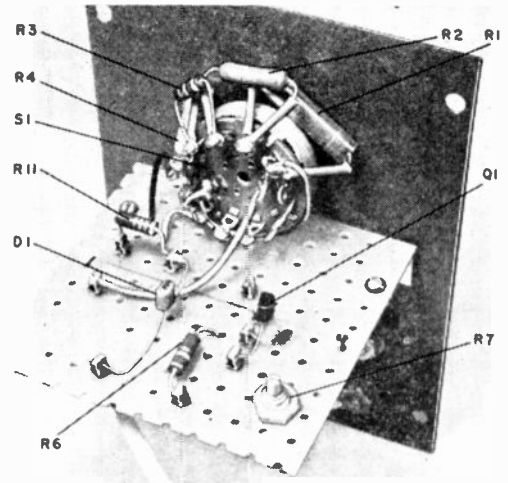


Fig. 4. Inside top view of converter shows voltage divider resistors mounted on the range-selector switch. "Breadboard" type construction can be used to hold the other components in place. A phenolic perforated board and small clips were used here.

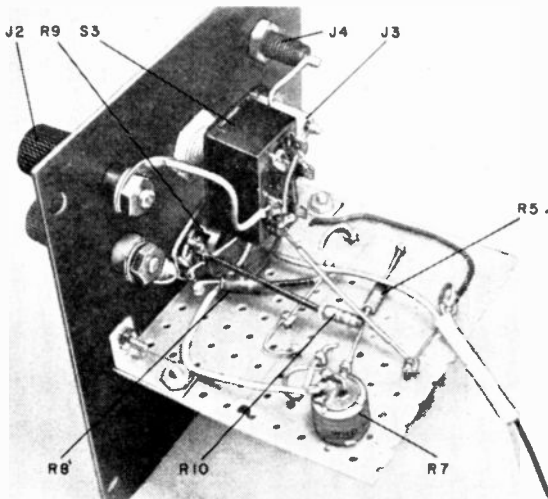


Fig. 3. All of the converter's parts can be fitted into a hand-held probe, or mounted inside a small cabinet. Parts layout and wiring are not critical.

control the battery power with a separate slide switch (*S3*).

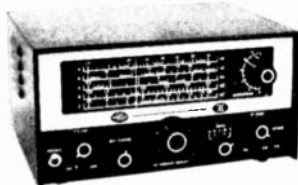
Mount the calibration potentiometer (*R7*), the zener diode, the FET (*Q1*), and the remaining resistors on a 2½"-square piece of perforated phenolic circuit board, and secure the board to the rear of the front panel by means of two small L-shaped brackets. The battery can be put in a holder and clamped to the base of the unit. Then complete the circuit wiring according to Fig. 1.

The front panel controls can be lettered, using dry transfers, and then sealed in with a clear plastic spray. If your VOM has a 0-50  $\mu$ A scale, mark the range positions from left to right as follows: OFF—0.5—5—50—500 volts. If

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a 0-100  $\mu$ A meter scale is used, mark the ranges: OFF—1.0—10—100—1000 volts.

**Calibration.** To calibrate the instrument, connect a pair of test leads from its output jacks to the input of the VOM, setting the VOM on its 50- $\mu$ A or 100- $\mu$ A d.c. current range. Turn switch *S1* to its lowest range and adjust the balance control (*R9*) for zero indication on the VOM.

Apply an accurate calibrating voltage (0.5 volt for a 50- $\mu$ A meter or 1.0 volt for a 100- $\mu$ A meter) to the converter's input and adjust calibration potentiometer *R7* for full-scale reading (50 or 100  $\mu$ A). To check linearity, reduce the applied voltage in small increments while observing that the VOM tracks with the calibrating voltage. Linearity and voltage divider accuracy depend upon the accuracy of the 5% resistors. Use precision 1% resistors if possible. You can also make comparison readings with a known accurate VTVM.

-30-

## GETTING MOST FROM CB RIG

(Continued from page 108)

er cases, the modulated output could be increased considerably. Note that in every single case the modulated input was increased and the r.f. output somewhat reduced.

Transceiver set number 3 is a very interesting example. This was a kit-type transceiver that had been "improved" (?) by the builder to get more output (illegally). Although the r.f. output was slightly above the legal limit, the maximum possible modulation had been reduced about 30%. Aligning this transceiver for maximum modulation dropped the r.f. output by more than a watt, but simultaneously doubled the amount of modulated output. This not only indicates the gain possible with proper adjustment, but also points up the fact that attempting to increase the output of your set is sometimes not worth the effort.

With a little practice, you should be able to align your transceiver using the method described to obtain optimum CB results.

-30-



## FET REGEN RECEIVER

(Continued from page 94)

The back view of the completed receiver is shown in Fig. 8. The battery holder is mounted on the side of the cabinet with small wood tacks, while small brass wood screws are used to mount the Fahnestock clips. One clip is used for the antenna connection and the other for the ground connection.

**Alignment and Operation.** For best reception, use an end-fed antenna between 50 and 75 feet long, mounted as high as possible, and a good ground. But the receiver will operate satisfactorily on shorter lengths of antenna because of its excellent sensitivity. For camping, picnics, and other portable applications, a short length of insulated wire tossed into the nearest tree will suffice.

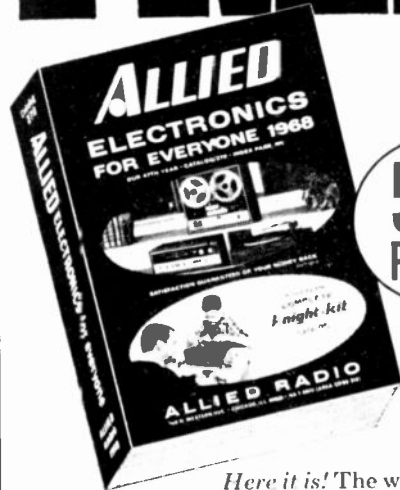
If you have never played with a regenerative receiver, it will not take you long to get the "feel" of tuning it for best results. Control *R1* will have to be reset from one end of each band to the other. When scanning large segments of the band, it is best to "back off" on *R1* until a station or group of stations is found. Then advance the control to the point just before the receiver "pops" into regeneration. At this point, the received signal will increase in strength and selectivity.

If you duplicate the receiver exactly as outlined here, the calibration markings shown in Fig. 9 will fall right into place. The receiver can be calibrated precisely by adjusting the tuning slugs on the plug-in coils and tuning in on stations of known frequency. This is easy enough to do on the broadcast band—if the station frequencies are unknown, you can always use another broadcast radio to correlate the frequencies. On the short-wave bands, the WWV time-signal stations can be used as "frequency standards." WWV stations will be found on 2.5, 5.0, 10, and 15 MHz.

On the short-wave bands, reception will usually be very limited and spotty during the day. It will begin to improve late in the afternoon, however, and by evening the bands will be "crawling" with stations!

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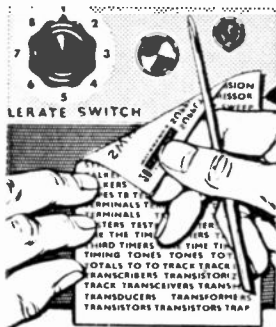
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## MULTIPURPOSE SIGNAL TRACER

(Continued from page 117)

1-millivolt scale will hold for all ranges. You can check meter linearity by successively reducing the input signal to 800, 600, 400, and 200 microvolts and observing the meter reading. Frequency response can be checked by maintaining a constant 1-mV signal while varying the source frequency from 40 hertz to 20 kHz.

**Operation.** When signal-tracing in receiver r.f. and i.f. circuits, use a demodulator probe at the INPUT binding posts. For audio circuits, a direct probe or shielded lead can be used. Suitable low-cost demodulator probes and direct probes are available commercially in kit form or fully assembled. Or you can build your own demodulator probe, if you wish, following one of the diagrams in Fig. 5.

When this meter is in use, the audio amplifier can be turned off, if desired, by

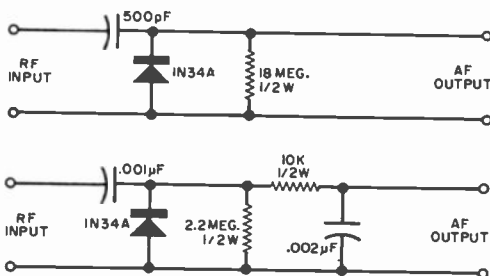


Fig. 5. Either of these circuits can be put together and used as a demodulator probe. However, you may prefer a commercial unit, such as the EICO PSD demodulator probe, for economy and convenience.

turning the **GAIN** control fully counter-clockwise till you get a "click." If you want to use the audio amplifier alone, you can turn off the meter by flipping the **METER** switch to *off*. The unit's preamplifier is always on when power is applied, and can be used to monitor signals with a crystal headphone.

To use the preamplifier, turn both the meter and audio amplifier off. With the **SENSITIVITY** control set to 1 mV, the voltage gain will be approximately 200. At the 10-mV setting, the gain is about 20.

## REMOTE COMMANDER

(Continued from page 14)

should be mounted in a separate miniature metal box as shown in Fig. 7, and then the small metal box should be mounted in a larger box. The same precautions taken for the transmitter also apply to the construction of the receiver: insulator between board and box, rubber grommets to insulate antenna from box, etc. Then drill a small access hole in the module case directly over *L1* in the receiver.

**System Alignment.** Either one or both of two methods can be used to tune the transmitter and receiver units in the "Remote Commander" R/C system for maximum range and sensitivity. The first method is the "seat-of-your-pants" technique requiring no test equipment of any kind. Simply tune the slugs in coil *L1* in both units so that *K1* in the receiver relay pulls in as soon as *S1* in the transmitter is depressed. Continue tuning the coils for the desired results several times, each time putting a greater distance between both units.

The second alignment method requires the use of a 0- to 50-milliamp meter movement. Alignment is first performed in the transmitter, then the receiver.

Connect the meter in series with the negative side of *B1* in the transmitter and *S1*. Depress *S1*, and tune *L1* for a maximum meter indication; then back off slightly. Remove the meter from the transmitter, and reconnect the negative side of *B1* to *S1*.

To tune the receiver, connect the meter movement between the positive side of the receiver's battery and *S1*. Depress the power switch on the transmitter and tune *L1* in the receiver for a maximum indication on the meter.

Tuning of both the transmitter and the receiver should be performed with each unit completely enclosed in its respective metal case.

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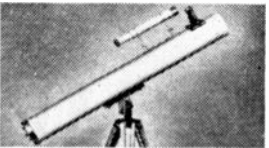
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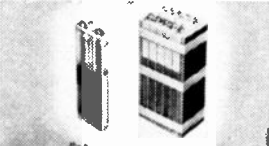
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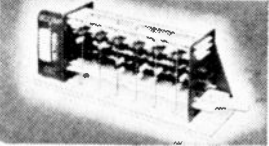
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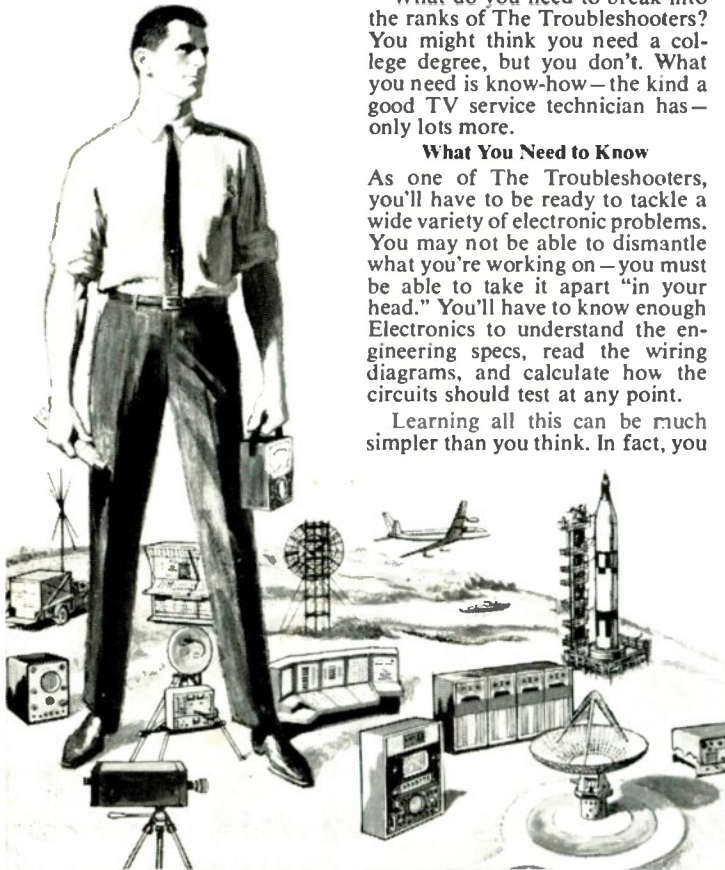
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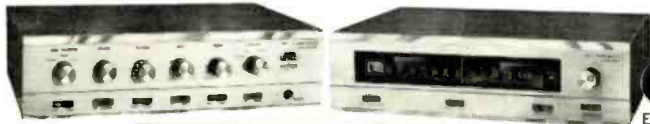
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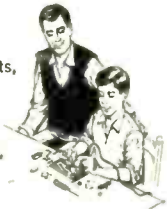


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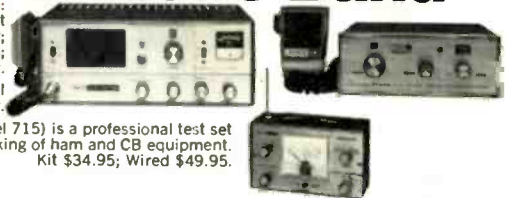


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