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POPULAR ELECTRONICS

ELECTRONIC EXPERIMENTER'S HANDBOOK

WINTER EDITION

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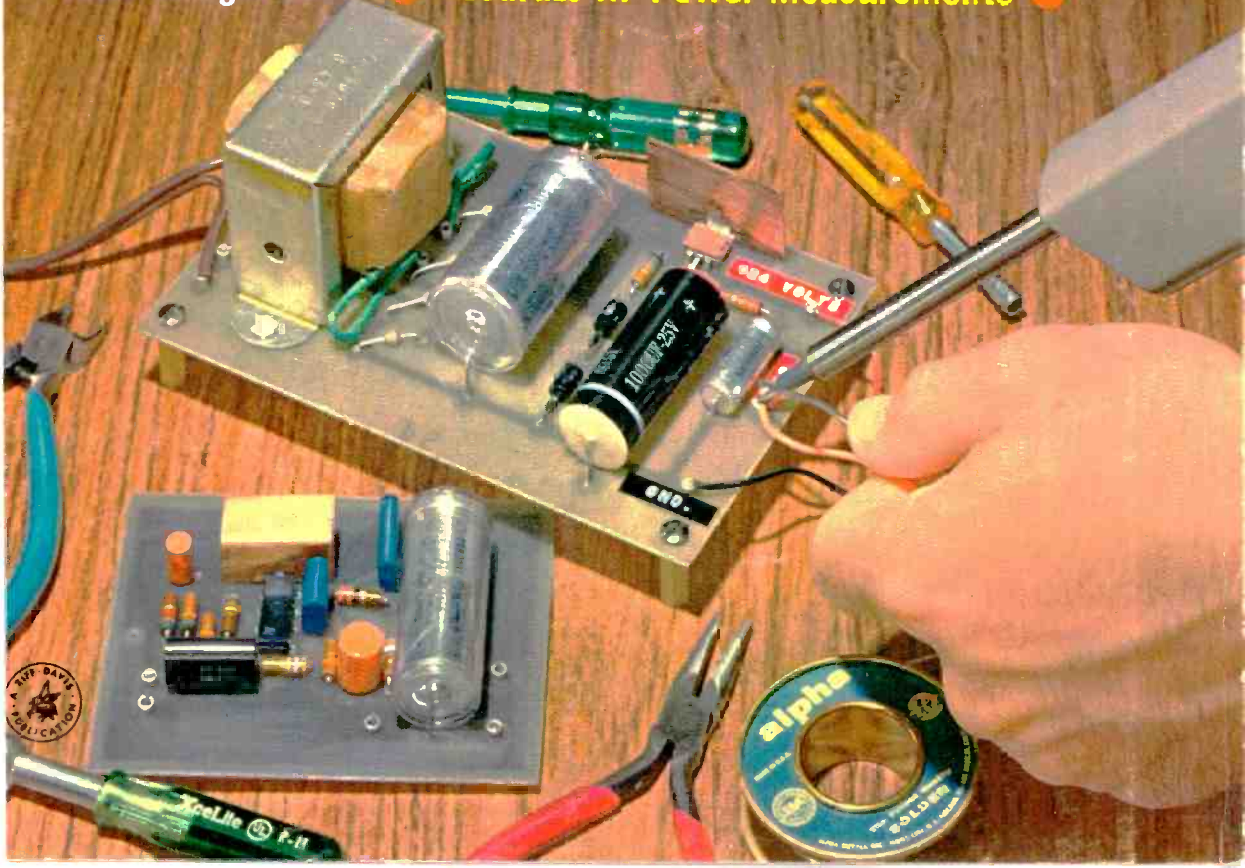

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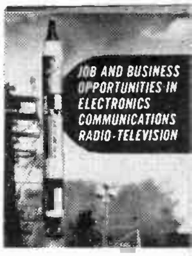

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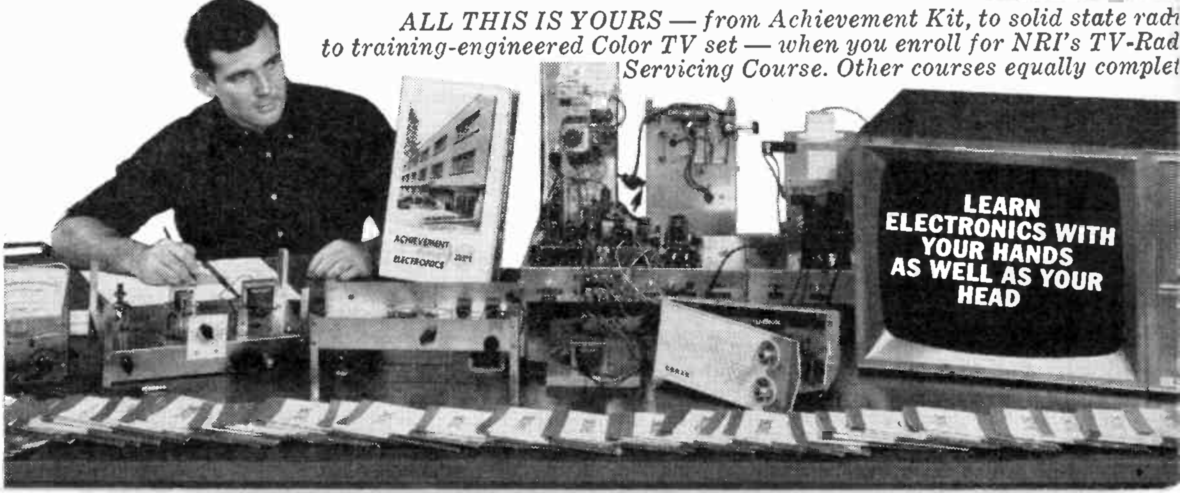

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DECADE PLUS 2

The semi-annual editions of the ELECTRONIC EXPERIMENTER'S HANDBOOK are fascinating recaps of the progress in hobby electronics. Not only have we seen in the past 12 years some gigantic strides in component technology and consumer applications, but an important maturing has taken place in the hobby itself. Looking back only 10 years, the 1960 edition of EEH contained about two dozen gimmicky construction projects of which the most complex was a variable-voltage power supply. Simple transistor circuits were in their heyday and the prevailing design philosophy behind some circuits seems to have been that anything tubes could do, a transistor could do—practically as well. All-in-all, they were a far cry from some of the highly sophisticated but easily reproduced projects on the following pages.

But then, isn't it simply an evolution? My earliest experiment with radio (nee electronics) consisted of building a regenerative receiver with a type 30 tube. It howled like a banshee!

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V-O-M

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BUILD NOISE BLANKER 47 *A. E. McGee, Jr., K5LLI*
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BUILD FET-QM 63 *Robert N. Tellefsen, Jr.*
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Good radiation characteristics at low cost

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(Continued on page 8)

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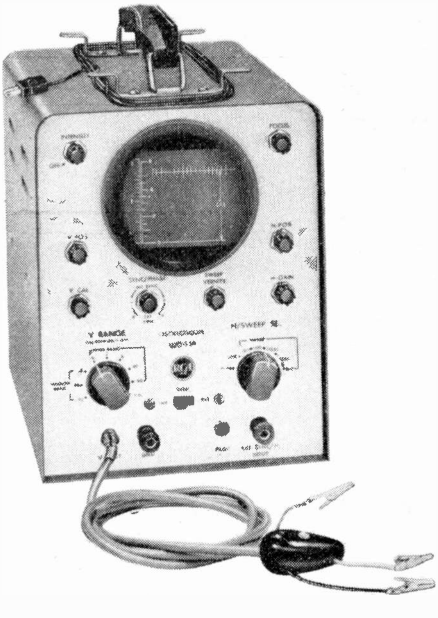

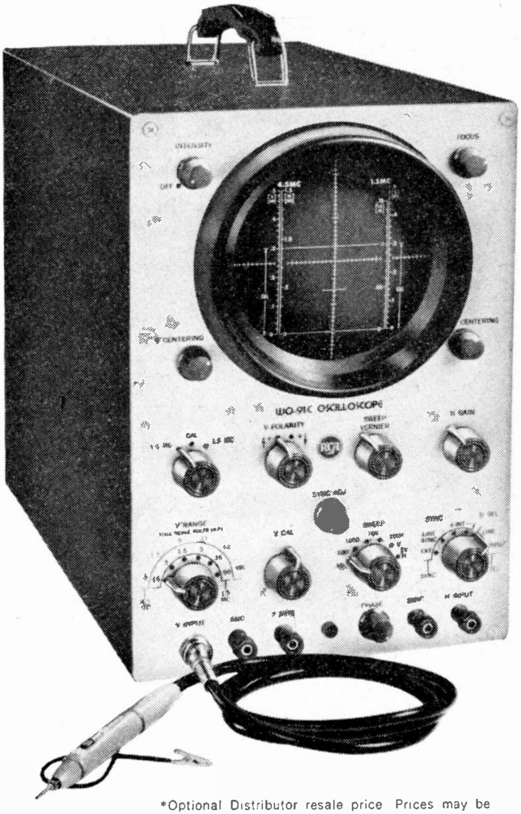

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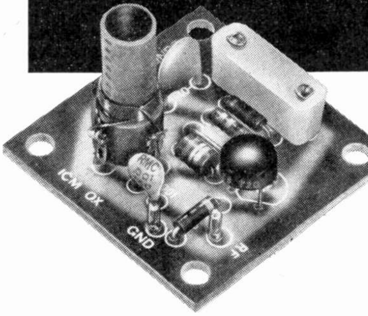

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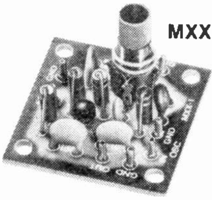
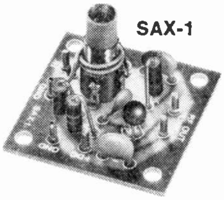
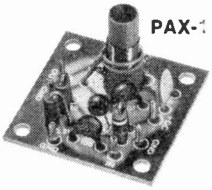


MXX-1



SAX-1



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ALL-PURPOSE

NIXIE® READOUT

Minimum-component decimal counting unit (DCU) uses high-visibility glow-discharge tube

By LESLIE SOLOMON
Technical Editor

and ALEXANDER W. BURAWA
Associate Editor

THE APPEARANCE of the decimal-counting unit article by Don Lancaster ("Build a Low Cost Counting Unit," 1969 Winter EEH) intrigued thousands of hobbyists, experimenters and engineers. We at EXPERIMENTER'S HANDBOOK have been deluged with mail telling us of literally hundreds of unusual circuit applications in which readers have used the DCU. And many requests have been coming in asking us for instructions for converting the original DCU from readouts using incandescent lamps to glow-discharge (Nixie® tube) readout.

The major objection to converting the original DCU to Nixie tubes is cost—it would have been almost twice the original kit price. Add to this the facts that the circuit would be overly complex and the circuit-board size would be increased. Hence, a totally new DCU had to be developed. The "Professional DCU" described here is the result of the new design.

Nixie-tube readout is a distinct improvement over the incandescent readout. The circuit-board dimensions are smaller, and whereas the original DCU required four IC's, seven transistors, six resistors, and ten incandescent lamps, the new unit uses only two IC's, one resistor, and a Nixie tube. Although fewer parts are required, the new DCU is somewhat more expensive than the original circuit. However, for $30, you can construct a professional DCU that has all of the advantages of many commercial units costing two or three times as much.

The DCU described here has other advantages: Transistor-transistor logic

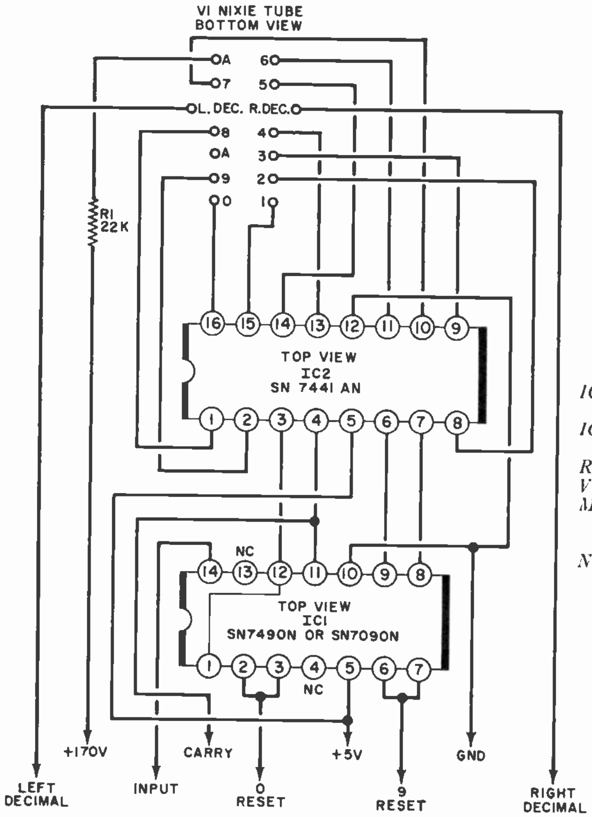


Fig. 1. Entire counting circuit is made up of four components—demodulator IC1, driver IC2, glow-discharge tube V1, and current-limiting resistor R1. Value used for R1 is determined by number of counting units operated from a given power supply, as described in text.

PARTS LIST

IC1—Integrated-circuit decade counter, (Texas Instruments SN7490N or SN7090N)
IC2—Integrated-circuit decoder driver, (Texas Instruments SN7441AN)
R1—22,000-ohm, ½-watt resistor (see text)
V1—Nixie indicator tube, (Burroughs B-5750)
Misc.—Printed-circuit board, wire for jumpers, PC-board edge connector (Amphenol 142-010-01 or similar)
Note: A complete kit of DCU components, including PC board, is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, for $30. The PC board alone is available for $2.25. A cabinet for mounting six DCU's with power supply components capable of driving six DCU's is available for $12. A special Polaroid window is also supplied with the cabinet kit.*

(TTL) is used; this gives the unit an operational speed of 18 MHz, twice that of the older circuit, which uses resistor-transistor logic (RTL). Also, because TTL requires a much larger input trigger level, erratic indications due to line transients or other electrical noise have been almost eliminated.

Construction. The DCU, whose schematic is shown in Fig. 1, is best assembled on a printed-circuit board similar to that shown actual size in Fig. 2. Once the board has been made or purchased (see Parts List), the two IC's, one resistor, one jumper, and the Nixie readout are mounted on the board as shown in Fig. 3. Note that the terminals on the board for the Nixie tube are not arranged in the same pattern that they are on the tube itself. (The actual Nixie-tube terminal arrangement is shown in Fig. 1.) Also, the PC board has been arranged so that it can be connected either directly into a circuit (via soldered connections)

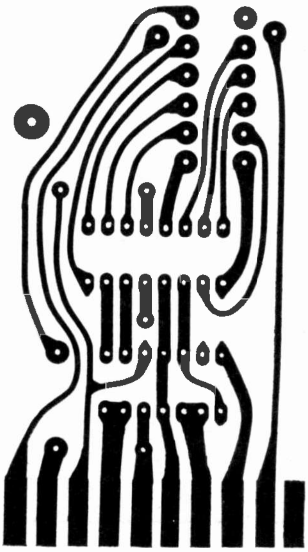
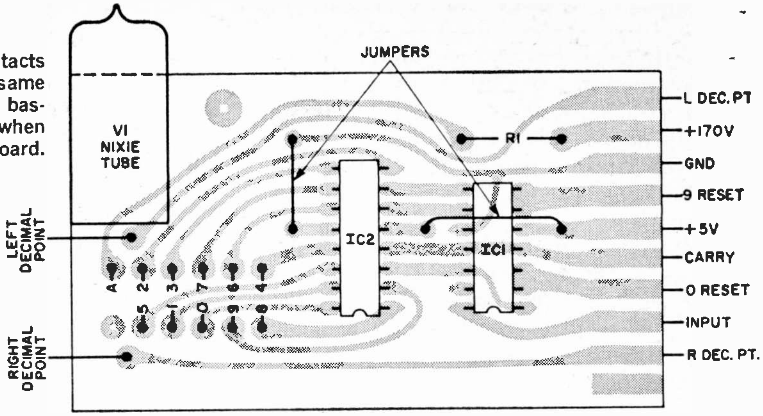


Fig. 2. This actual-size etching guide is used for circuit board employing edge connector (heavy mark at lower right serves as connector key), or for circuit board to be soldered into circuit.

Fig. 3. Circuit board contacts for Nixie tube are not in same arrangment as actual tube basing. Keep this in mind when soldering V1's leads to board.



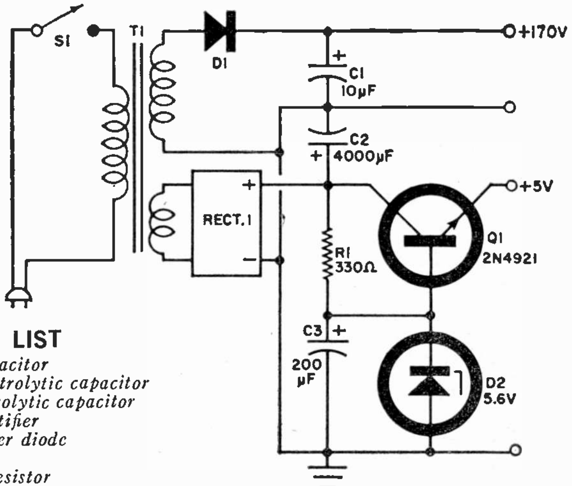
or used with a PC-board edge connector. After mounting and soldering *IC1* in place, install the second jumper.

A 22,000-ohm resistor is specified for *R1* in Fig. 1. This resistance is used when three or less DCU's are operated from the suggested power supply and it keeps the Nixie from being too bright. If four or more DCU's are driven from the same power supply, reduce the value of *R1* to 10,000 ohms.

The Nixie tube is mounted on its side as shown in the photos. Be sure that the viewing side is placed as shown. The plastic pin guide that comes with the Nixie tube can be secured to the PC board with a bead of cement; do not cement the glass to the board. Install the Nixie tube by first bending the "left decimal" lead directly at the pin guide and feeding it into its hole on the board. Put the leads of the first row into the appropriate holes, using insulating tubing over each lead. Finish with the upper row of leads and the "right decimal" lead. Note that there are two anode leads on the tube. The anode connected to. pin 10 is not used and can be cut off at the base. The short leads will be sufficient to support the tube.

Power Supply. Each counter requires

Fig. 4. Up to six DCU's can be efficiently driven with power supply shown here. Don't skimp on component quality in +5-volt circuit, or DCU's will operate erratically.



PARTS LIST

C1—10-μF, 250-volt capacitor
C2—4000-μF, 6-volt electrolytic capacitor
C3—200-μF, 6-volt electrolytic capacitor
D1—1-ampere silicon rectifier
D2—5.6-volt, 1-watt zener diode
Q1—2N4921 transistor
R1—330-ohm, ½-watt resistor
RECT1—2-ampere silicon rectifier bridge
T1—Power transformer. Secondary: 125 and 6.3 volts.
Note: A complete power-supply kit with chassis is available. See Parts List for Fig. 1.

170 volts d.c. to drive the Nixie readout, and 5 volts d.c. for the IC's. The schematic of a power supply sufficient for six DCU's is shown in Fig. 4. If any other power supply is used, be sure that its outputs do not exceed 170 and 5 volts, since the Nixie tube and the IC's can be irreparably damaged by voltages that are too high.

The power supply is assembled in the case as shown in Fig. 5. The various components are mounted on terminal strips and point-to-point wiring is used. Use an insulated mica washer and silicone grease when mounting transistor *Q1*.

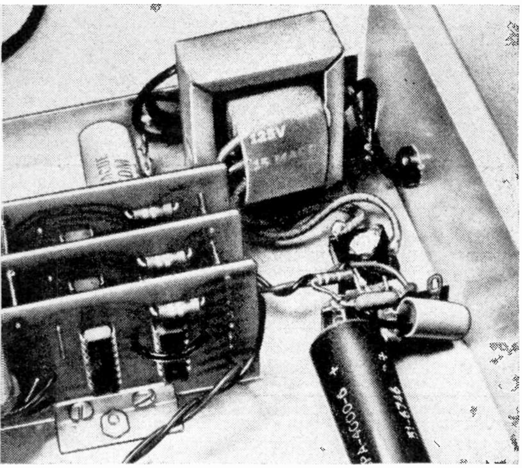


Fig. 5. Terminal strips and point-to-point wiring should be employed when assembling power supply.

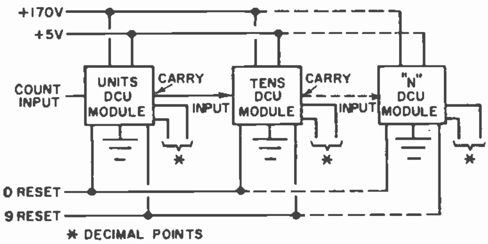
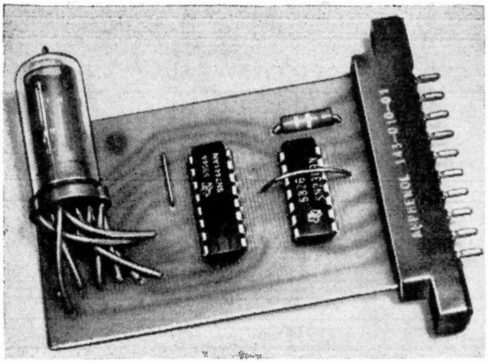


Fig. 7. Carry output of each module provides input for following module. As many modules as desired can be used; units, tens, hundreds, etc., modules.



The jumper wire shown at center of photo should not be allowed to touch case or leads of decoder.

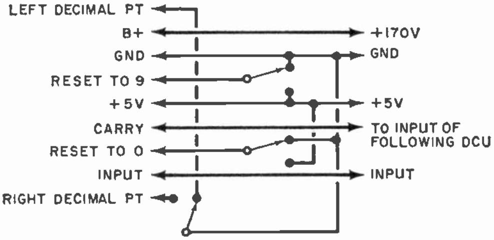
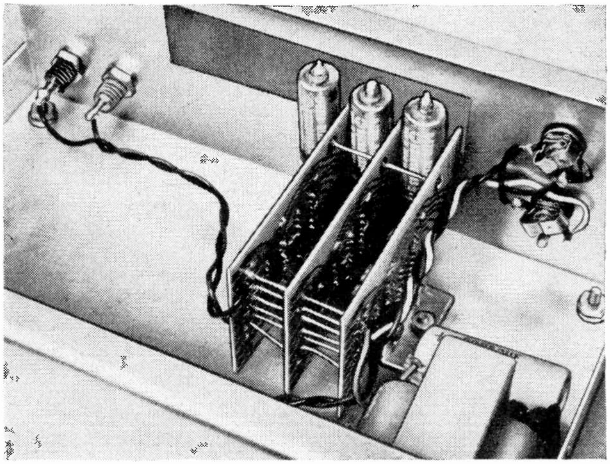
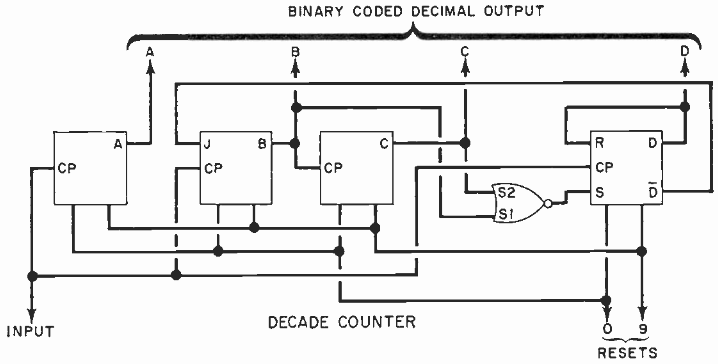
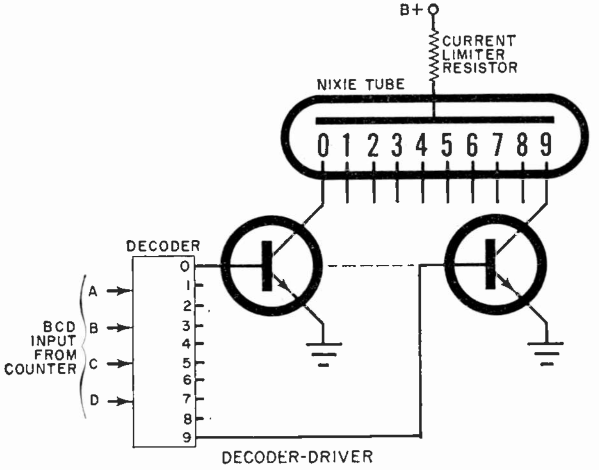


Fig. 6. Prior to wiring them into chassis, test individual DCU's using this circuit.



By mounting DCU's side by side so "common" holes line up with each other, assembly is simplified, and possibility of wiring errors is minimized.





HOW IT WORKS

Decade Counter. Integrated circuit *IC1* is a decade counter consisting of four master-slave flip-flops with gating and internal connections designed to perform the desired counting functions. The output is a binary-coded-decimal signal which drives the companion decoder-driver module.

The monolithic counter uses transistor-transistor logic with a counting rate of about 18 MHz. It will accept positive-going input pulses of 2 volts or more and the shape of the input waveform is not important.

Decoder-Driver. Integrated circuit *IC2* is a monolithic BCD-to-decimal decoder having relatively high-voltage output transistors for direct driving of gas-filled readouts, miniature lamps, or low-power relays.

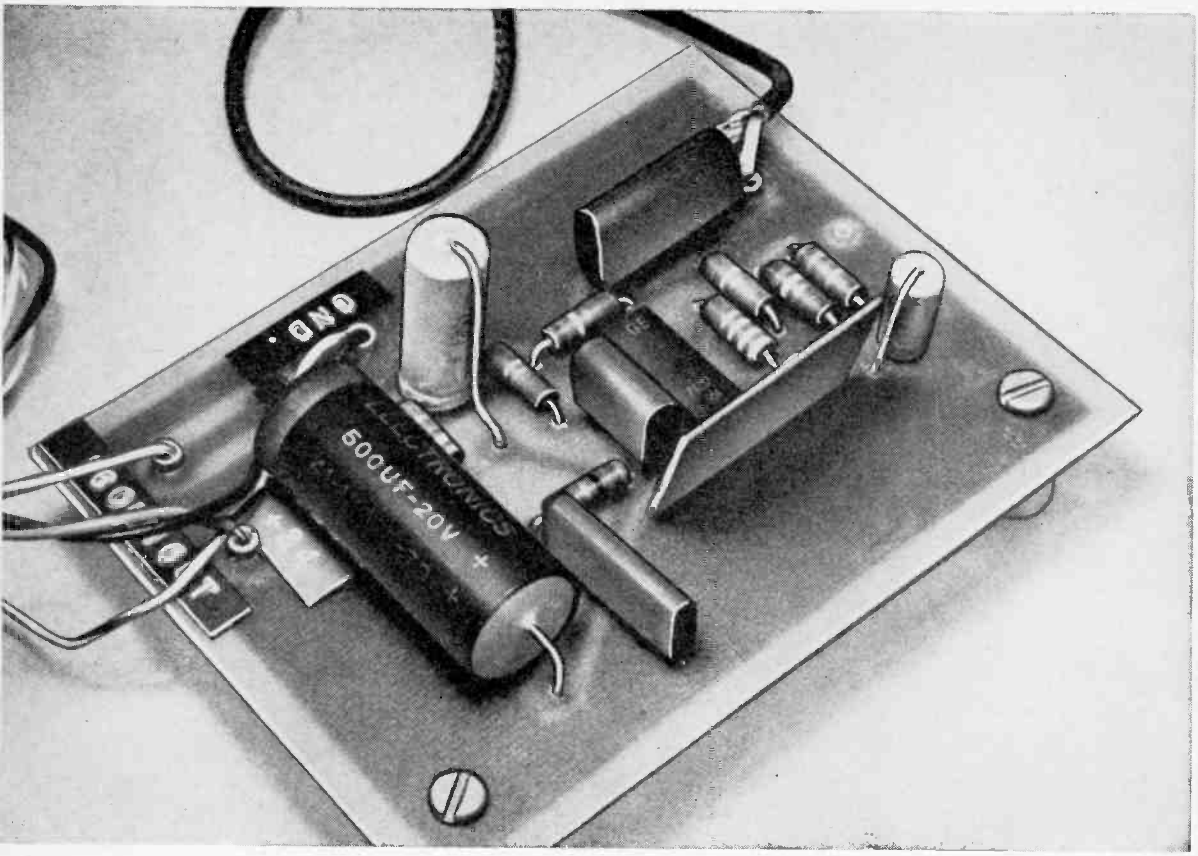
It has ten output transistors which are connected to the appropriate terminals of the readout tube. The BCD input is decoded and applied to the appropriate output transistor to turn it on and supply current to the proper element in the tube.

Testing. Connect the DCU to a test circuit such as that shown in Fig. 6. Operating the zero-reset switch should cause the Nixie tube to indicate the numeral zero. Operating the nine-reset switch should produce a nine indication on the tube. (The nine-reset connection is used in "nines complement" decimal operations.) Operating the decimal-point switch should cause either the right or the left decimal point to glow. Reset the unit to zero before making the next test.

Any a.c. waveform that has a magnitude of at least 2 volts can be used to test the DCU. A low-frequency audio generator makes a convenient source for an input signal. Apply a signal of less than 10 Hz to the input of the DCU and you should see the numerical progression in the Nixie tube. During the transition from 9 to 0, a pulse should be observed at the "carry" output. This pulse is used to drive succeeding Nixie-readout stages.

A number of DCU's can be connected together as shown in Fig. 7. All power leads and resets are connected in parallel, while only the units module receives the input signal to be counted. The carry output of this module is fed to the input of the second (or tens) module. The carry of the tens module drives the hundreds module, etc. The decimal points are connected to a switching system (optional) to indicate the correct decimal point position.

Various auxiliary circuits for use with the Professional DCU will appear in future issues of the EXPERIMENTER'S HANDBOOK. We will also show how circuits and components can be combined to make up digital voltmeters, frequency counters, etc. -30-



Mini-Watt IC Amp

AUDIO IC HAS 2-WATT OUTPUT

BY WILLIAM KIRES
General Electric Company

WHEN YOU ARE building or experimenting with a tuner or an audio-signal generator, one thing you need is an amplifier to bring the signal up to an audible level. You can use an amplifier from another system; but it's a real convenience to have a small, simple amplifier designed especially for the purpose.

The amplifier described here can be built to provide either 1 or 2 watts output (with some minor circuit differences). For the 2-watt unit, you'll need a 24-volt power supply, which is also described. The 1-watt unit can be operated from a 12-volt battery such as that used in your car or boat. (This makes it good for use with a portable phono on picnics or outings.)

The secret of this low-cost, compact amplifier is an integrated circuit designed for audio circuits. The IC is rated for a 24-volt input with a 2-watt output, but with a 12-volt input it will still deliver 1 watt, which may be just what you need.

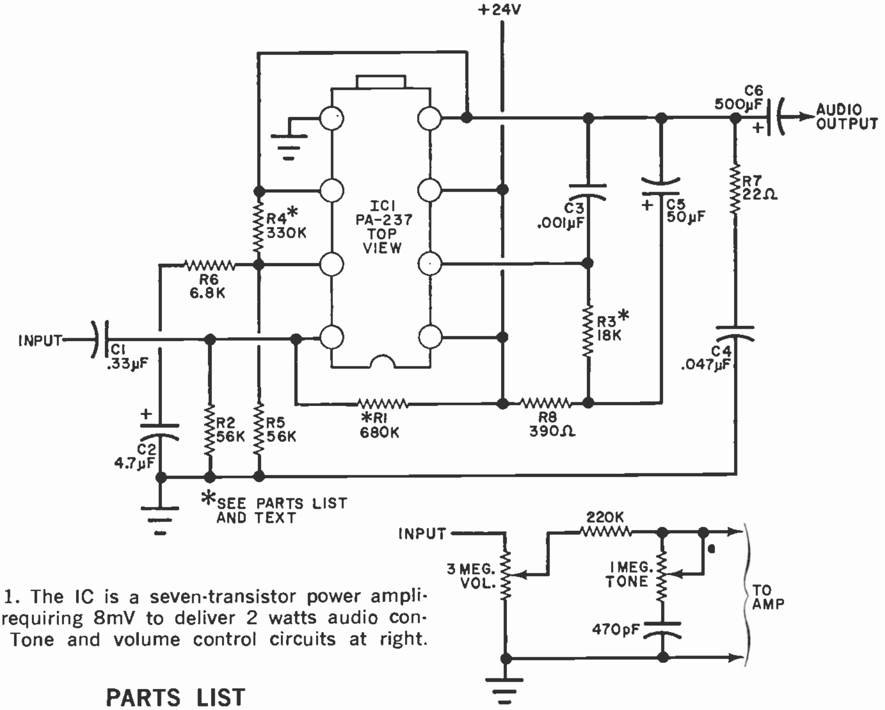


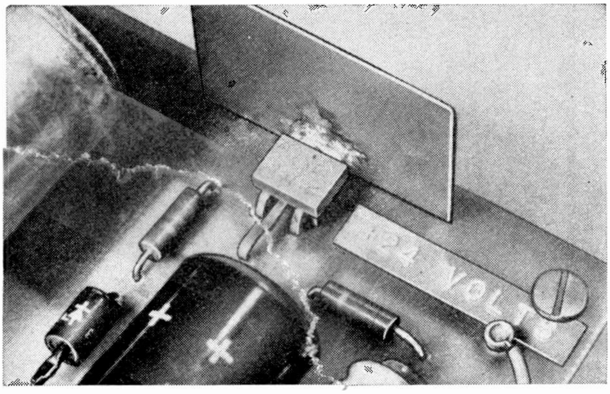
Fig. 1. The IC is a seven-transistor power amplifier requiring 8mV to deliver 2 watts audio control. Tone and volume control circuits at right.

PARTS LIST

C1—0.33-µF capacitor
C2—4.7-µF, 15-volt electrolytic capacitor
C3—0.001-µF capacitor
C4—0.047-µF capacitor
C5—50-µF, 25-volt electrolytic capacitor
C6—500-µF, 20-volt electrolytic capacitor
IC1—Integrated circuit (General Electric PA-237)
*R1—680,000-ohm**
R2,R5—56,000-ohm
*R3—18,000-ohm**
*R4—330,000-ohm**
R6—6800-ohm
R7—22-ohm
R8—390-ohm
All resistors ½-watt

Misc.—1" x 1" x $\frac{1}{32}$" copper sheet heat sink, printed circuit board, insulated standoffs (optional, 4 if used)
**For a 1-watt amplifier, with 12-volt supply, use R1—390,000 ohms, R3—12,000 ohms, R4—180,000 ohms, all ½ watt. 8-ohm speaker*

Note: An etched and drilled printed circuit board #158B is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, for $2.00, postpaid. A kit, #158CP, containing the PC board and all parts to be mounted on it, including the PA-237 is also available from the same source for $7.50, postpaid.



In the power supply, the copper heat sink is soldered to both transistor tab and PC board foil.

Construction. The circuit for the 2-watt amplifier is shown in Fig. 1. It is assembled on a printed circuit board such as the one shown actual size in Fig. 2. When you have completed the board, mount all of the components, except *IC1*, as shown in Fig. 3. To prepare the IC for mounting, use a pair of long-nose pliers to bend its leads, including the large heat-sink tab, so that they are at right angles to the body of the IC. Be sure that the IC is properly positioned before mounting it on the board; a small notch at one end of the IC must be oriented as shown in Fig. 3.

After bending the leads, insert the IC pins and the heat-sink tab into the board and solder them to the foil. Use no more

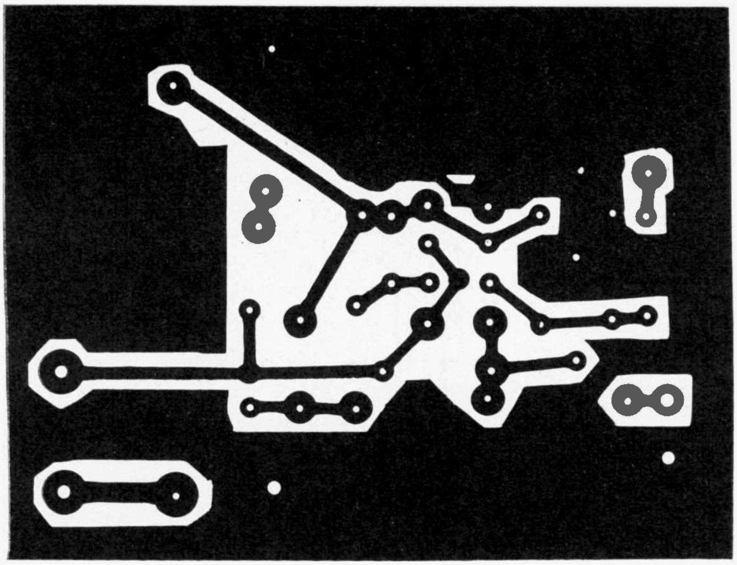


Fig. 2. Use this actual size layout for the PC board for the amplifier. Large amount of foil left on the board acts as an extra heat sink for IC1.

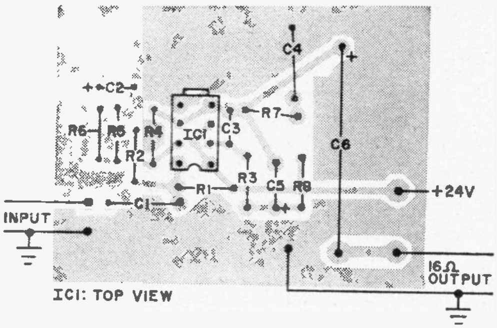
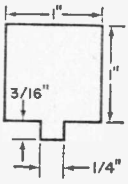


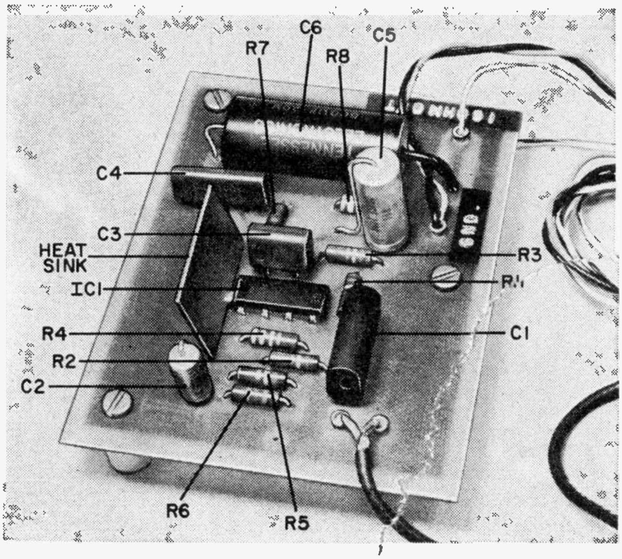
Fig. 3. Install the components as shown here. If you don't have a 16-ohm speaker, use two 8-ohm units in series. Be sure they are phased right.

heat than is necessary to get a good solder joint.

To make a heat sink for the IC, cut out a 1″-square piece of heavy-gauge copper (at least 1/32″ thick, see drawing). Tin the heat sink tab and tin the piece of the IC heat-sink tab that is on the component side of the board. Solder the heat sink to the tab of the IC so that the heat sink is vertical to the board. This completes the 2-watt amplifier.

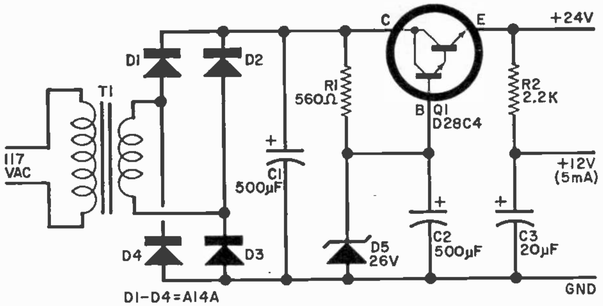
To use this design for a 1-watt amplifier with a 12-volt supply, use the same printed circuit board but make the fol-





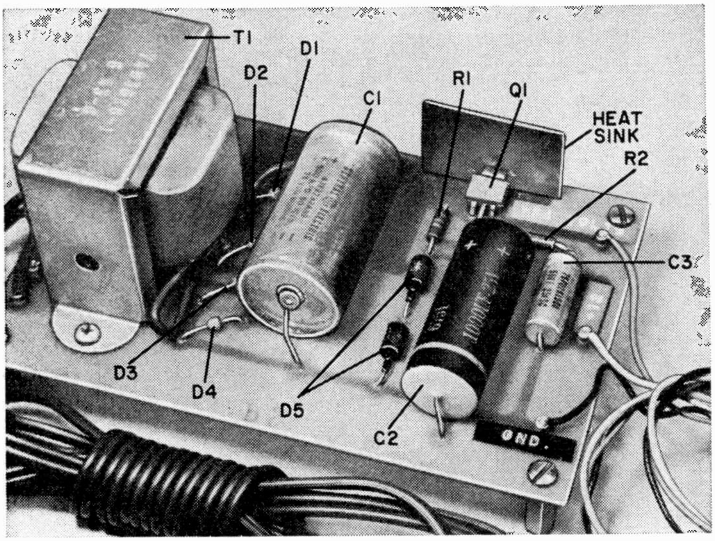
Although not required, you can mount the finished amplifier on four standoffs, as shown. In attaching the heat sink to the IC and PC board, do not apply too much heat to the IC tab while soldering since heat can damage the IC. Tin both connections before joining and flow solder in.

Fig. 4. Besides the 24 volts required by the 2-watt amplifier, the power supply has a 12-volt, 5-mA output for use with a preamplifier.



PARTS LIST

C1, C2—500-µF, 50-volt electrolytic capacitor
C3—20-µF, 25-volt electrolytic capacitor
D1-D4—1-ampere, 100-volt rectifier diode (GE A14A or similar)
D5—24-volt, 1-watt zener diode
Q1—Power transistor, npn (GE D28C4 or similar)
R1—560-ohm, ½-watt resistor
R2—2200-ohm, ½-watt resistor
T1—Power transformer, secondary—24 volts, 1.2 amperes.
Misc.—1" x 1" x 1/32" copper sheet heat sink, printed circuit board, line cord, insulated standoffs (optional, 4 if used)



If you do not have a 24-volt zener, use a pair of 12-volt units in series as shown here. You must break the foil that shorts one diode connection.

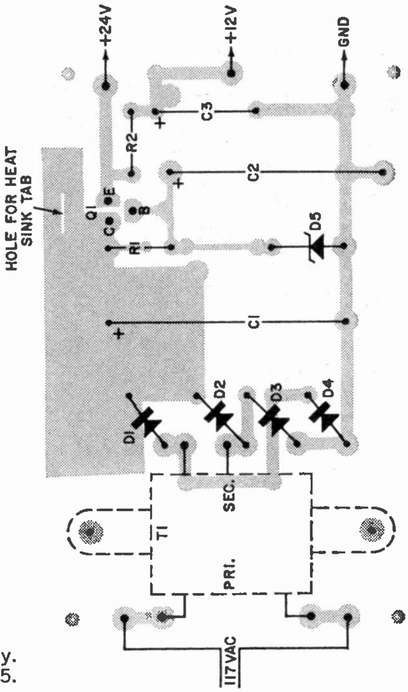


Fig. 6. Component installation for power supply. Only one zener diode is shown here for 24-volt D5.

lowing component changes: for R1 use 390,000 ohms, for R3, 12,000 ohms, for R4, 180,000 ohms, and use 8-ohm speaker.

Power Supply. The schematic of a 24-volt d.c. regulated supply for the 2-watt amplifier is shown in Fig. 4. The circuit also has a 12-volt, 5-mA output for a preamplifier. This power supply can be constructed on a printed circuit board, if desired, using the actual-size foil layout shown in Fig. 5. When the board is finished, install the components as shown in Fig. 6.

To make a heat sink for the transistor, cut out a 1" square of heavy-gauge cop-

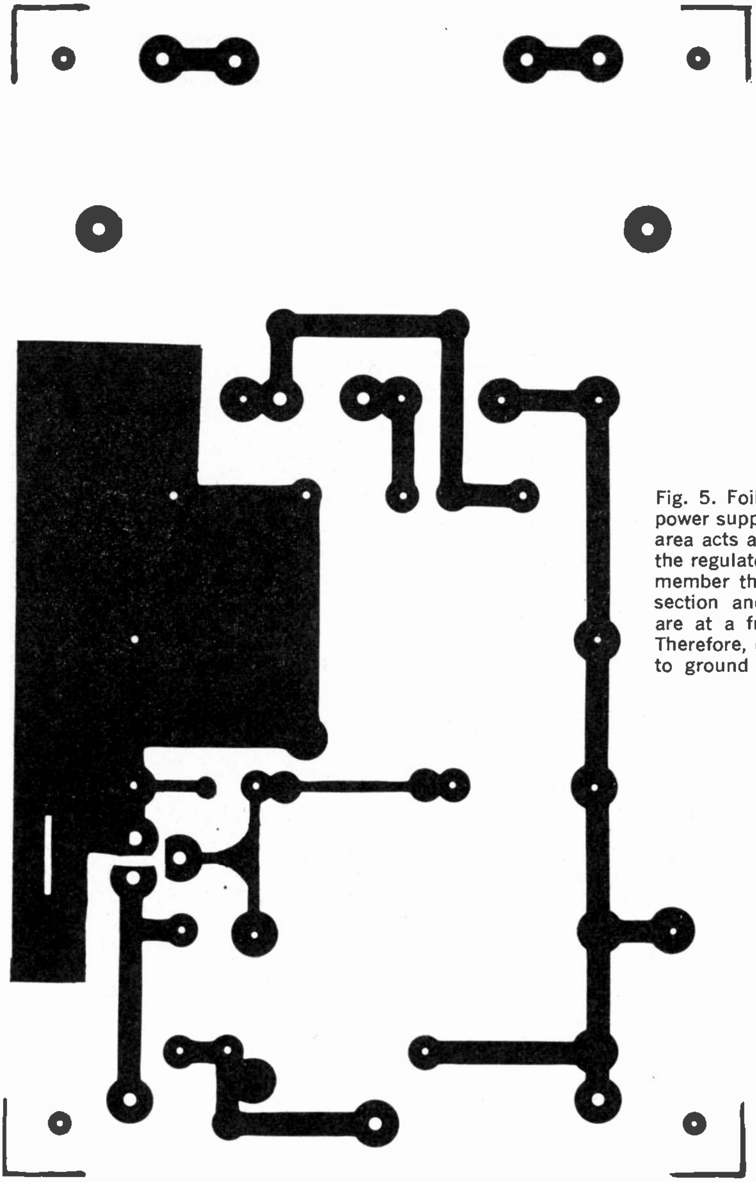


Fig. 5. Foil pattern for the power supply. The large foil area acts as a heat sink for the regulator transistor. Remember that both this foil section and the heat sink are at a full 24-volt level. Therefore, don't short them to ground for any reason.

per (at least 1/32" thick) with a 3/16" wide by 1/8" long tab at the center of one edge of the square. This tab is to be inserted through the PC board for mounting the heat sink. Solder the heat sink to the heat-sink tab on the transistor and to the foil on the bottom of the board. On this transistor, the heat-sink tab is actually connected to the collector and is at a potential of 24 volts so be sure that neither the tab nor the heat sink is shorted to ground. Position the copper heat sink so that it is vertical to the board.

Volume and Tone Controls. If volume and tone controls are desired for the amplifier, insert a circuit such as that shown in the inset in Fig. 1 at the input to the amplifier. The tone control is of the "losser" type so that, as the rotor of the tone-control potentiometer approaches the capacitor end, the high frequencies are attenuated. –30–

solid-state pH meter

electronics
IN THE
chemistry
LAB

ACID OR ALKALINE? HOW MUCH? THIS LOW-COST, HIGHLY ACCURATE PROJECT HAS DIRECT READOUT

BY R. C. DENNISON

THE HIGH COST of pH meters ($100 to $500) has ruled out their use in many small schools and laboratories. Now, through the use of low-cost metal-oxide-semiconductor field-effect transistors (MOSFET's), it is possible for any amateur scientist to have his own high-quality pH meter. It can be built for about $33. The recommended pH probe (see Parts List) is specially designed for student use with its delicate glass electrode surrounded by a protective polyethylene shield. Its price of $20 is about half that of most other probes.

The circuit (see Fig. 1) uses two MOSFET's in a differential-amplifier configuration. An advantage of this symmetrical circuit is that temperature and drain-voltage variations tend to affect the currents in *Q1* and *Q2* equally and are effectively cancelled in their effect on the meter reading. Stability is further improved by the use of a zener diode (*D1*) to regulate the drain voltage.

A portion of the meter scale (between pH 12.5 and pH 14) is colored green and is used to determine whether or not the battery is in good condition. With the function switch (*S1*) in the BAT position, only the battery with normal loading is connected to the meter. The battery's condition is good if the meter

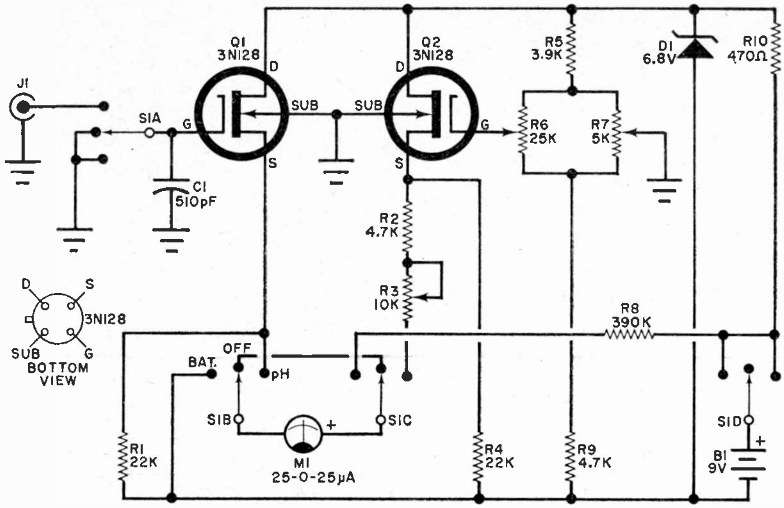


Fig. 1. The symmetrical configuration of the differential-amplifier circuit cancels errors caused by temperature and drain-voltage variations in MOSFET'S.

PARTS LIST

B1—9-volt battery
C1—510-pF, dipped mica capacitor
D1—6.8-volt, 400-mW zener diode (TI 1N3514 or similar)
J1—BNC jack, UG-1094/U
M1—25-0-25 microammeter, 4½-inch
Q1, Q2—3N128 n-channel MOSFET (RCA)
R1, R4—22.000-ohm
R2, R9—4,700-ohm
R5—3,900-ohm
R8—390,000-ohm
R10—470-ohm
All resistors ½-watt
R3—10,000-ohm, trimmer potentiometer, (Mallory MTC14L1 or similar)
R6—25,000-ohm, ½-watt linear potentiometer
R7—5,000-ohm, trimmer potentiometer (Mallory MTC53L1 or similar)
S1—Five-pole, three-position, non-shorting ceramic switch (Centralab PA-2015) (Do not substitute.) Note only four of the poles are used.
Misc.—3" x 5" x 7" metal cabinet (Bud CU-3008-A or similar), aluminum handle, thumbscrew, ¼" metal spacers, knobs, battery connector, screws, nuts, wire, solder, Print-Kote, etc.
The following items are available from Analytical Measurements, Inc., 31 Willow St., Chatham, N. J. 07928: pH probe with BNC fitting—$20; KCl refill solution for pH probe, 4-oz bottle—$1; buffer kit, (3) 500-ml plastic bottles, 3 pkgs each of powdered buffer salts, 4, 7, 9 pH—$6. Include postage & N. J. tax.

reading is in the green portion of the scale.

When *S1* is in the OFF position, the meter is shunted to protect the sensitive movement during transportation. All pH measurements are made with *S1* in the pH position.

Construction. The transistors, resistors, and other small components are mounted on a printed-circuit board shown full size in Fig. 2. Use glass-epoxy-base copper-clad board instead of the ordinary paper-phenolic type to maintain high input resistance in humid weather. After the board is etched, wash it at least ½ hour in running water; then dry it thoroughly and drill it. Install all components, except the transistors, but including one circuit jumper and two temporary jumpers as shown in Fig. 3. A finished board is shown in Fig. 4.

MOSFET's are easily damaged by static electric charges unless certain precautions are observed. They are shipped with their leads inserted in a metal ferrule. Do not remove this ferrule until you are ready to solder the transistor to the board. Solder all the other components in place first. Make sure that the temporary wire jumpers are in place as shown in Fig. 3. These jumpers protect the MOSFET's during assembly and wiring. Now remove the ferrules and bend the MOSFET leads to fit into the holes in the board. Get the soldering iron hot but

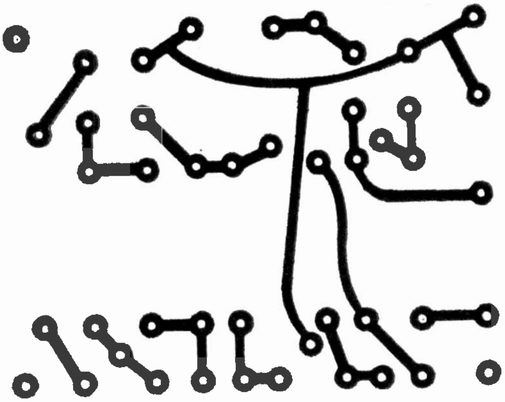


Fig. 2. Use best-quality copper-clad glass - epoxy - base board to maintain high input resistance of pH meter.

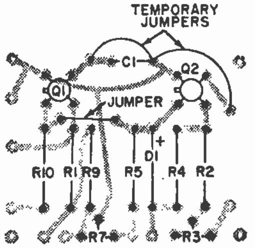


Fig. 3. To protect MOSFET's against damage, connect temporary jumpers as shown until meter is fully assembled.

WHAT IS pH?

An acid is a substance that yields hydrogen ions (H^+) when dissolved in water. Actually, each hydrogen ion attaches itself to a molecule of water to form a hydronium ion (H_3O^+). The concentration of hydronium ions in a solution is a measure of the strength of the acid.

Chemists usually measure concentration in moles per liter. For example, 0.1 molar hydrochloric acid contains 3.65 grams (0.1 mole) of hydrogen chloride in one liter of solution because the molecular weight of hydrogen chloride is 36.5. Since HCl tends to dissociate completely into ions in solution, the concentration of hydronium ions in this solution would also be 0.1 mole per liter. Some substances dissociate only slightly. Thus, in acetic acid, only 1.36% of the molecules in a 0.1 molar solution dissociate. Therefore, the hydronium ion concentration would be 0.00136 moles per liter.

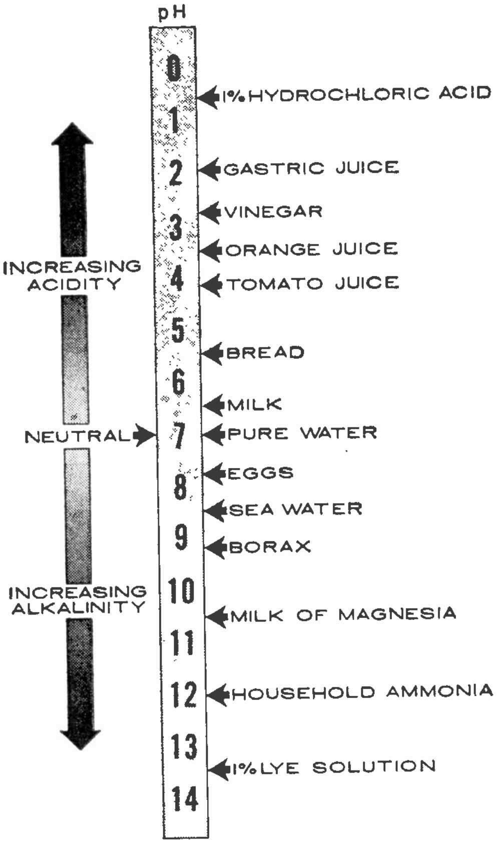
To avoid the use of such small, inconvenient numbers, it is customary to express the hydronium-ion concentration in terms of pH values defined by the equation

$$pH = \log (1/H_3O^+)$$

where H_3O^+ is the hydronium ion concentration in moles per liter. Thus, in the examples above, the 0.1 molar solutions of hydrochloric and acetic acid have pH values of 1.0 and 2.87 respectively.

The pH scale is a logarithmic scale similar to that of the decibel. Each 10-fold change in acidity changes the pH value one unit. The pH values of some common substances are shown on the accompanying scale. From this, we see that orange juice is 1000 times more acidic than milk. Note that the scale runs from 0 to 14. Pure water is neutral with a pH of 7. Lower pH values indicate an acidic substance while higher values indicate alkalinity.

Many chemical processes are greatly affected by small changes in the degree of acidity or pH value. Some examples are the speed of chemical reactions, the growth of micro-organisms, the quality of electroplated deposits, the polymerization of synthetic rubber, the growth of plants and the tendency of jellies to gel. Thus the accurate measurement of pH assumes great importance in chemical laboratories, medical and biological research, food preparation, agriculture, and industrial quality control. Often, pH instrumentation is used in continuous closed-loop (feedback) systems in process control.



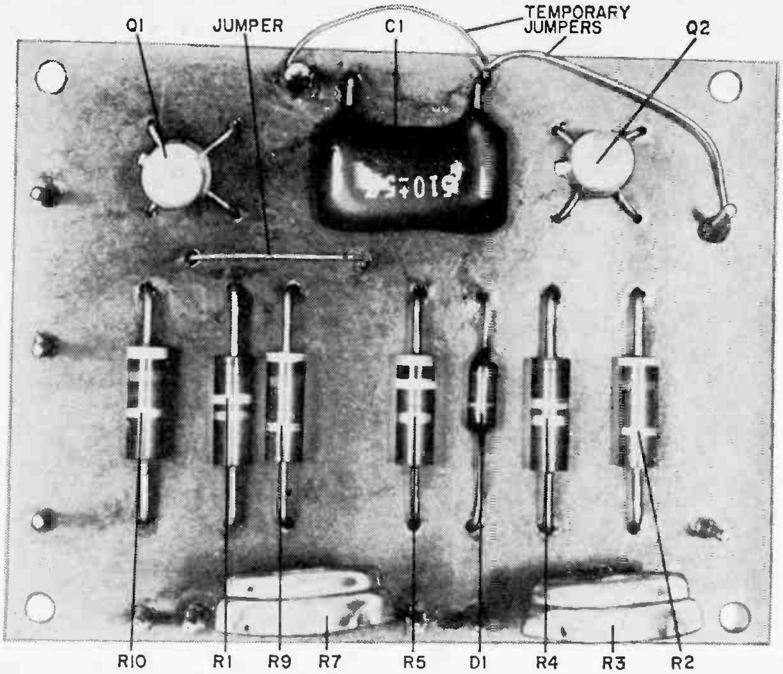


Fig. 4. Make sure that temporary jumpers are in place before soldering the MOSFET's into the circuit. When handling Q1 and Q2, and when mounting them on circuit board, do not remove the shorting rings. See text for precautions to take while soldering.

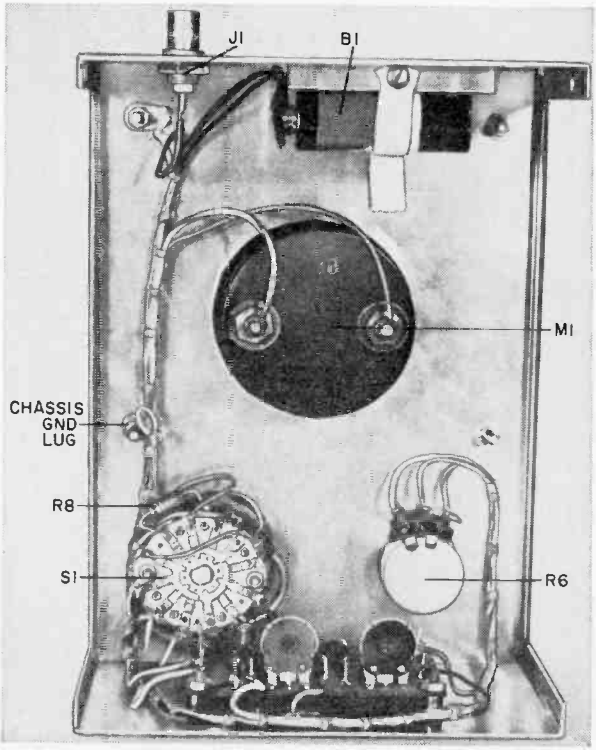


Fig. 5. After components and circuit board are mounted in their respective locations on the metal box, wire them together. To obtain a neat, professional appearance, use lacing cord to bundle the wires into harness configuration as shown in this photo.

then unplug it while soldering the transistors to the board. You may have to re-heat the iron to get all of the connections made, but be sure to have it unplugged while attaching the transistors. Failure to do so may result in permanent damage to the gates of the MOSFET's.

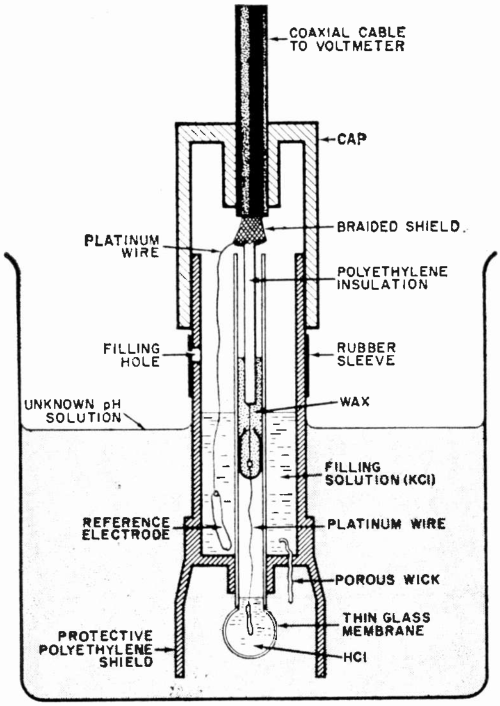
As in all work with printed circuits and semiconductors, use a low-wattage iron (25 to 35 watts) to avoid damage due to excessive temperatures. Remove all flux from both sides of the board using alcohol and a clean cloth. Dry the board thoroughly and then coat both sides with a silicone resin such as GC Print Kote to moisture-proof the board.

Mount potentiometer *R6*, switch *S1*, and BNC connector *J1* to the front of the chassis as shown in Fig. 5. The battery is supported on a 2" × 1" × ¼" block of plastic by a piece of ⅜"-wide dressmaker's elastic secured to the plastic with screws. The elastic band holds the battery securely, and the plastic base insulates the battery from the metal chassis.

The original scale of the meter must be removed and replaced with a linear scale calibrated from zero to 14 with 7 in the middle. Subdivide each major segment into five minor segments. (See photo of meter front panel.) The section between 12.5 and 14 should be colored green for the battery test described earlier.

Mount the board to the bottom of the chassis using ¼" metal spacers and appropriate hardware. Complete the wiring using only high-quality wire. If the wire from *J1* to *S1* is to be laced with the other wiring, it should have teflon, polystyrene, or polyethylene insulation. If the wires are laced, coat the wire harness with low-loss coil dope to exclude moisture. Do not substitute a phenolic switch for the ceramic switch specified. Keep all insulation clean and free of grease and soldering flux. A small packet of silica-gel desiccant may be kept inside the pH meter to remove the last traces of moisture.

The handle is made from a piece of ½" × 1/16" aluminum and may be secured in any position by means of a thumbscrew on one side. The thumbscrew engages a small piece of threaded brass which is held in place by flat-headed screws. The other side of the handle is fastened to the case by a free-turning



HOW pH IS MEASURED

Every schoolboy knows that litmus paper can be used to determine whether a substance is an acid or a base. Other chemical indicators which change color at various pH values are also available. However, the modern way to measure pH is by means of the electronic pH meter. Its operation is based on the use of a glass electrode and a reference electrode, often combined into a single probe similar to that shown in the diagram.

The thin glass membrane is permeated by the charge-carrying hydrogen ions, the number of ions that pass through the membrane being determined by their concentration in the liquid being tested. Therefore, when the probe is placed in a solution, it develops a voltage at its terminals which is proportional to the pH of the solution.

Because the resistance of the glass electrode may be as high as 200 megohms, the voltmeter portion of the pH meter must have a very high input resistance. Since some MOSFET's have input resistances of 10 million megohms or more, they may be used to make an excellent low-cost pH meter.

screw. This lockable handle can be used to support the pH meter in a tilted position to make it easier to use and read.

Adjustment and Calibration. After all wiring has been carefully checked, snip out the jumper associated with *Q2*. Rotate the STANDARDIZE control, *R6*, and the zero-adjust potentiometer, *R7*, to their mid-positions and set the calibrate potentiometer, *R3*, to maximum resistance. With *S1* set to OFF, install the battery. Put *S1* in the BAT position and check that the meter deflects nearly full scale (within the green region). Turn *S1* to the pH position and rotate the zero-adjust potentiometer to bring the meter pointer to center scale (pH7). Turn *S1* off and snip out the other temporary jumper (around *C1*). A note of caution: to protect the input MOSFET, *Q1*, switch *S1* shunts the gate to ground in both the OFF and BAT positions. Do not turn the switch to the pH position unless the pH probe is connected and immersed in a solution. (An exception to this rule occurs during calibration. Follow the calibration instructions below carefully to avoid damaging *Q1*.)

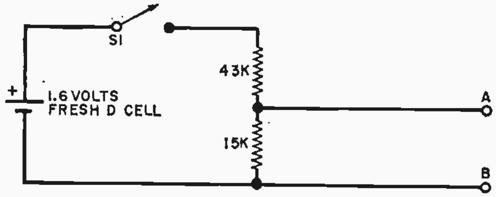


Fig. 6. The outboard calibration circuit for pH meter must be assembled around new, fresh D cell.

The meter is calibrated using the circuit shown in Fig. 6. Make sure the meter is off while making the following connections. Connect point B to the metal case of the meter and connect point A to the center terminal of the meter input jack, *J1*. Alligator-type clips are ideal for these test leads. Place the function switch on pH and adjust the STANDARDIZE control if necessary to make the meter read pH7. Close switch *S1* on the calibration circuit and the meter should deflect toward the left. Adjust calibration potentiometer *R3* to make the meter indicate 0 pH. Turn the function switch to OFF and disconnect the test circuit. The pH meter is now calibrated for use with solutions having a temperature of 25°C, which is typical room temperature. A formula to be given later can be used to correct the meter reading for temperatures other than 25°C.

Standardizing Buffers. Before the pH of a solution can be measured, it is necessary to standardize the meter. This is done by dipping the pH probe into a solution of known pH and rotating the STANDARDIZE control until the meter indicates the known pH. After the meter is thus standardized, the probe is rinsed in distilled water, wiped dry with a lint-free cloth, and then placed in the solution whose pH is to be measured. These standardizing solutions are called *buffer* solutions and are selected on the basis of their tendency to maintain a constant pH value in spite of small amounts of contamination or dilution during use. You can buy buffer solutions at a reasonable cost or you can make your own. For greatest accuracy, choose a buffer whose pH is close to that of the unknown.

- Buffer No. 1. pH = 4.01. Dissolve 5.1 grams of potassium hydrogen phthalate in sufficient water to make 500 milliliters of solution.
- Buffer No. 2. pH = 6.86. Dissolve 1.7 grams of potassium dihydrogen phosphate and 1.77 grams of anhydrous disodium hydrogen phosphate in sufficient water to make 500 milliliters of solution.
- Buffer No. 3. pH = 9.18. Dissolve 1.85 grams of sodium tetraborate decahydrate in sufficient water to make 500 milliliters of solution.

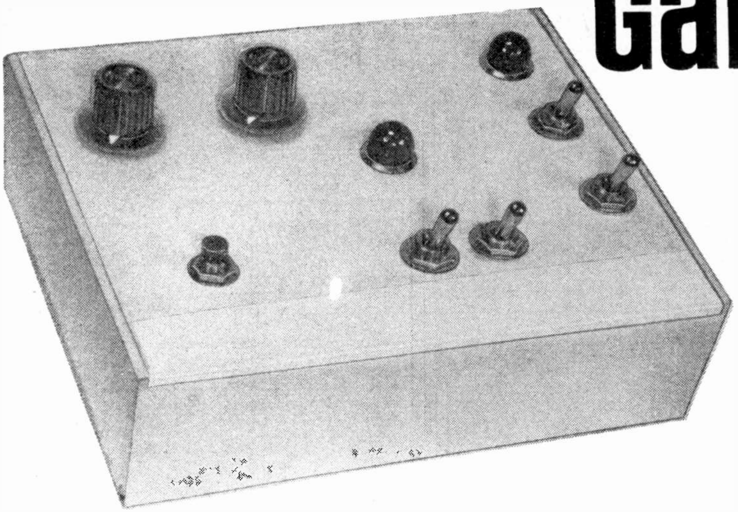
Use distilled water and keep the buffer in a tightly stoppered bottle. A small crystal of thymol may be added to the bottle to inhibit the growth of mold.

Temperature Compensation. Assume the temperature of the standardizing buffer and the unknown is T (in degress centigrade). The error in instrument reading, to be substracted from the indicated pH, is then

$$\text{pH error} = \frac{(T-25)\ (\text{pH}_r - \text{pH}_s)}{T + 273}$$

where pH_r is the instrument reading and pH_s is the pH of the buffer. —30—

GADGET BOX -Mark 99



ELECTRONIC TOY IS ALSO EDUCATIONAL

BY JOSEPH J. TASHETTA

IN THIS MODERN AGE, two things should be expected of any toy that you give to your children. First, it should be an effective attention-occupier. Then, even more important, it should be educational. While many toys are effective attention-*getters*, children often lose interest in them after the initial novelty wears off. And few toys are really educational. The "Gadget Box," however, is one toy that fills both requirements.

Children, especially toddlers who are easily fascinated, won't quickly tire of the Gadget Box. This electronic "toy" is loaded with special effect controls. Flip a switch or press a button, and a siren sounds; flip another switch, and a metronome-like ticking is heard; twirl a knob, and the rate of ticking changes. Through the use of various controls and lights, the toy can also help to develop motor reflexes and teach basic logic.

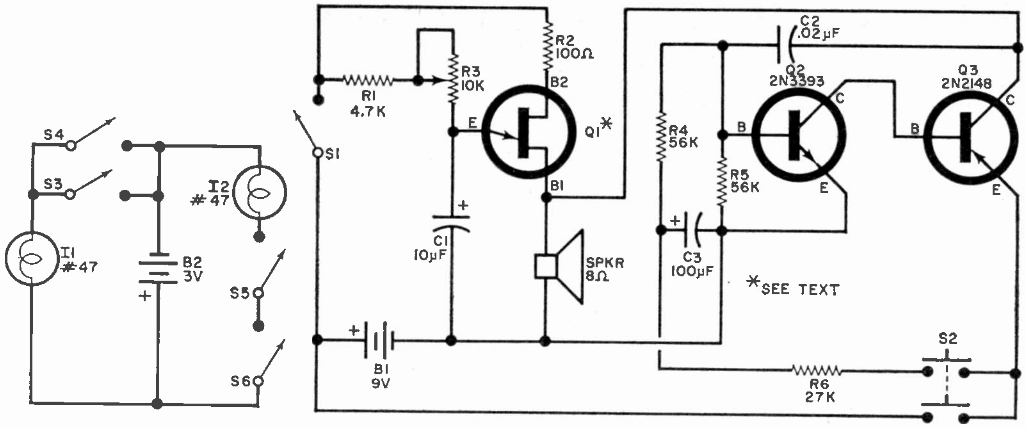
About the Circuits. The ticker circuit contains a unijunction transistor, *Q1*. Closing *S1* causes capacitor *C1* to begin charging through resistors *R1* and *R3*. At some time during the charge cycle (determined by the RC time constant of the circuit) the voltage at the emitter exceeds the voltage at *B2*, driving *Q1* into conduction. When *Q1* conducts, *C1* rapidly discharges through the UJT, causing a "tick" to be heard in the speaker.

This charge-discharge action repeats itself indefinitely as long as power is applied to the circuit. To vary the tick rate, you need only change the setting of *R3*.

The circuit containing transistors *Q2* and *Q3* is the siren. When *S2* closes, *C3* charges and switches on *Q2* and *Q3*. The output of *Q3* then provides regenerative feedback to the base of *Q2* to sustain oscillations. As *C3* charges, the output signal frequency increases. Conversely, as *C3* discharges, output frequency diminishes. The result is that the output signal wails up and down the scale like a real siren.

An independent circuit for developing the sense of basic logic is provided by the lamp and switch configuration shown in the schematic diagram. The circuit consisting of *I1, S3*, and *S4* makes up an OR circuit. Closing either of the two switches causes *I1* to glow; closing both switches still causes the lamp to glow.

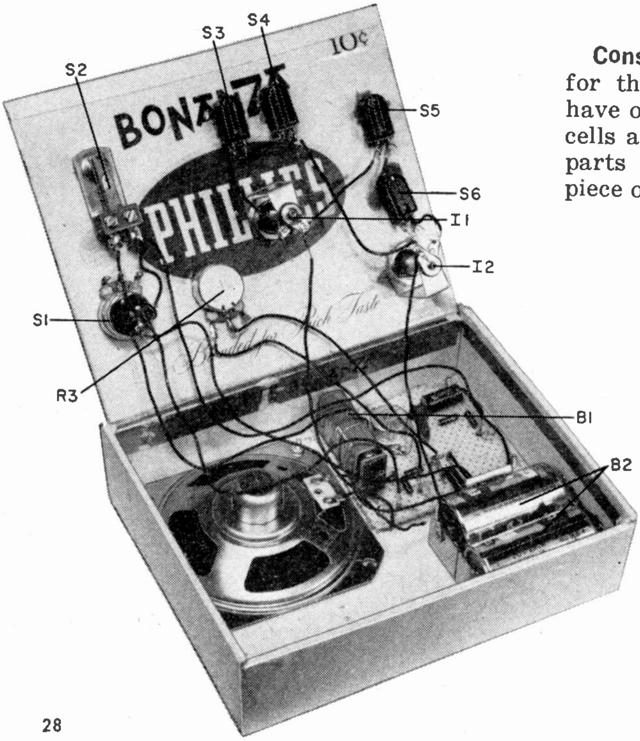
The circuit consisting of *I2, S5*, and *S6* forms an AND circuit. In this case both switches must be closed before the lamp will glow since closing just one switch will not complete the circuit.



PARTS LIST

B1—9-volt transistor battery
B2—Two 1.5-volt D cells
C1—10-µF, 10-volt electrolytic capacitor
C2—0.02-µF ceramic capacitor
C3—100-µF, 10-volt electrolytic capacitor
I1, I2—#47 lamp
Q1—General-purpose unijunction transistor (UJT)
Q2—2N3393 transistor
Q3—2N2148 transistor
R1—4700-ohm, ½-watt resistor
R2—100-ohm, ½-watt resistor
R3—10,000-ohm potentiometer (see text)
R4, R5—56,000-ohm, ½-watt resistor
R6—27,000-ohm, ½-watt resistor
S1—S.p.s.t. switch (see text)
S2—D.p.s.t. normally open momentary-action push-button switch (see text)
S3, S4, S5, S6—S.p.s.t. switch
SPKR—8-ohm PM speaker
Misc.—Cigar (or Bakelite or aluminum utility) box; battery holders; perforated board; flea clips; lamp sockets; hardware; hookup wire; solder; etc.

Unijunction transistor stage Q1 makes up the ticker, and stages Q2 and Q3 form the siren circuits. The AND circuit (left) consists of I2, S5, and S6; the OR circuit uses I1, S3, and S4.



Controls and lamps mount conveniently on lid, all other components on floor, of cigar box. After mounting speaker, affix rubber bumpers to bottom of box to allow the sound to come through.

Construction. Many of the parts needed for the Gadget Box you will probably have on hand. Except for the speaker, D cells and holder, lamps, and controls, all parts can be mounted on a 3"-square piece of perforated board, using flea clips

(*Continued on page* 93)

BUILD The Big Six

THE SPEAKER SYSTEM THAT'S BIG— AND PROUD OF IT

BY DAVID B. WEEMS

THERE IS more to some large speaker systems than impressive size—namely, quality. Some compact speaker systems have an amazingly low resonance and use long-throw woofer design to reduce distortion. But think of the results you could get by using a woofer whose resonance is already at the low end of the audio spectrum and putting it in an enclosure designed to maintain the speaker's resonance below that of any available compact. The enclosure might be much larger than any compact, but the system would be capable of producing deeper, smoother bass response right down to the bottom of the music spectrum.

The "Big Six" speaker system described here uses this approach and also provides room for another feature you're not likely to find in any compact system—a column of four midrange speakers. Add a super tweeter and a crossover network, and you have a speaker system that doesn't have to apologize for its large size. The performance of the Big Six speaks for itself.

Overall System. The Big Six speaker system is built around a low-resonance Jensen Model W12NF "Flexaire" woofer, mounted inside a modified labyrinth. The 20-Hz characteristic resonance of the woofer is raised somewhat by the enclosure, partly because the labyrinth is shorter than the optimum quarter-wave length. (Fourteen feet, after all, would be a bit large for the average-size listening room.) The cross-section area of the labyrinth is greater than the theoretical maximum because experiments indicate that the larger "tube" produces deep, unrestricted bass.

Four economy priced Cinaudagraph 6½" midrange speakers are arranged in a sealed column to prevent interaction with the woofer. The Cinaudagraph speakers have an extremely wide frequency response and upgrade the overall quality of the Big Six.

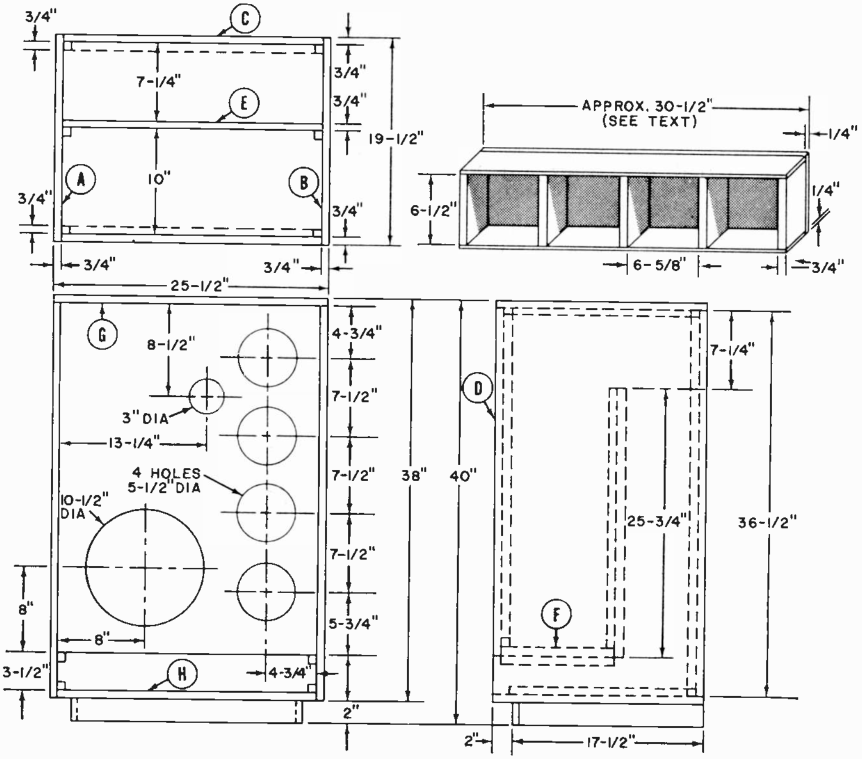


Fig. 1. To avoid confusion, all plates in basic enclosure are identified by letter symbols A through H. Cleats and corner blocks are referred to by lengths as they are used in text.

To round out the speaker system, a University Model T-202 "Sphericon" super tweeter is used because of its superior high-frequency dispersion characteristics. However, if you wish to economize, you can substitute a less expensive tweeter with dispersion characteristics similar to those of the Sphericon's. Further economizing can be accomplished by substituting less expensive fixed crossover networks for the more versatile ones specified in the Bill of Materials. Do not, however, substitute the "Flexaire" woofer or you may degrade system performance.

Construction. To avoid confusion during construction, the eight major parts of the enclosure are identified by letters A through H in the text, Bill of Materials, and dimensioned drawings of Fig. 1. Instructions for fastening parts together (with the exceptions of speaker mounting board D, rear enclosure wall C, and the rear wall of the midrange speaker column) mean "glue and screw."

Start construction by attaching the 16½" cleats ¾" in from the side edges and 1½" in from the front and rear edges of plates G and H. Then attach the 30¾" cleats to the front and the 25" cleats at the center of side plates A and B. Make sure the front cleats are flush with the top edges and recessed ¾" in from the front edges of the side plates, and that the center cleats are 7¼" from the top and 10" from the front edges. The rear cleats for plates A and B will be attached later.

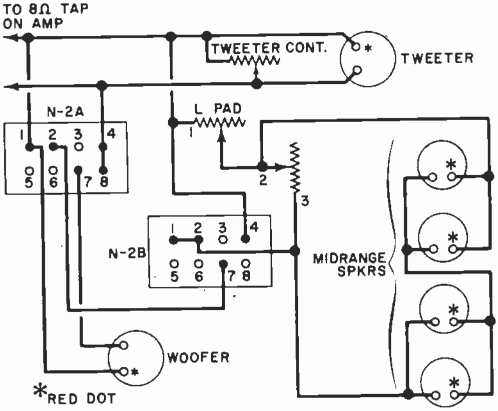


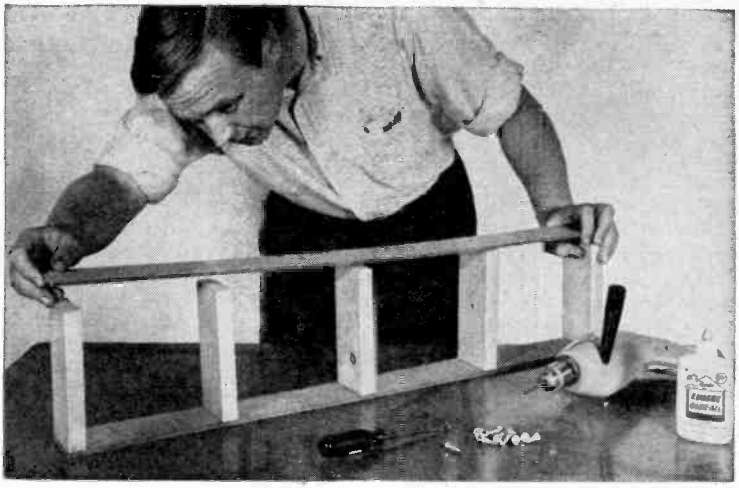
Fig. 2. To obtain proper phasing, be sure to wire all speakers together as shown here. Terminal numbers are stamped right on crossover networks. Tweeter control is supplied by the manufacturer.

BILL OF MATERIALS

1—Jensen Model W12NF "Flexaire" woofer
1—University Model T-202 "Sphericon" tweeter
4—Cinaudagraph 6½" midrange speakers (stock no. 6-½"-MR from McGee Radio, 1901 McGee St., Kansas City, Mo.)
1—University Model N-2A crossover network
1—University Model N-2B crossover network
1—University Model AP-8 L-pad for midrange control
2—37½" × 19½" pieces of ¾" plywood (parts A and B)
1—36½" × 24" piece of ¾" plywood (part C)
1—33" × 24" piece of ¾" plywood (part D)
1—25¾" × 24" piece of ¾" plywood (part E)
1—24" × 10" piece of ¾" plywood (part F)
1—25½" × 19½" piece of ¾" plywood (part G)
1- 24" × 19½" piece of ¾" plywood (part H)
5—6½" × 2⅝" pieces of ¾" white pine for ends and partition separators of midrange column
2—30¼" × 2⅝" pieces of ¼" Masonite for sides of midrange column (see text)
1—30¼" × 7" piece of ¼" Masonite for rear of midrange column (see text)
2—35¾" pieces of ¾" × ¾" pine (rear cleats for parts A and B)
4—24" pieces of ¾" × ¾" pine (top and bottom cleats at rear, top cleat for part D, and front cleat for part F)
4--16½" pieces of ¾" × ¾" pine (top and bottom side cleats)
2—25" pieces of ¾" × ¾" pine (side cleats for part E)
2—30¾" pieces of ¾" × ¾" pine (front side cleats)
2—10" pieces of ¾" × ¾" pine (side cleats for part F)
1—21½" piece of 2" × ¾" pine (front of footing)
2—16¾" pieces of 2" × ¾" pine (sides of footing)
30—¾" × #10 flathead wood screws for Masonite parts in midrange column
120—1¼" × #8 flathead wood screws
4—1¼" × #12 panhead sheet metal screws for woofer
28—¾" × #10 panhead sheet metal screws for midrange speakers, tweeters, and crossover networks
4—³⁄₁₆" × 1" bolts for conductors
25'—2" × 24" fiberglass house insulation (see text)
Misc.—Pine for front trim; grille cloth; stain; paint, hookup wire; spade and ring lugs; solder; aluminized "duct" tape, etc.

Invert top plate G onto a clean, flat surface, and secure the side plates in place. Now do the same for plate H. During construction make frequent reference to the dimensioned drawings in Fig. 1 to insure that each part of the enclosure is properly fitted into place.

To complete assembly of the enclosure shell, anchor the footing pieces to the bottom of plate H by driving the screws down through the bottom plate and into the footing. Set the enclosure shell aside temporarily.



Start construction of midrange speaker enclosure by assembling sides, ends, and compartment separators. Use glue and screws to anchor the members together.

Attach 10″ cleats to the bottom side edges of plate F and the 24″ cleat to the front top edge. Anchor plates E and F together by letting E overlap F at the rear (see side view drawing in Fig. 1 for details).

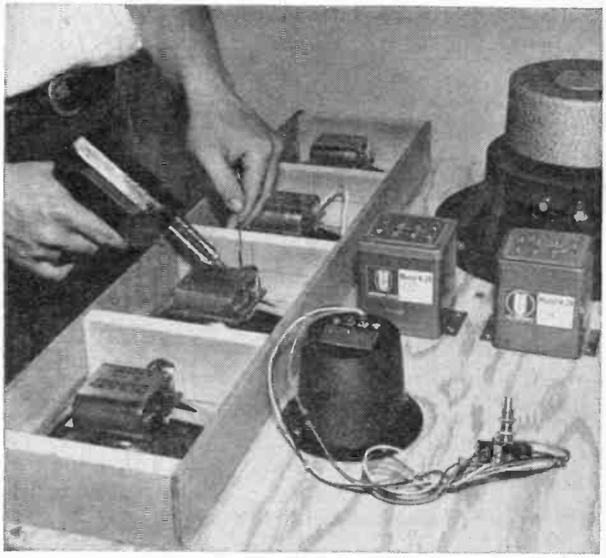
Coat with glue the interior surfaces that will make final contact with plates E and F. Slide the E-F assembly into place and anchor it with wood screws along both cleats at the sides. Attach the 30¾″ cleats at the front and the 35¾″ cleats at the rear of plates A and B. (Note, the front and rear cleats will be recessed ¾″ in from the front edges of the side plates.)

Prepare back plate C by drilling the guide holes for the anchoring screws and two 11/64″ holes to accommodate the bolts for electrical hookup. Finally, drill two ⅜″ holes near the top of this plate to accommodate the midrange and tweeter controls.

Referring to the front view drawing, carefully prepare speaker mounting board D. Now you can begin assembling the midrange speaker column.

First, drill ½″ holes through the centers of the three compartment separators to facilitate routing of the wiring. Temporarily set the partition separators, sides, and ends of the column over the speaker cutouts, and check for the proper locations of each part. (Because of the possibility of slight variations in the locations of the speaker cutouts, the length dimension given in the top right drawing in Fig. 1 is only approximate.)

If necessary, trim either the column or the cleats to insure that the column fits properly between the top and bottom cleats on the speaker mounting board when all parts are in place. When satisfied with the fit, assemble the column enclosure (except rear wall) with glue and screws, and set it temporarily in place on plate D. Scribe with a pencil the outline of the column and partitions. Remove the column from the speaker mounting board, and drill countersunk guide holes through plate D, two for each partition and end. Locate these holes 1″ in from both ends of the individual partitions and ends. Attach the column.



When properly mounted, the crossover networks should be located between woofer and tweeter.

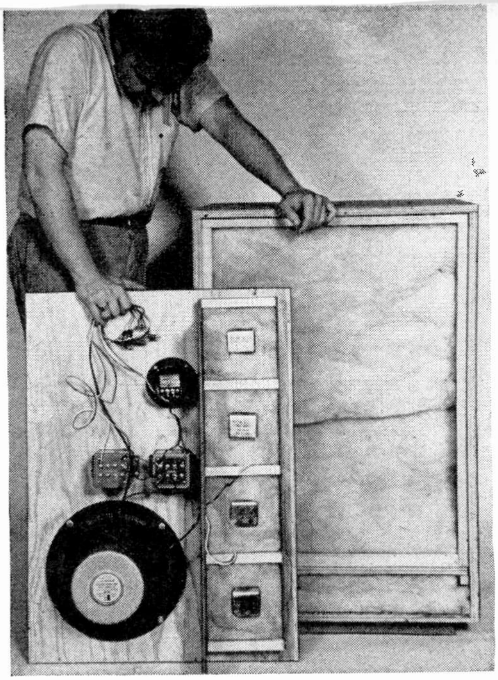


Fig. 3. For proper damping, loosely folded fiberglass wool should fill entire enclosure volume.

Fill the enclosure with fiberglass wool. (Because of the amount of fiberglass wool needed, about 25′ × 24″ × 2″, it is suggested that you use house insulation fiberglass to effect savings. The cost of a 50′ length of this material is generally less than $5, and you will have enough to fill two enclosures.) First strip the fiberglass wool of its aluminum foil backing. Cut a 3′ length, fold it in half, and place it on the floor of the enclosure. Triple fold another 8′ to 9′ length, and place it in the well immediately behind the speaker mounting board, arranging a hole for the woofer. Finally, fill the rear well of the enclosure with folded fiberglass wool.

Install the midrange speakers in the column, and wire them according to Fig. 2. One of the terminals on each of these speakers is color coded with a red dot; so be sure to use these dots as guides during wiring. Then terminate the wires in conducting bolts (which you can mount on the rear wall of the column's enclosure). Code the bolt that connects to the terminals with the red dots.

Now, cut four squares of fiberglass wool to a size just large enough to fit into the speaker compartments, and remove the centers to make room for the magnet assemblies (see Fig. 3). Set the squares over the speakers, and screw the Masonite rear panel in place, using two screws for each partition and end and placing the screws one inch in from the sides of the enclosure. Test the midrange column with a battery (all speaker cones move in the same direction when the terminals of the battery are momentarily touched against the conducting bolts.) Then tape the rear corners of the column with aluminized cloth "duct" tape to seal the column against air leaks.

(*Continued on page* 72)

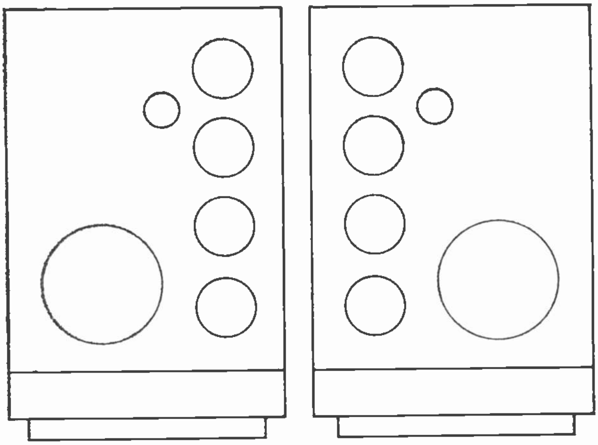
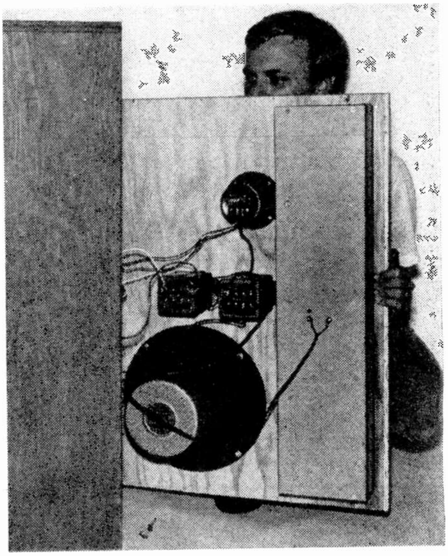


Fig. 4. Speaker mounting boards must be mirror images of each other for proper balancing of stereo.

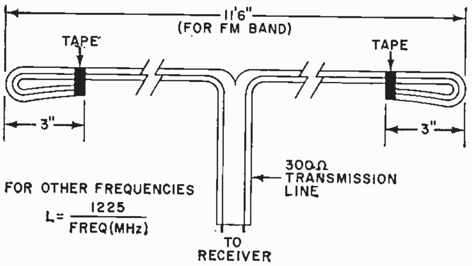


Assembled and wired speaker board is anchored to enclosure front with flathead wood screws.

Extended Double Zepp Antenna

BY JOHN NELSON, W2OLU

ADD A FEW INCHES TO YOUR ANTENNA AND WATCH THE SIGNAL LEVEL INCREASE



For 88-108-MHz FM band, the extended double Zepp is made of 11 feet 6 inches of split 300-ohm line.

MOST INDOOR antennas for FM or TV are conventional half-wave dipoles. Thousands of dipoles have been bought or made up by experimenters from a length of conventional 300-ohm transmission line. Usually the length of a dipole is restricted to half of the wavelength at the frequency of interest.

However, most experimenters don't realize that if they made the antennas slightly longer than half a wavelength, the gain would be increased noticeably. In fact, some AM BCB stations, in order to increase their coverage area without increasing transmitter power, use a ⅝-wavelength radiator. This improves the low-angle radiation and gives these broadcasters greater coverage than they can get with the usual antenna.

Hams who are familiar with this principle of extending the dipole, often use a center-fed antenna 1¼ wavelengths long. This gives a net gain of 3 dB. The same principle is used in the design of the "Extended Double Zepp" (EDZ) antenna described here.

What's a Zepp? In early short-wave radio, an antenna consisting of a half-wave dipole, end-fed through a quarter-wave transmission line was developed as an antenna system for the then popular Zeppelin airship. Because of the large metal base of the Zeppelin, the antenna system had to be designed so that only the antenna proper, and not the transmission line, radiated. This antenna later became popular with hams under the name "Zepp."

The EDZ can be supported by string, rubber bands, or thumbtacks; it can be placed under a rug or hidden behind wall mouldings; it has no bulky or breakable insulators; and, if you should forget and leave it out in the woods on a camping trip, all you lose is about 50¢.

Fabrication. To make an EDZ antenna for the 88-108-MHz FM band, use the dimensions given in the illustration. Cut a piece of conventional twin-lead, 300-ohm TV line that is 6 feet long plus enough to go from the antenna to your receiver. Cut down the center of the twin lead for 6 feet. Make a knot (using the two loose ends) to keep the twin-lead from being further torn apart. At each of the two free ends, form a loop to permit the antenna to be hung. Use plastic tape to close the loops. This completes the antenna itself; the remainder of the uncut twin lead is used as the transmission line to the receiver. The latter should be only as long as necessary to keep signal loss to a minimum.

To construct an antenna for other than the FM band, calculate the length of the antenna portion by dividing 1225 by the frequency in megahertz. If you want to cover a relatively wide band, cut the antenna length for the highest frequency.

Using the Antenna. You can mount the antenna anywhere but remember that its directivity is rather sharp. It should be placed so that its length is broadside to the stations you want to hear.

Some further signal enhancement can be obtained by wrapping a 6-inch square of aluminum foil around the transmission line and sliding the foil up and down the line until the desired signal is maximized. Use a piece of plastic insulating tape to secure the foil to the line at the desired spot. -30-

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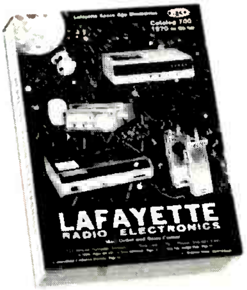

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MAKING PC BOARDS FROM THE PRINTED PAGE

Low-cost photocopying method can be used by experimenter

DUPLICATING PRINTED-CIRCUIT foil patterns for home-built construction projects has always been a laborious chore. Some experimenters try painfully to duplicate the foil pattern on a PC board using liquid resist and a sharp pen, only to find that it is not as easy as it appears at first glance. Others prefer the trusty razor blade and a set of stick-down strips and dots. Both of these systems are tiresome and seldom produce a pattern that looks like the one in the magazine. By the time a PC board has been redone a couple of times, a lot of project interest goes down the drain. This is why many novice experimenters invest in a commercially etched and drilled printed board usually made available with many projects.

Now, with just a little painting skill, a simple piece of homemade equipment, and a few easily available chemicals, you can fabricate a printed board that will look exactly like the one in the magazine in a very short time.

The heart of this process is a new photo-sensitive resist that comes in a pressurized aerosol can and is simply sprayed on a clean, cut-to-size copperclad board. Because this resist is sensitive to the ultra-violet portion of the spectrum it can be handled in subdued lighting, and it is not necessary to have a photographic darkroom. There are no critical temperatures to worry about.

Equipment Required. The basic chemicals were developed for industrial application by the Dynachem Corp., and you will need their photo resist (in a 16-oz aerosol can, $5), dye (also in a 16-oz aerosol can, $2.50), and developer (in a gallon can, $2.50). These are available from any Dynachem representative shown in the table. The basic kit will suffice for about 25 square feet of PC board—enough for quite a large number of circuits. Also available is a Photo Resist Trial Kit ($5) that includes reduced proportions of photo resist, dye, devel-

by Thomas R. Rosica

Sylvania Entertainment Products

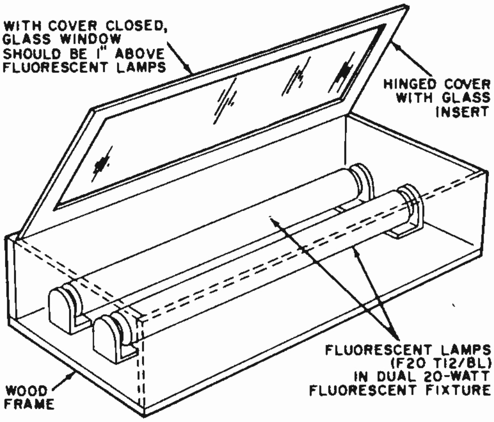


Fig. 1. Suggested printing frame houses the two UV fluorescent lamps and their associated circuitry.

oper, a developing tray, a test negative, three copper-clad boards, and a set of instructions.

You will also need a source rich in ultra-violet light to expose the photo resist. This source can be a high-intensity light source, a mercury-vapor lamp, or a pair of low-cost black-light fluorescent lamps (Sylvania F20 T12/BL) available at most electrical supply houses. A pair of these lamps, mounted side-by-side in a conventional two-lamp 20-watt fluorescent fixture, can properly expose a PC board in three minutes.

Although not essential, a printing frame can be built to simplify the procedure. This consists of a wooden frame housing the dual-lamp fixture, with a window-glass cover that can be set one-inch above the lamps. The basic arrangement is shown in Fig. 1. Otherwise, the negative and the treated PC board can be "sandwiched" between a pair of glass sheets held together with rubber bands.

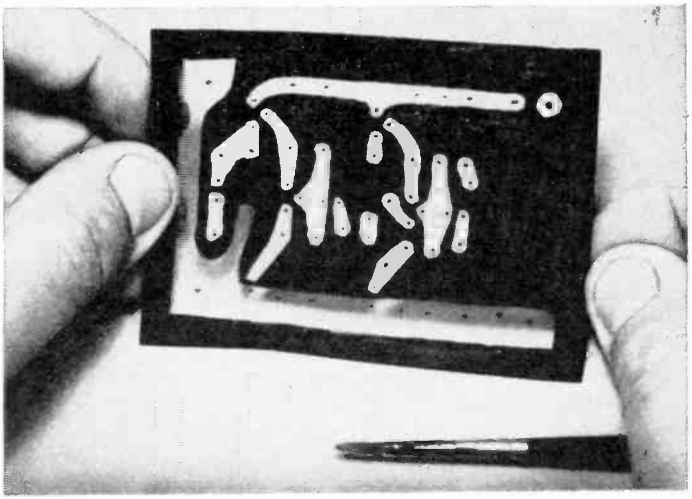
Preparing the Negative. To make a negative of the foil pattern as it appears in the magazine, you can either have a photographer make a negative (on a transparent background), or you can make your own negative using opaque paint on a sheet of thin clear acetate (available at all art stores). If you make your own negative, place the sheet of acetate over the foil pattern as it appears in the article; then using the opaque paint and a fine-pointed brush, carefully cover all the areas in which the copper has to be removed. Always remember, you are making a negative, so the parts to be left copper must be transparent, while the parts to be etched away must be opaque. Because the art work in the magazine is usually black, use a contrasting color of opaque paint for drawing clarity. Don't forget a tiny dot of color where holes will have to be drilled through the foil. A razor blade edge can be used to "clean up" any slight mistakes. India ink is not recommended, as it may bead on most plastics and may not produce a sufficiently opaque coating. A typical sequence is illustrated in Fig. 2. While the paint is drying, prepare the copper-clad board.

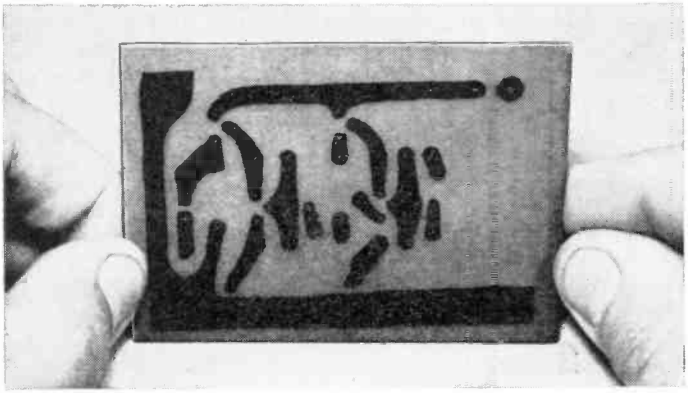
Preparing The Board. Cut the PC board so that the entire circuit, plus a small border, will fit within the area. Thoroughly clean the copper surface using a household abrasive (not a detergent, as the wetting agents in the detergent may form a film which might hinder further applications). You can use a piece of fine steel wool for the cleaning. Once the copper surface has been cleaned, let it dry and from then on handle the copper-clad board only by its edges to avoid contaminating the shiny copper surface with natural body oils. You can lay the cleaned board on a sheet of cardboard if you have to move it around.

The board can now be coated with the photo resist. This should be done in a semi-dark room illuminated by a 40-watt incandescent lamp at least eight feet away. A yellow bug lamp, or a photographic safe lamp is fine. Place a sheet of newspaper behind the board to prevent the aerosol spray from getting on any other surface. Shake the can of photo resist to stir the contents, then spray the copper surface of the board from a distance of 6 to 8 inches. The coating should be as uniform as possible. Try to avoid having any running droplets. After coating, keep the board away from any other light and allow it to dry to a tack-free consistency. To speed up the drying process, place the board in an oven set for 115°F for about 15 minutes. Then remove the board from the oven and allow it to cool. Keep the area reasonably dark during this process and don't allow any light to fall on the board. Remember that the board is now light sensitive.

Fig. 2. If you are making your own negative, the first step in preparing a PC board is to place a piece of transparent plastic over the foil pattern. Using opaque paint, fill in areas where copper is to be removed. When it is completed. . . .

. . . the plastic sheet will look like this. Don't forget to put a small dot of paint at each component mounting hole. Use the method described in the text to expose and dye the PC board. After etching is done. . . .





. . . the finished board will be an exact duplicate of the one in the magazine. The foil will be covered with black resist. Use steel wool to remove the dyed resist from the copper. Drill the required mounting holes and assemble components.

Determining Exposure Time. If a light source other than the F20 T12/BL fluorescent lamps is to be used, the required exposure time will have to be determined. To do this, take a small piece of scrap PC board and spray it with the photo resist. (Don't forget about the safe light!) Then take a spare piece of the transparent acetate, and using the opaque paint, make a small design (cross, circle, etc.) on it. After the board has dried completely, lay the design over it and expose the pair to the light source at some fixed, close distance, for 2 minutes. Then place the exposed board on the developer for about 30 seconds, remove, and spray it with the black dye. Allow the dye to remain for a few seconds, then wash the board in running cold water. This not only stops development, but enables you to see the condition of the pattern on the board in normal room light. At this point, the board is no longer light sensitive. The dyed pattern should be clean and true. If not, dip the board back into the developer and wipe it clean. Reclean and dry the board, go back to the safe light, and repeat the exposure process lengthening the exposure time by one minute, until you get a good, clean pattern of resist. In this way, you will be able to determine the optimum exposure time for the light source and distance you are using. Record the type of light source, distance between the light and the board, and the optimum exposure time required. This will be used whenever you make a printed circuit board using that light source.

Making The Board. With the light source turned off, lay the foil negative on the light-frame window. Remember that the magazine usually shows the foil as seen from the bottom of the PC board, so place the pattern with the painted side up. Place the sensitized surface of the board on top of the negative, aligning it as required. You can place a small weight on top of the board to make sure that the negative and board are lying in close proximity and are flat.

If you are using the fluorescents, turn them on for three minutes. If you are using some other light source, refer to the previously noted exposure time and distance and expose the required time.

DYNACHEM REPRESENTATIVES

Chem Etch Products
1781 Oakton Blvd.
Des Plaines, Ill. 60018

Chemical Etching Equip. & Supply Co.
7629 Crawford Court
Alexandria, Va. 22310

Cirplex Enterprise
524 W. Rosecrans
Gardena, Calif. 90247

Etchomatic, Inc.
151 Newton St.
Waltham, Me. 02154

E.J. Foley & Assoc.
3840 N. Jokake Dr.
Scottsdale, Ariz. 85251

Franklin Sales Co.
2149 S. Clermont
Denver, Colo. 80222

T.K. Gray, Inc.
1812 S. Sixth St.
Minneapolis, Minn. 55404

Hi Co. Associates
415 St. Andrews St.
Winter Park, Fla. 32790

Litho Supply Co.
1900 Vassar, N.E.
Albuquerque, N.M. 87106

Mercer Industrial Sales
U.S. Highway 206
Princeton, N.J. 08540

Photo Reproduction Materials
19166 Glendale Ave.
Detroit, Mich. 48223

Precision Industries
13410 Enterprise
Cleveland, Ohio 44135

Wolcott-Park, Inc.
1149 E. Ridge Road
Rochester, N.Y. 14621

Lew Wenzel & Company
520 S. Peoria
Tulsa, Okla. 74120

Lew Wenzel & Company
1700 Levee Street
Dallas, Texas 75207

Lew Wenzel & Company
712 W. Gray
Houston, Texas 70019

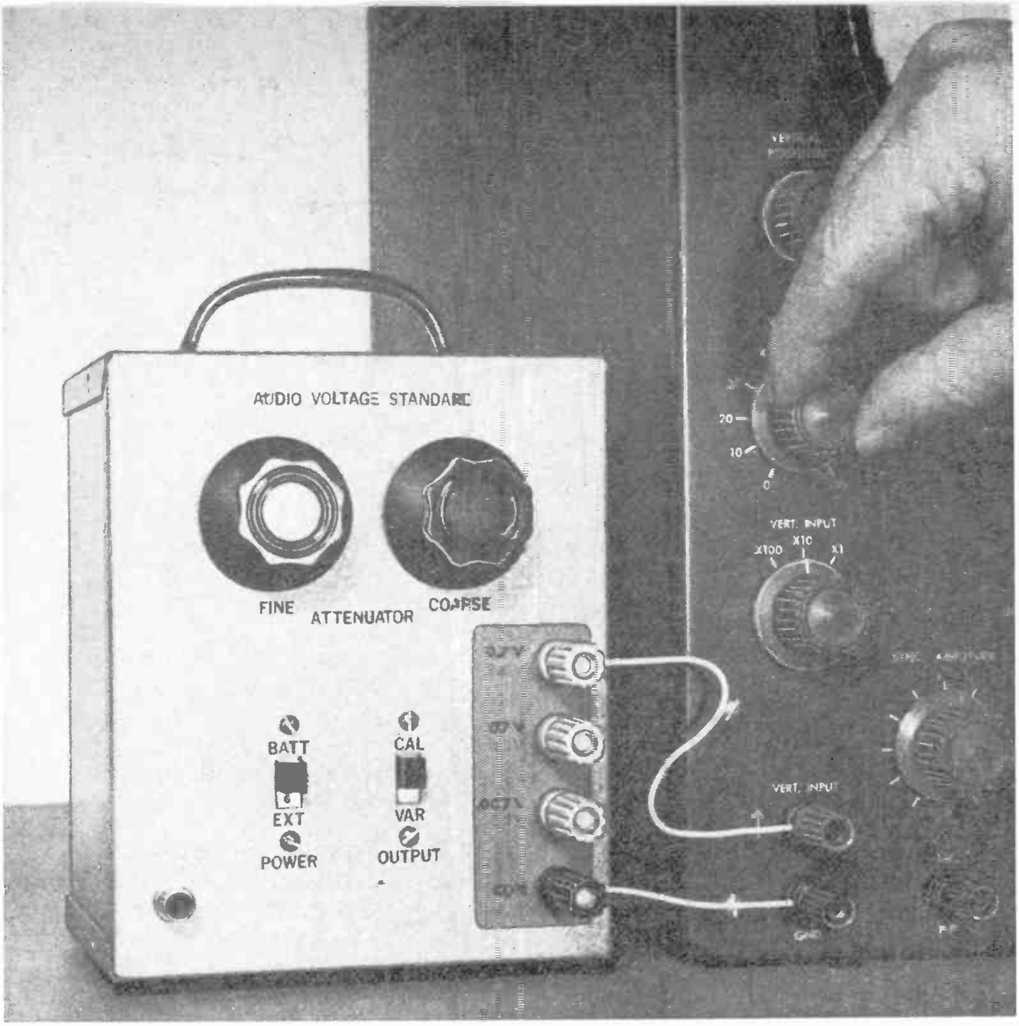
Imperial West Chemical Co.
1701 Wilbur Ave.
Antioch, Calif. 94509

After exposure, place the board in a metal or glass tray containing the developer, and allow it to stay there for about 30 seconds. DO NOT use a plastic tray, as the developer is a solvent for certain types of plastics.

After developing, remove the board from the developing tray and using the newspaper again as a backdrop, shake the aerosol can of dye, and spray the wet board. In 5 to 10 seconds, an image of the pattern will appear. At this point, rinse the board in cold water—preferably a water spray—for about half a minute or so. Shake the board clear of water and allow it to dry. DO NOT use a towel or any other cloth to dry the board at this stage, as the plastic forming the resist is soft and can be destroyed by the abrasive action.

Once dry, the board is ready for the etchant. Almost any etchant can be used as directed by its instructions. Incidentally, if you want to speed up the etching process, use a thin-walled plastic or glass tray to hold the required amount of etchant, and place this tray in a sink and run hot tap water around the tray. Lay

(*Continued on page* 154)



Precision Audio Voltage Standard

A LAB/WORKSHOP INSTRUMENT FOR ACCURATE MEASUREMENTS

BY FRANK H. TOOKER

ELECTRONIC measuring instruments are so sophisticated—versatility combined with style and ease of use—that we often take the instrument's accuracy for granted. An audio VTVM, for example, may have a claimed accuracy of ±5% and we might assume that this means it is accurate to 5% at any time. However, the VTVM can have a *total variation* of 10% and still be within the manufacturer's specifications! In other words, unless the calibration is checked frequently, and readjusted as necessary, ±5% can easily be 0 and −10% or 0 and +10%.

Of course VTVM's can be calibrated using their internal calibration circuits, but age and temperature affect such circuits and the calibration is sometimes not as accurate as might be desired.

As another example, many oscilloscopes don't even have built-in calibrators; and, of those that do, the line voltage may be used as the calibration

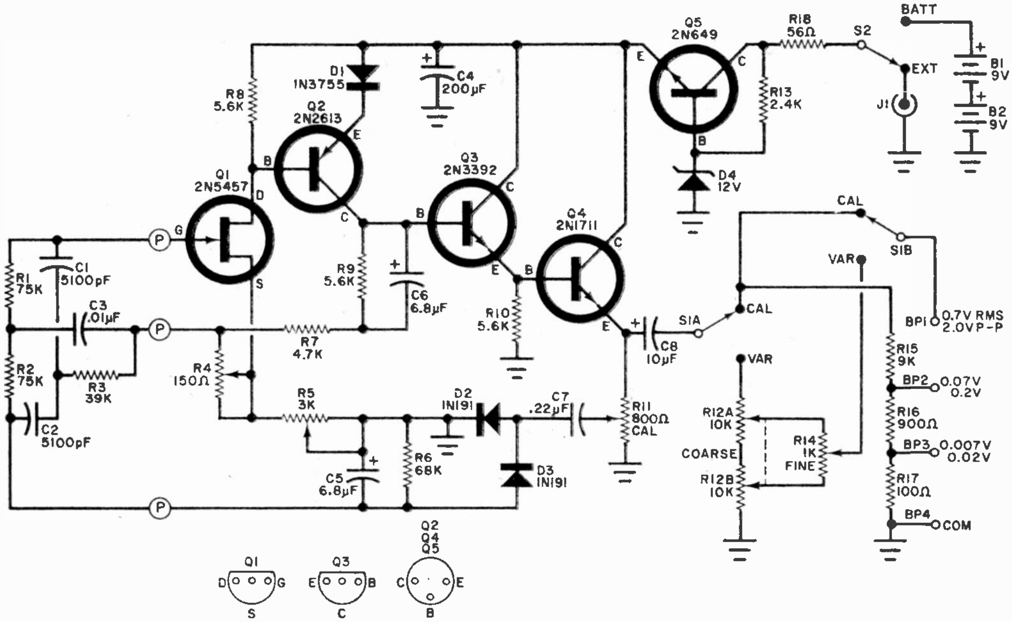


Fig. 1. The twin-T feedback oscillator incorporates both positive and negative feedback for stability and waveform purity. Frequency can be changed by replacing the twin-T filter.

PARTS LIST

B1, B2—9-volt alkaline transistor battery (Mallory MN1604B or similar)
BP1-BP3—5-way binding post, yellow (E. F. Johnson type 111-107 or similar)
BP4—5-way binding post, black (E. F. Johnson type 111-103 or similar)
C1, C2—5100-pF, 5%, polystyrene capacitor (Mallory type SX or similar)
C3—10,000-pF, 5%, polystyrene capacitor (Mallory type SX or similar)
C4—200-µF, 12-volt, miniature electrolytic capacitor
C5, C6—6.8-µF, 6-volt, polarized solid-tantalum capacitor (Sprague type 150D or similar)
C7—0.22-µF, 100-volt Mylar capacitor
C8—10-µF, 12-volt subminiature electrolytic capacitor
D1—1N3755 diode
D2, D3—1N191 diode
D4—12-volt, 1-watt zener diode
J1—RCA-type phono jack
Q1—2N5457 field-effect transistor
Q2—2N2613 transistor
Q3—2N3392 transistor
Q4—2N1711 transistor
Q5—2N649 transistor
*R1, R2—75,000-ohm**
*R3—39,000-ohm**
R4—150-ohm, miniature PC-type, wire-wound potentiometer (Clarostat type U-39 or similar)
R5—3000-ohm, miniature PC-type, wire-wound potentiometer (Mallory type MR3000P or similar)
*R6—68,000-ohm**
*R7—4700-ohm**
*R8-R10—5600-ohm**
R11—800-ohm, miniature PC-type, wire-wound potentiometer (Clarostat type U-39 or similar)
R12—Dual potentiometer, 10,000 ohms per section, molded composition, linear taper (Ohmite type CCU or similar)
*R13—2400-ohm**
R14—1000-ohm, molded-composition potentiometer, linear taper (Ohmite type CU or equal)
R15—9000-ohm, 1% precision resistor
R16—900-ohm, 1% precision resistor
R17—100-ohm, 1% precision resistor
R18—56-ohm, 10%, ½-watt resistor
S1—D.p.d.t. slide switch
S2—S.p.d.t. slide switch
1—6"x5"x4" aluminum cabinet
Misc.—Glass-epoxy PC board stock, L-brackets, ¼"-I.D. soft rubber grommets (3), short lengths of ¼"-diam. metal rod, dual battery clip, battery connectors (2), knobs, carrying handle, rubber feet (4), hardware, wire, solder, etc.
**These resistors are 2%, ½-watt (IRC Metal-Glaze type RG-20).*

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source. At best, the accuracy of this type of calibration is no more dependable than the accuracy of the power-line potential. Even a zener-controlled calibrator can be in error by as much as 20%, depending on the tolerance of the diode.

Thus, to obtain reliable use from instruments such as the audio VTVM or the oscilloscope, you need an accurate audio voltage calibration standard. Using such a standard, it is possible to tell immediately whether the instrument is reading high or low—and by how much. The instrument calibration can then be

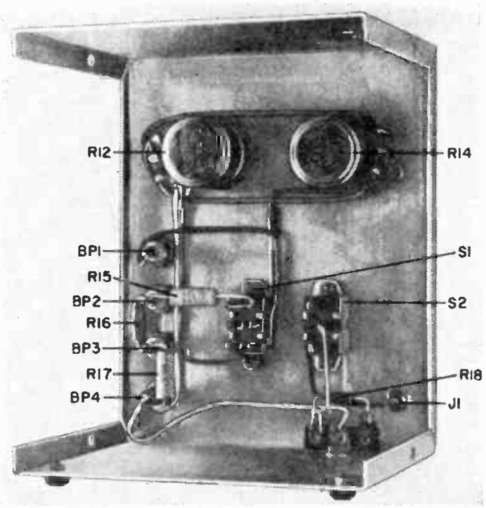


Fig. 2. Rear view of front panel showing component mounting. The four rubber feet are optional.

touched up to bring its accuracy up to that of the standard.

A commercial audio voltage standard can be quite expensive. The instrument described here, however, can be assembled for about $35.00. When properly calibrated, it has an accuracy of ±1% over a temperature range from 60° to 90°F. Negligible variation occurs in the output signal level when the supply voltage is varied between 12 and 20 volts d.c. Compensating for temperature and voltage variations accounts for much of the cost of commercial instruments.

Actually the standard shown in Fig. 1 can be used for three purposes. It is a precise audio voltage standard; it is a

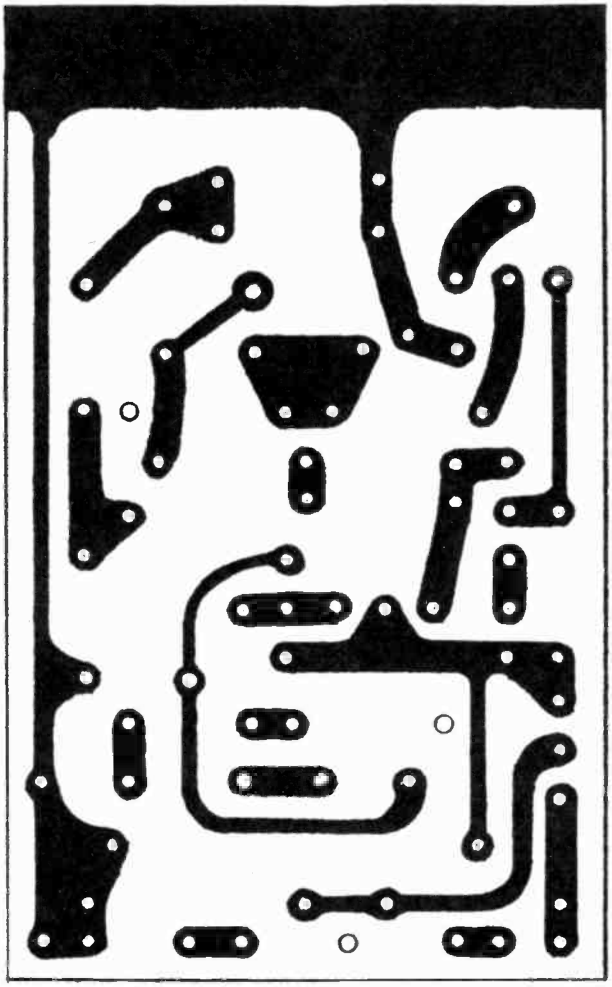
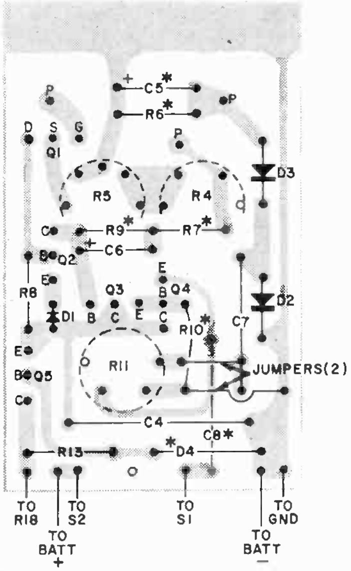


Fig. 3. Actual size foil pattern for the standard. Drill all holes including the three isolated plain circles.



*MOUNTED ON FOIL SIDE
P-MOUNTING HOLE FOR TWIN-T MODULE

Fig. 4. Note that some of the components are mounted on the foil side of the board to ease construction.

calibrator with accurate output levels of 0.7, 0.07, and 0.007 volts r.m.s.; and it is a 400-Hz audio signal generator with a clean, highly stable, sine-wave output of zero to 0.7 volts r.m.s., which is continuously variable and controlled by a double attenuator to provide both fine and coarse adjustments.

The seemingly odd value of 0.7 volts output is no accidental or arbitrary selection. Actually the figure is 0.707, the reciprocal of the square root of 2. Thus 0.7 volts r.m.s. is 2 volts peak-to-peak. The r.m.s. value is used in calibrating a VTVM; 2 volts peak-to-peak is used to calibrate the vertical deflection of an oscilloscope. Both values are marked next to the output binding posts on the calibrator.

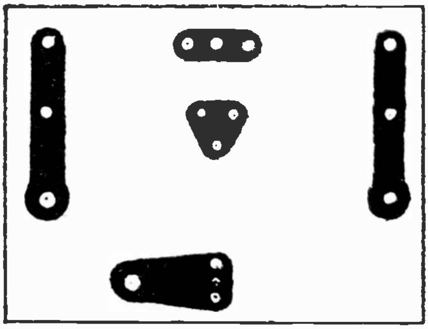


Fig. 5. Actual-size foil pattern for the twin-T PC board. A separate board is used so that, if it is desired to change frequency, you merely remove three screws and insert a new twin-T filter PC board.

Power consumption for the instrument, from two 9-volt alkaline batteries connected in series, is about 90 milliwatts.

Construction. The audio voltage standard is assembled in a 6″ × 5″ × 4″ metal enclosure, whose front-panel layout is shown in Fig. 2. The rest of the components are mounted on a pair of printed-circuit boards attached to the back of the front panel. Two circuit boards are used so that the twin-T frequency-determining network can be a separate, interchangeable unit. It is mounted on the main PC board using three ⅝″-high aluminum-alloy spacers and three 4-40 binder-head screws. Thus when it is desired to change the basic operating frequency of the standard, it is only necessary to replace the twin-T board.

The main PC board is prepared using the actual-size foil layout of Fig. 3. The preferred material for the board is glass epoxy. After the board has been fabricated, assemble the components as shown in Fig. 4. Note that *R6*, *R7*, *R9*, *R10*, *C5*, *C8*. and *D4* are mounted on the foil side.

The twin-T board can be prepared using the actual-size foil layout shown in Fig. 5. After etching, mount the components on the board (Fig. 6) noting that C3 is mounted on the foil side. When both boards are complete, attach the twin-T board to the main board. The assembled PC board should be mounted securely in the cabinet, but preferably *not rigidly*. In the prototype, a three-point flexible mounting was made by using soft rubber grommets, short length of ¼″-diameter rod (which fits the inner diameter of the rubber grommets snugly), flat washers, screws and nuts. Two of these assemblies were fitted to a 4¼″ L-bracket at the top of the cabinet, and one was centrally located attached to a 1⅛″ bracket at the bottom. (See Fig. 7.) The grommet hole in the lower bracket was elongated to permit a vertical play of about 1/16″. Details of the flexible board mount are shown in Fig. 8. The batteries are secured to the bottom of the chassis. The finished chassis is shown in Fig. 9.

Adjustment and Calibration. You will need a variable-voltage power supply capable of adjustment from zero (or near zero) to at least 18 volts d.c.; an oscilloscope; an accurate 400-Hz voltmeter standard; and a stable electronic audio voltmeter which can be calibrated against the voltmeter standard at 0.7 volt r.m.s. If you don't have a voltmeter standard, the audio voltage standard may be calibrated as accurately as available means

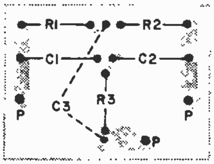


Fig. 6. Capacitor C3 is mounted on the foil side of the twin-T PC board. The three holes marked "P" mate with similar holes on the main circuit board.

HOW IT WORKS

The standard consists of an audio oscillator *(Q1* and *Q2)*, a buffer current amplifier *(Q3)*, and an output current amplifier *(Q4)*. To control the operating level, a portion of the output signal is rectified in a voltage-doubler circuit *(D2* and *D3)*, filtered, and applied as reverse bias to the gate of *Q1*. This type of circuit is similar to the a.v.c. used in a radio receiver and, in this case, will hold the output voltage level extremely close to its calibrated setting.

Operating frequency is determined by a twin-T network *(R1, R2, R3, C1, C2,* and *C3)*. Both positive (through *R4)* and negative (through *R5)* feedback are used to obtain stability and waveform purity (minimum harmonic content). Although the twin-T network described is designed for 400 Hz, any other frequency may be used.

The frequency stability of the circuit is excellent—on the order of ±0.5% at 400 Hz. To make the circuit independent of power supply variations, a supply regulator is used. Because the circuit consumes only 90 milliwatts, internal batteries are used, but provisions have been made for the use of any external power supply that can deliver regulated 18-volt d.c.

permit and can be depended on to hold this calibration for reference and comparison, even though its output may not be precisely 0.7 volt r.m.s.

The first step is to set the negative feedback control *R5* so that oscillation begins when the d.c. power-supply level is at 10.5 volts. To do this, first set OUTPUT switch *S1* at CAL, and POWER switch *S2* at EXT. On the main PC board, set potentiometer *R4* at maximum resistance and potentiometers *R5* and *R11* at midposition.

Connect the oscilloscope to the 0.7 V and COM output binding posts. Connect the variable-voltage d.c. power supply to J1 (lower left corner of the front panel). Set the power supply for zero output voltage and turn it on.

Advance the output control of the d.c. power supply *slowly* while observing the oscilloscope screen. Stop as soon as oscillation shows on the oscilloscope and note the output level of the power supply. If it is below 10.5 volts, *R5* should be advanced slightly; if it is above 10.5 volts, *R5* should be set for lower resistance. Set the power supply back to zero output, adjust *R5* as necessary, and make the check over again. Continue this process until oscillation begins at exactly 10.5 volts of power supply. Once oscillation begins, it will continue until the power supply has been reduced to 8 volts or

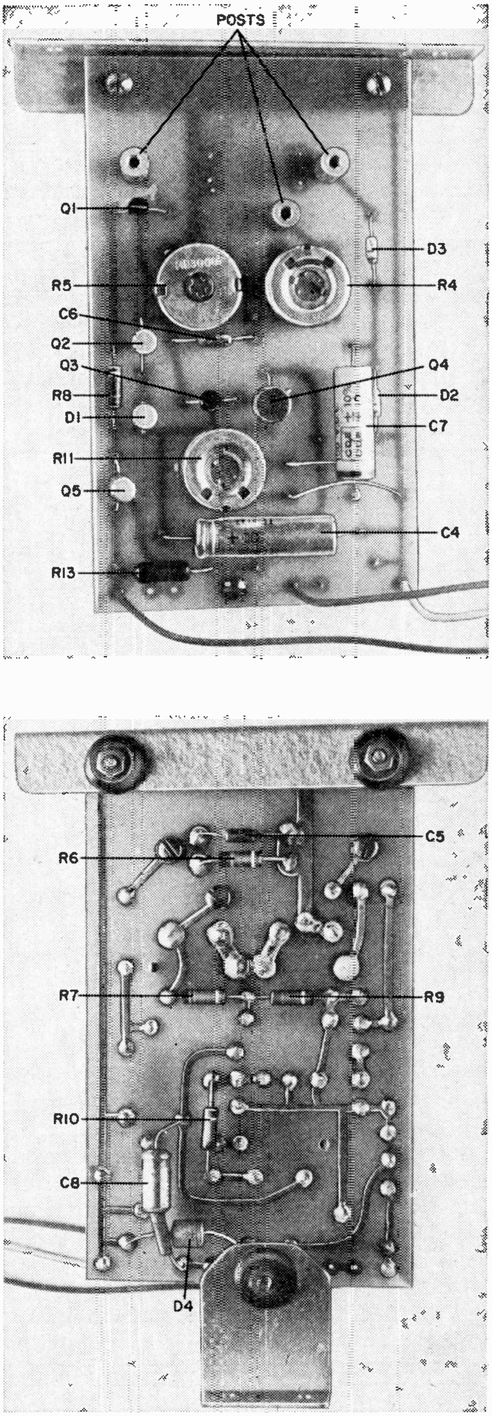


Fig. 7. Component location on the main PC board. The lower view also shows the method of installing the two flexible mountings. Use of these mountings reduces the possibility of instrument vibration which affects the stability of the oscillator.

less. Thus, *R5* should not be adjusted while the oscillator is operating. Set the power supply back to zero each time, and wait a few moments for the electrolytic capacitors to discharge.

When *R5* is properly adjusted, run the power supply up to about 18 volts d.c. Connect the electronic audio voltmeter across the oscilloscope connection and adjust potentiometer *R11* to give an output signal level of 0.7 volt r.m.s. Observe the waveform on the oscilloscope screen. It should be a clean, highly stable sine wave with a frequency close to 400 Hz. If there is any distortion, it should be slight, and it should be on the negative-going excursions of the waveform. A small adjustment of the positive feedback potentiometer, *R4*, should clean up the distortion. If *R4* is adjusted, *R11* must be reset to bring the signal level back to a 0.7-volt output. It is desirable that both *R4* and *R11* be set as high as possible (consistent with an acceptably clean waveform) to maintain the accuracy of the output.

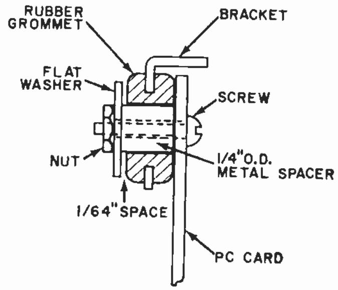


Fig. 8. Details of the flexible mounting. Rubber grommet is fitted in a hole in the L-bracket.

When the output is at precisely 0.7 volt r.m.s., the calibration is complete and the instrument is ready for use.

Use. To use the instrument as an audio voltage standard or r.m.s. calibrator, set switch *S1* at CAL. Outputs of 0.7, 0.07, and 0.007 volt are then available between the respective binding posts and common. To use the instrument as a 400-Hz signal generator, set *S1* at VAR. Continuously variable output between zero and 0.7 volt is then available at the 0.7 V binding post. With this setting of *S1*, the binding posts for 0.07 and 0.007 volt are dead. The FINE ATTENUATOR control, *R14*, permits a variation of about 60 millivolts at any setting of the COARSE ATTENUATOR control, *R12*.

Output Loading. In general, voltage standards such as that described here, are not intended to deliver power. Since the input impedance of the average audio VTVM or oscilloscope is on the order of a megohm or two, loading of the precision audio voltage standard in the course of calibration is of no consequence. However, should it be desired at any time to use the standard for some other purpose, a resistive load as low as 10,000 ohms connected between the 0.7 V and COM binding posts, with switch *S1* in either CAL or VAR, produces negligible variation in accuracy. Heavier loading, however, will cause clipping of the negative excursions of the output waveform. -30-

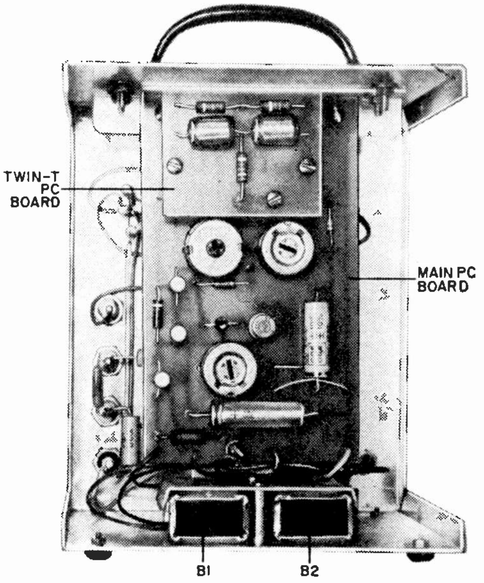


Fig. 9. Rear view of completed instrument. The two batteries are secured with an aluminum strip.

Build NOISE BLANKER

Impulse noise suppressor can be added to any SWL, Ham or CB receiver

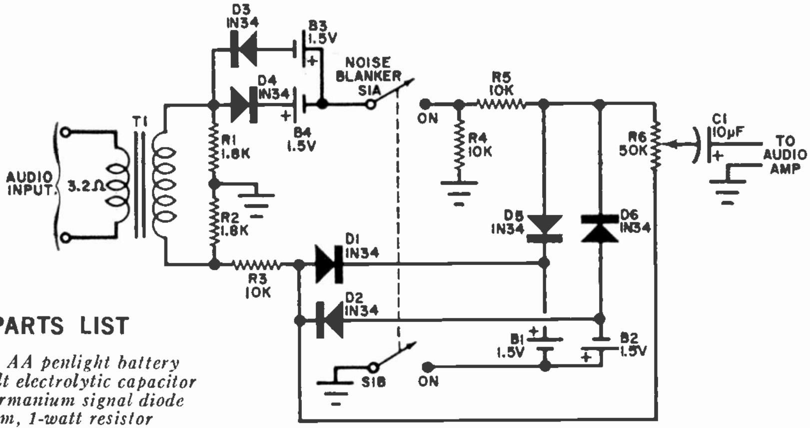
BY A. E. McGEE, Jr., K5LLI

AUTOMOBILE-IGNITION and electrical-impulse noise is a serious problem for the ham station operator or SWL who lives near a busy street. Most commercial receivers have noise clipping provisions, but the circuit used is not effective for SSB or CW operation. Some receivers have no noise limiter of any kind. If your receiver is deficient in this respect and if you are bothered by ignition noise or other noise created by electrical impulses, the "Audio Noise Blanker" is what you need.

The noise blanker works equally well with SSB, AM, and CW signals. It accepts a signal that is nearly indistinguishable because of impulse noise and makes it 90% readable. It is not necessary to modify your receiver; the noise blanker is connected between the low-impedance output of the receiver (3.2 to 16 ohms) and the speaker. The noise blanker itself requires no external power supply. A good quality audio amplifier used to raise the low-level output of the blanker to a comfortable speaker level does require a power supply.

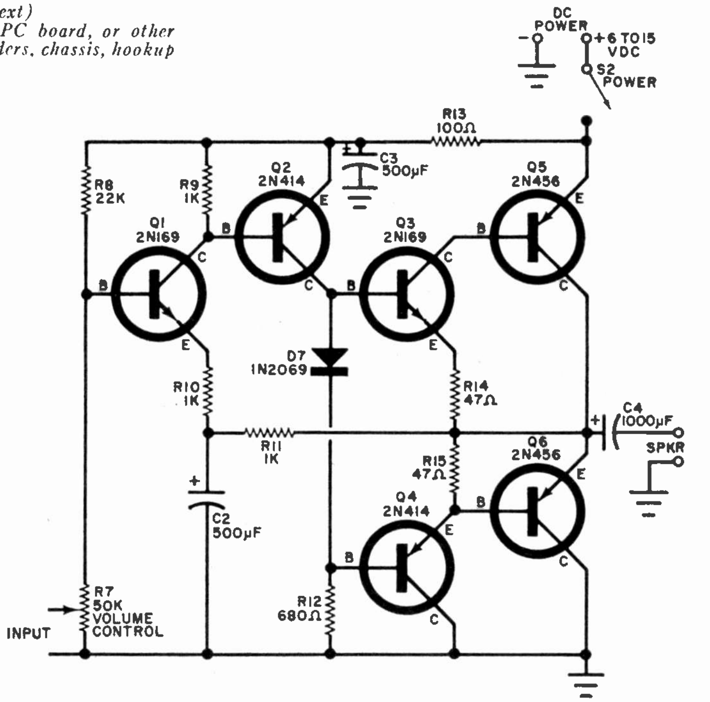
Construction. The circuit of the noise blanker is shown in Fig. 1. It can be assembled on a printed circuit board, on perf board, or with point-to-point wiring on multi-tab standoffs. The author's version, shown in Fig. 2, uses perf board. (Most of the board is taken up by the audio amplifier, which will not be described here since any type of circuit can be used. Even the compact audio modules available at low cost from any electronics distributor will do. Remember, however, that you must supply power for this audio amplifier.)

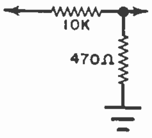
Transformer *T1* is a 50L6 audio output transformer, but any other type can be used if it has a low-impedance speaker winding and a 2000- to 5000-ohm pri-



PARTS LIST

B1-B4—1½-volt, AA penlight battery
C1—10μF, 15-volt electrolytic capacitor
D1-D6—1N34 germanium signal diode
R1, R2—1800-ohm, 1-watt resistor
R3, R4, R5—10,000-ohm, ½-watt resistor
R6—50,000-ohm miniature potentiometer
S1—D.p.s.t. switch
T1—50L6 transformer (see text)
Misc.—Suitable perf board, PC board, or other wiring method, battery holders, chassis, hookup wire, etc.





PARTS LIST

C2, C3—500-μF, 15-volt electrolytic capacitor
C4—1000-μF, 15-volt electrolytic capacitor
D7—1N2069 silicon rectifier diode
Q1, Q3—2N169 transistor
Q2, Q4—2N414 transistor
Q5, Q6—2N456 transistor
R7—50,000-ohm potentiometer
R8—22,000-ohm
R9, R10, R11—1000-ohm
R12—680-ohm
R13—100-ohm
R14, R15—47-ohm
S2—S.p.s.t. switch

All resistors ½-watt

Fig. 1. Diode circuits in the noise blanker (top) clip the audio input to eliminate noise represented by spikes. Clean signal is then amplified in the audio amplifier (bottom). The amplifier should be of good quality with low inherent distortion. Also if the Blanker overloads the amplifier, insert the simple attenuator shown in the separate drawing at left.

mary winding. Diodes *D1* through *D6* can be any general-purpose, germanium, signal units—such as 1N34. Be sure to observe the polarities on the diodes, and, when soldering, use a heat sink on the leads.

Adjustment. Balance potentiometer *R6* can be adjusted by ear, or, for more exact results, with an oscilloscope. Connect the low-impedance output of the receiver speaker to the blanker input (see Fig. 3) and connect the blanker output to the audio amplifier. Turn on the receiver and the amplifier and place noise-blanker switch *S1* in the OFF position. Set the receiver volume control to its normal position and turn the audio amplifier gain up so that you can hear a signal. Adjust the Noise Blanker amplifier gain to a comfortable listening level and turn *S1* ON. Turn up the receiver volume control until the speaker output is very distorted. Adjust balance control *R6* until the audio output is at a minimum. This will be close to the mid-position of *R6*. Once

HOW IT WORKS

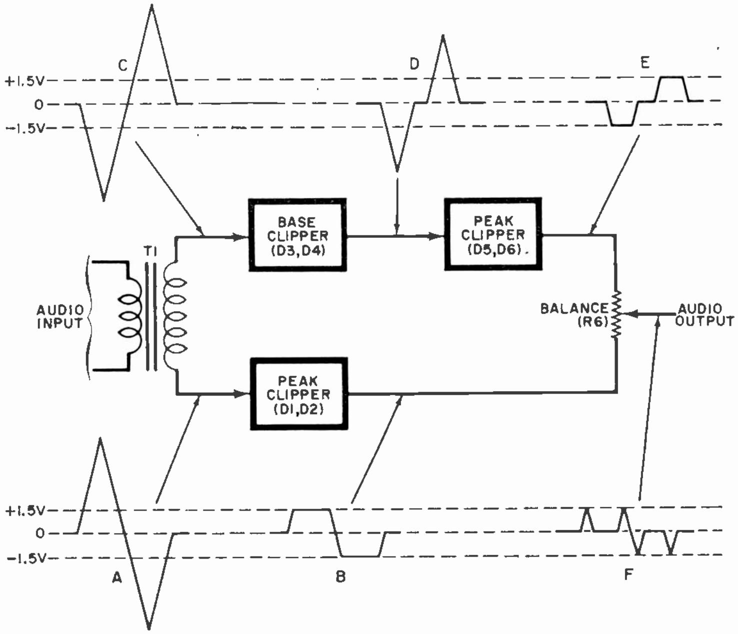
Assume that a high-level noise pulse, whose amplitude greatly exceeds the blanking level, enters the system. After passing through transformer *T1*, where it is split into two identical signals 180° out-of-phase with each other, the signal takes two different paths as shown in the diagram.

In the lower path, the signal (waveform A) passes through a peak clipper consisting of diodes *D1* and *D2* which are connected in opposite polarity and are in parallel with the signal path and ground. When the noise-pulse amplitude reaches the voltage level equal to the reverse bias on the diodes, both diodes conduct and shunt everything above this level to ground. The truncated signal (waveform B) is then passed to balance potentiometer *R6*. This type of circuit is called a peak clipper, and similar circuits are found in many receivers.

The other input signal, waveform C, is fed to a base clipper consisting of a pair of diodes, *D3* and *D4*, connected in opposite polarity and in series with the signal path. The arrangement does not allow the signal to pass until its amplitude exceeds the blanking level. The portion of the signal that exceeds the level (waveform D) is passed to a peak clipper consisting of reverse-biased diodes *D5* and *D6* which are connected in opposite polarity between signal and ground. Operation is the same as in the *D1, D2* peak clipper.

The two clipped output signals, waveforms B and E, are applied to opposite ends of balance potentiometer *R6*. If the rotor of this potentiometer is adjusted to receive signals of equal amplitude, the composite signal appearing as the audio output then looks like waveform F. Note that this signal contains far less power than the original input waveform, and even less power than a peak-clipped waveform.

The result is that, regardless of how great the noise is compared with the desired signal, any noise pulse that exceeds the blanking level will not only be greatly reduced, but will in fact have an audio power less than that of the desired signal. Thus the noise can hardly be heard.



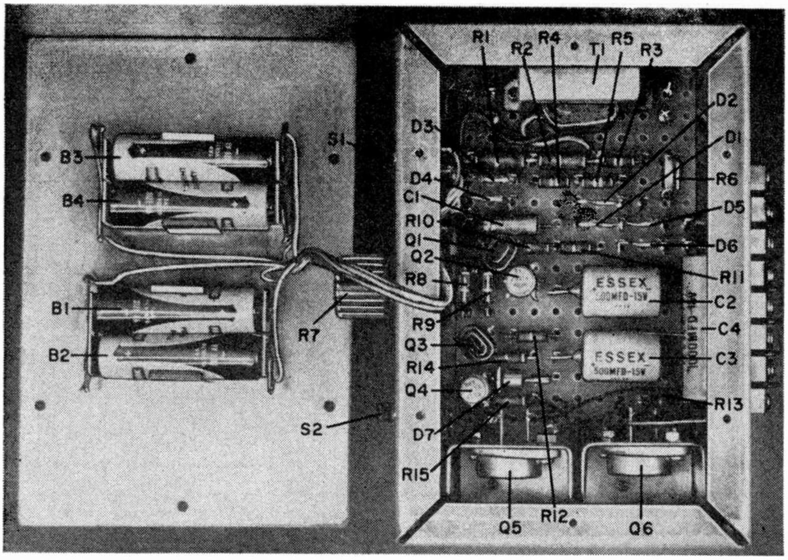
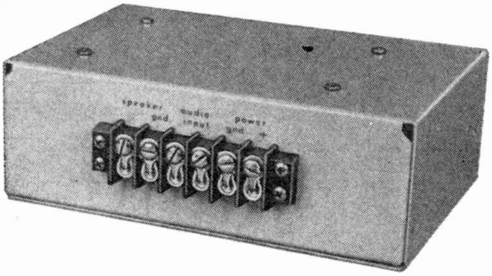


Fig. 2. In layout used by the author, much of the circuit is part of the audio amplifier. If a separate amplifier module is used, the blanker assembly is made smaller. Arrangement of components is not critical. The four batteries are for the noise blanker only. The amplifier requires a separate battery or a power-supply unit.



Connections to the circuit are made through a six-terminal barrier strip.

R6 is adjusted, it will remain correct for a long period of time unless components age or are replaced.

Fig. 3. The noise blanker connects between the receiver loudspeaker output and external audio amplifier.

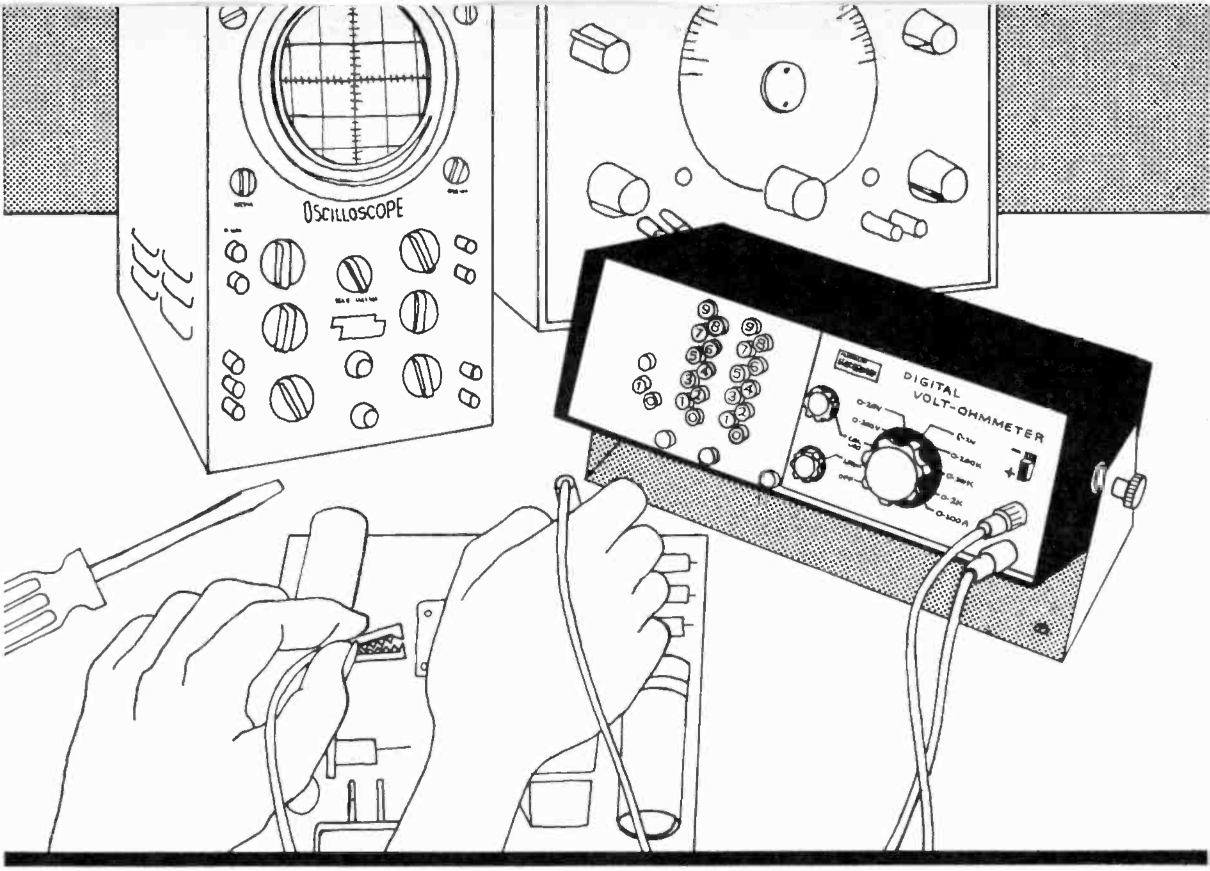
Operation. Tune in a signal, set the external audio amplifier gain for a comfortable listening level, and advance the receiver volume control until some audio distortion is noticed. At this point, back off the receiver volume control slightly until the audio is clear. This means that the noise blanker is operating properly; the receiver volume control is now the blanking-level control, and the audio output level is controlled by the gain control on the Noise Blanker amplifier.

When you tune in very weak or very strong signals, the receiver volume control may need to be readjusted, depending on the effectiveness of the receiver a.g.c. system. If the receiver volume control is set too low, the noise blanker will not be as effective as desired; if the receiver audio control is too high, the desired audio will be distorted.

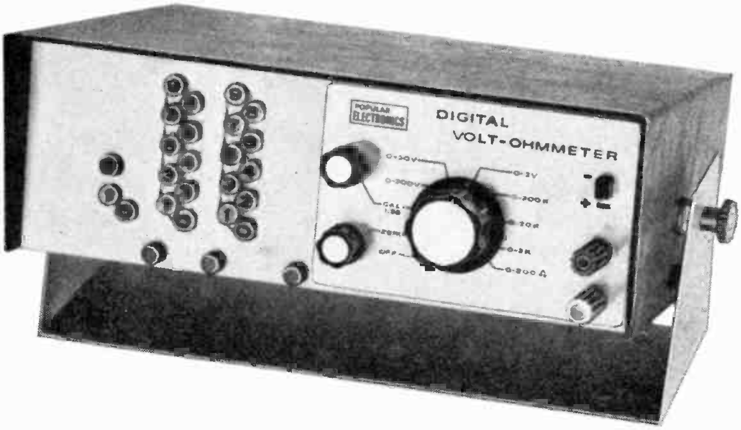
The noise blanker does not begin to work until the amplitude of the impulse noise is greater than that of the signal; it works best when the noise amplitude is several times that of the signal. Therefore, it is important that the noise pulse not be limited or suppressed by the receiver. In some cases, turning off the receiver a.g.c. may improve the noise suppression characteristics of the system.

The noise blanker has been used very successfully with a mobile SW receiver in an automobile having no ignition-noise suppression. In this case, reception without the blanker was nearly impossible unless the signal was exceptionally strong. With the blanker, even the weakest signals are not bothered by the ignition noise.

Batteries *B1* through *B4* will last approximately as long as their shelf life since the current drawn by the reverse-biased diodes is only a few micro-amperes. Fresh batteries will last about a year before showing signs of leakage—an indication that they must be replaced.–30–



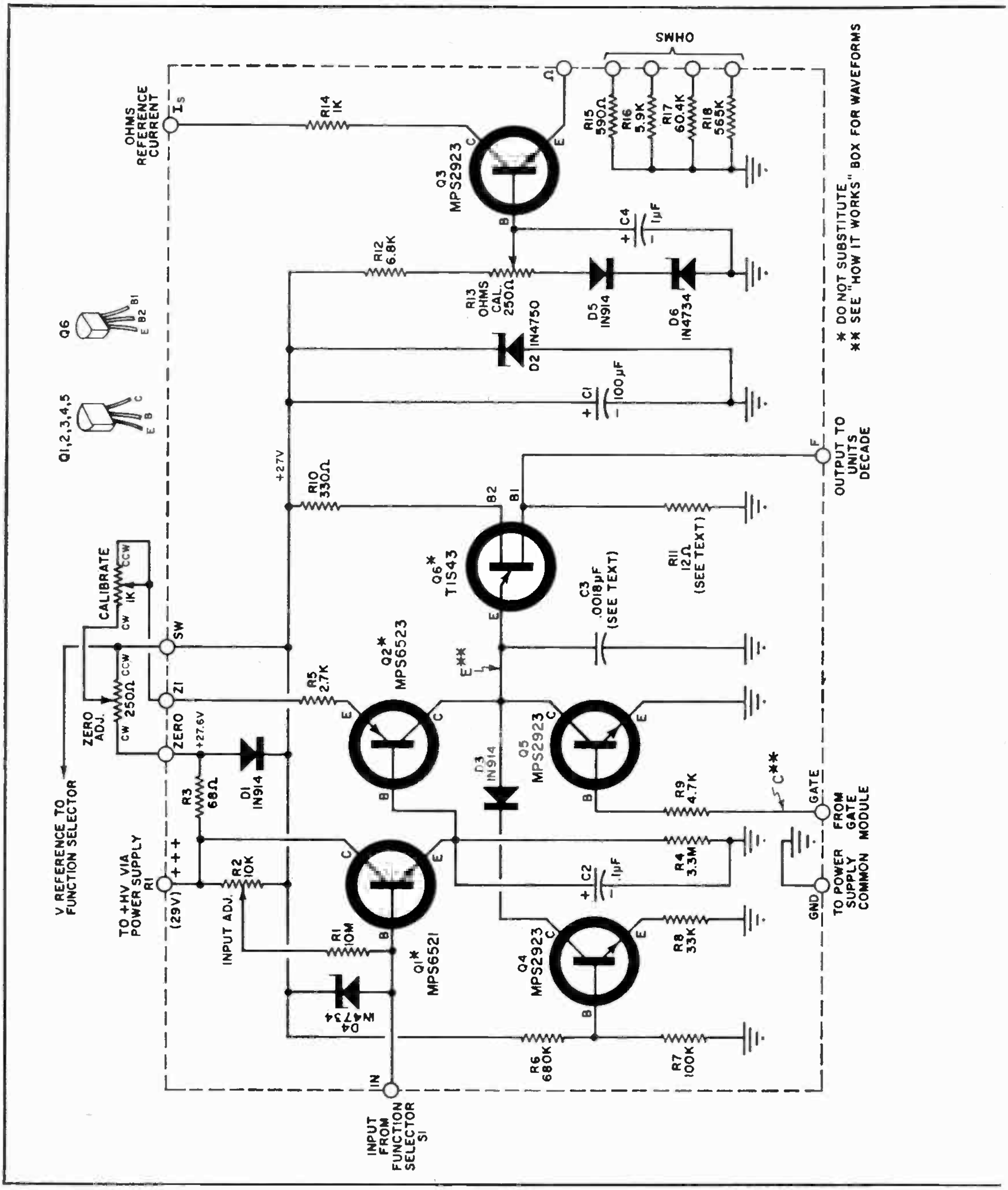
Build the Popular Electronics Digital Volt-Ohmmeter



BY DON LANCASTER

For less than the price of many transistor multimeters, you can now build your own real digital volt-ohmmeter. Gone forever will be your days of having wobbly meter pointers, reading the wrong scales, or trying to read accurately from a cramped and highly nonlinear ohms scale. There will be no more problems caused by VOM circuit loading or bent or broken pointers resulting from circuit overload.

You can just clip the DVM to your circuit and read volts or ohms as they brightly and unquestionably pop up on the front panel of the instrument. Just clip and read—instantly! It's that simple.



This DVM is no slouch on performance either. It has better than ±1 percent accuracy over most portions of the seven available scales. It is self-zeroing and automatically self-calibrating. Three voltage scales, 0-2, 0-20, and 0-200 volts are provided, each at reasonably high impedances—in fact, you can read down to 10 millivolts with ease. Four ohmmeter scales, useful from one ohm to over 200,000 ohms, are also available. If you like, you can easily add extra outside circuits to measure digitally anything you can convert into a 0-2-volt d.c. signal, including a.c. voltage and current, d.c. current, speed, and temperature.

Like its far more expensive brothers, this DVM is a multiple-slope integrating device. This means it averages the input signal over a relatively long measuring time. It's done in a way that automatically rejects all a.c. line-induced hum and noise and also eliminates practically all other high-frequency noise that may be present. The instrument is essentially "blind" to 60-Hz hum and only measures the d.c. component of the input, even if hum or noise is present. All this is done automatically—all you do is watch a continuous output display that updates its readings fifteen times a second.

While not a beginner's project, the extensive use of integrated circuits makes the construction of the DVM relatively straightforward and easy on a module-by-module basis. A complete kit is available as well as individual circuit boards, dialplates, and individual module kits. If you'd rather build things on your own, all parts are obtainable on the market, and complete preparation details of all the circuit boards are given here. Either way, when you're done, you'll have a real DVM—at a fraction of the cost of commercial equivalents and with performance untouched by anything analog.

V/F MODULE PARTS LIST

C1—100-µF, 25-volt electrolytic capacitor
C2—0.1-µF, 35-volt Mylar or tantalum capacitor
C3—0.0018-µF, 50-volt Mylar or polystyrene capacitor (see text)
C4—1-µF electrolytic capacitor
D1, D3, D5—1N914 silicon computer diode or equivalent
D2—1N4750 1-watt, 27-volt zener diode
D4, D6—1N4734 1-watt, 5.6-volt zener diode (do not substitute D4, as leakage is critical)
Q1—Transistor (Motorola MPS6521, do not substitute)
Q2—Transistor (Motorola MPS6523, do not substitute)
Q3-Q5—Transistor (Motorola MPS2923)
Q6—Unijunction transistor (Texas Instruments TIS43, do not substitute)
R1—10-megohm
R3—68-ohm
R4—3.3-megohm
R5—2700-ohm
R6—680,000-ohm
R7—100,000-ohm
R8—33,000-ohm
R9—4700-ohm *all resistors*
R10—330-ohm *¼-watt*
R11—12-ohm
R12—6800-ohm
R14—1000-ohm
R15—590-ohm
R16—5900-ohm *1% precision*
R17—60,400-ohm
R18—565,000-ohm
R2—10,000-ohm trimmer potentiometer (CTS type U-201 or similar)
R13—250-ohm trimmer potentiometer (CTS type U201 or similar)
Misc.—3" x 3-¼" PC board, PC terminals or eyelets (14) (optional), aluminum mounting bracket (see Fig. 11) with hardware, solder.
Note:—The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216: etched and drilled printed circuit board, #155V, $3.25; complete kit of all above required parts, #CV-155, $16 postpaid in USA.

Construction. The project has been broken down into five modules plus the case and some panel components. Module 1 is the voltage-to-frequency (V/F) converter. Modules 2 and 3 are decimal counting units (DCU's) described in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK.

Module 4 is the gate circuit, which simultaneously provides the 0, 1, and overrange counting needed to complete the digital display. Module 5 is the power supply.*

It is best to construct each module separately following the details very carefully. Each module has its own parts list and schematic. If you prefer to purchase circuit boards or partial kits, details are given in the parts lists.

Voltage/Frequency Converter. This circuit, shown in Fig. 1, is the "heart" of the DVM and converts the input d.c.

**Important: The circuits labeled GND throughout this project are not actually ground connections and should not be connected to the metal case. They are common connections constituting an individual circuit and grounding them to the case may produce circulating currents which interfere with the operation of the meter. The metal case should be either left floating or connected to the SW terminal on the V/F module. This is one side of the input signal and is actually the reference point for the system.*

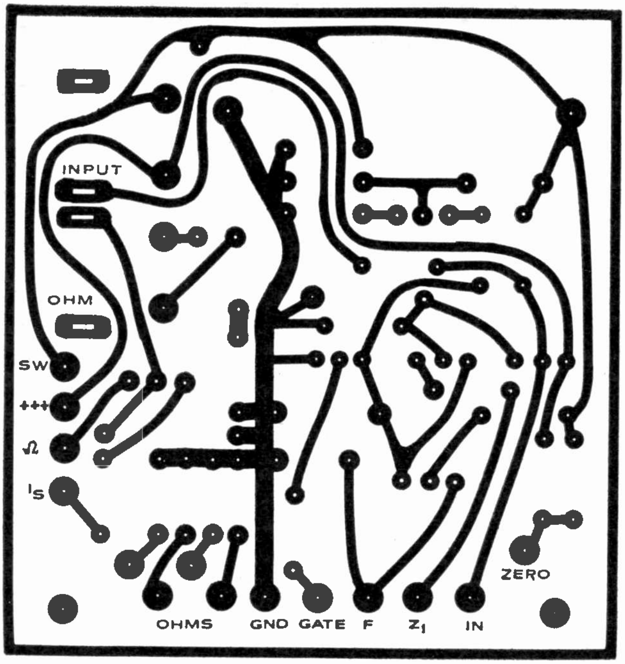
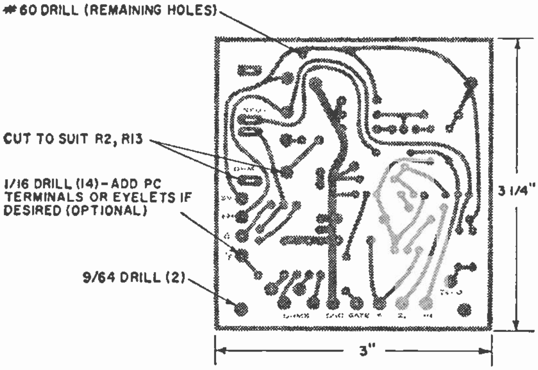


Fig. 2. If you make your own V/F converter-ohmmeter current reference PC board, carefully copy this actual-size etching guide.

Fig. 3. Place etched and cleaned board foil-side up on a block of scrap wood, carefully locate and mark hole centers, and drill all the way through from foil side.



ONE REQ'D - MAKE FROM 1/16" SINGLE-SIDED FIBERGLASS PC MATERIAL

signal to a series of pulses that are counted by the DCU's.

You can purchase the printed-circuit board for this module or you can make one using the actual-size layout shown in Fig. 2 and following the drilling details of Fig. 3. File or multiple-drill the slots required for the two trimming potentiometers (*R2* and *R13*). If you wish, you can add optional terminals or eyelets to make wiring easier.

Components are installed on the board as shown in Fig. 4. Be sure to install all semiconductors properly and double-check electrolytic capacitor polarities. Be especially careful not to interchange *R2* with *R13*.

Gate Module. This is actually the control center of the DVM. The start and stop signals for the V/F converter and the reset signals for the various counting circuits are generated in this module. The schematic for this module is shown in Fig. 5.

A printed-circuit board is suggested for this module. You can purchase one (see Parts List for Fig. 5), or you can etch and drill your own following the actual-size layout shown in Fig. 6 and the drilling information shown in Fig. 7. Don't forget to install the two jumpers on the component side of the board as shown in Fig 7. Do not use a drill larger than #67 for the IC mounting holes. Optional eyelets or PC terminals can be added where indicated.

Mount the components as shown in Fig. 8. Use a low-wattage soldering iron and fine solder when mounting the IC's. The rectangular IC's are identified by a notch and dot at one end, while the round IC's have either a flat or a dot at pin 8.

Power Supply. The power supply is not assembled on a PC board, but is wired point-to-point at one end of the chassis. The schematic is shown in Fig. 9. A conventional tube-type transformer is used. The 250-volt, center-tapped secondary has two functions. It provides the 125-volt a.c. reference, and its output is

HOW IT WORKS

V/F CONVERTER

The block diagram for this module appears here while the complete schematic is shown in Fig. 1. The waveforms are keyed to test points shown on the diagrams.

The 0-2-volt input from the function selector is subtracted from a +27-volt supply generated by the power supply module and regulated by zener diode *D2*. Thus the input voltage at the V/F converter actually varies from +27 to +25 volts as the instrument input goes from 0 to +2 volts. *Note that all input signals are referenced to +27 volts and not to the power supply common (GND).*

Diode *D4* provides reverse polarity and overload protection for the circuit. Transistor *Q1* is an emitter follower that provides a high input impedance. Transistor *Q2* is a complementary emitter follower that bucks out the offset produced by *Q1* and causes a voltage identical to the input voltage to appear across *R5* and the front-panel CAL 1.35 control. The current through these resistors can be set for a constant input voltage by adjusting the CAL 1.35 control. Practically the same current appears at *Q2*'s collector as flows through *R5* and the CAL 1.35 control. Transistor *Q2*'s output current is then proportional to the original input voltage. Transistor *Q2*'s output current drives a conventional unijunction sawtooth oscillator consisting of UJT *Q6* and integrating capacitor *C3*. A series of pulses at *B1* of *Q2* changes in *frequency* as the input voltage changes in *amplitude*. These output pulses are sent to the 0-199 digital counter and display modules.

The UJT oscillator is turned on and off by gating transistor *Q5*. This transistor is driven by the Gate module and allows the oscillator to run for 16.7 milliseconds and then shorts it out for the next 50 milliseconds and keeps this up continuously, recycling 15 times a second. The frequency produced by the oscillator is determined by the input voltage. The time this frequency is produced is determined only by the Gate module and *Q5*. As a result, the oscillator generates 0 to 199 pulses for a 0-1.99-volt input signal, once each measurement interval. This is how the digital display appears to be reading the actual value of the input signal.

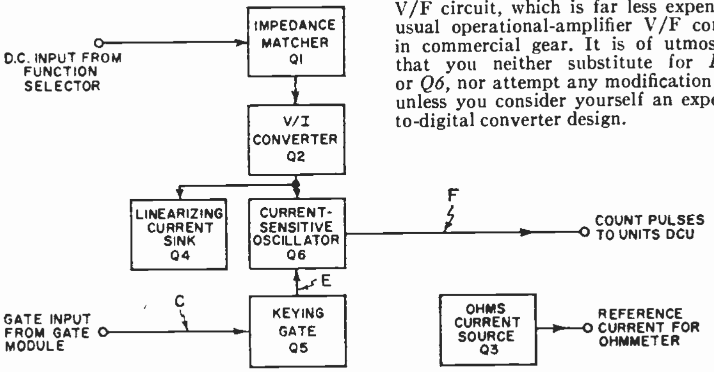
There would be a slight linearity problem if the current on *Q2* were allowed to go down to zero. Thus a little more emitter voltage (about 0.3 volts) is added by the front-panel ZERO potentiometer and a correspondingly constant amount of collector current (about 100 microamperes) is removed all the time. This shifts the operating point of *Q2* to a more linear region but still lets 0-2 volts of input produce 0-200 pulses per 16.7 milliseconds at the output.

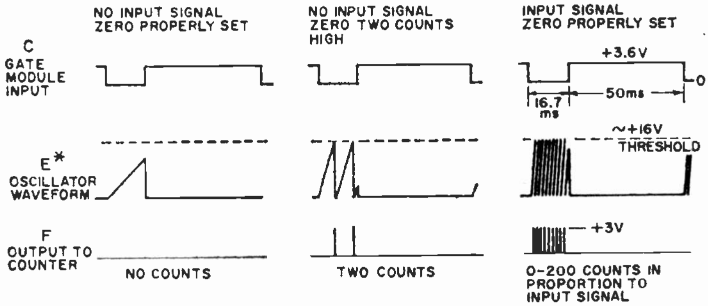
The extra 100 microamperes of current is "dumped" into the collector of *Q5*, which is biased to act as a current sink.

The current source for the ohmmeter is also on the V/F board, but it is a completely separate circuit. The collector current of transistor *Q3* is either 0.01, 0.1, 1, or 10 milliamperes, depending on the resistor selected for its emitter circuit (*R15*, *R16*, *R17*, or *R18*). These resistors are not quite decade multiples of each other, because they compensate for slight circuit nonlinearities.

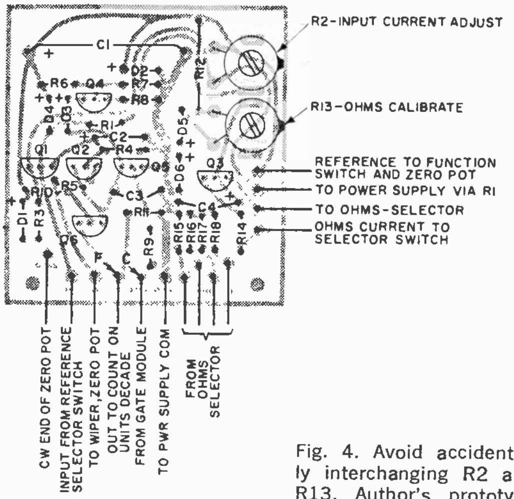
Base current for *Q3* is regulated by *D6*, temperature-compensated by *D5*, and adjusted over a limited range by *R13*. Resistor *R14* prevents oscillation but otherwise does not affect the output current.

Many hours of design went into this particular V/F circuit, which is far less expensive than the usual operational-amplifier V/F converters used in commercial gear. It is of utmost importance that you neither substitute for *D4*, *Q1*, *Q2*, or *Q6*, nor attempt any modification of the circuit unless you consider yourself an expert in analog-to-digital converter design.





* CAN BE MEASURED ONLY WITH 10M SCOPE PROBE



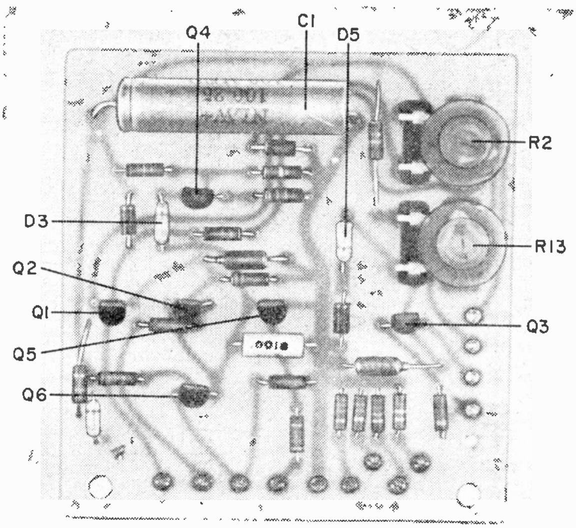
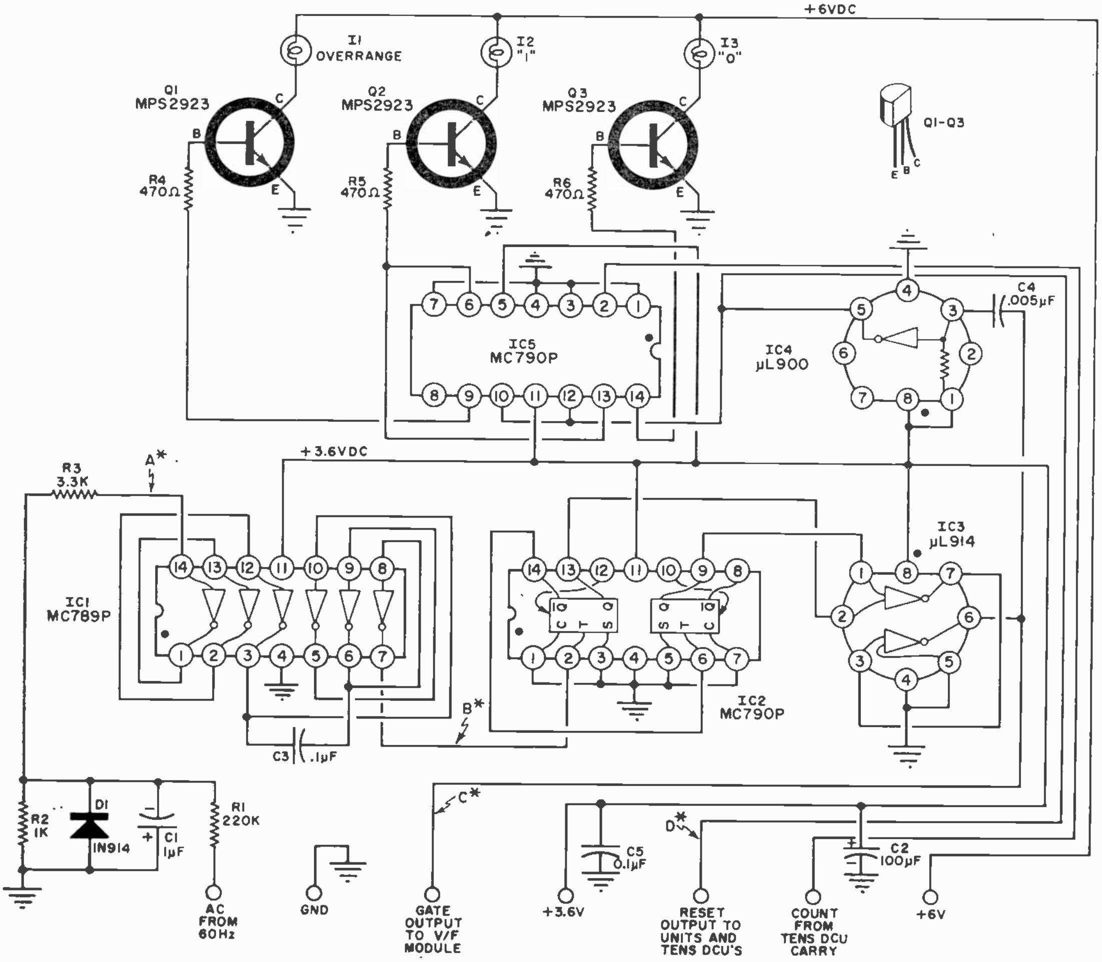


Fig. 4. Avoid accidentally interchanging R2 and R13. Author's prototype is shown in photo, right.



ALL IC'S VIEWED FROM TOP

* SEE "HOW IT WORKS" BOX FOR WAVEFORMS

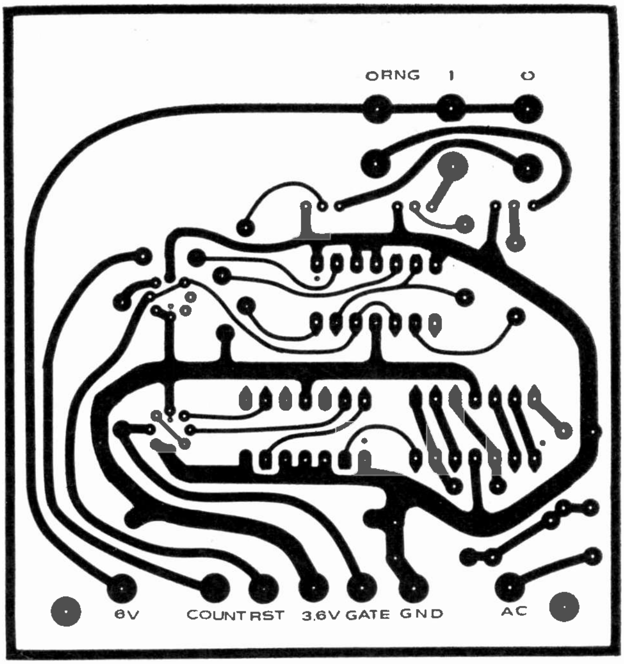
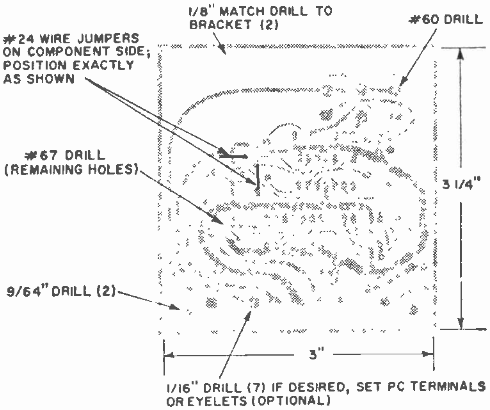


Fig. 6. Actual-size etching guide must be copied exactly as shown to insure proper component fit. Small dots near solder terminals indicate IC indexes.

Fig. 7. Proper location of hole centers and selection of drills are critical for the Gate module board. Once holes are drilled, immediately install jumpers.



also rectified to provide a 30-volt d.c. supply. Resistor *R1* is a voltage dropping resistor which dissipates a large amount of power and must be located where the heat produced will do no damage.

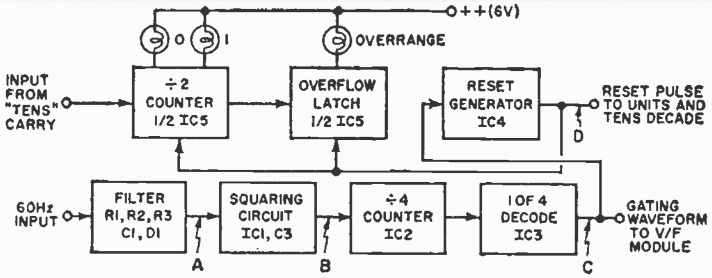
The power from the "filament" winding of *T1* is rectified to provide 6-volt and 3.6-volt d.c. supplies. Rectifier *RECT1* is a full-wave bridge. Capacitors *C2*, *C3*, and *C4* provide filtering for the d.c., and diodes *D3*, *D4*, and *D5* drop the rectified voltage from 6 to 3.6 volts. The unrectified voltage from the 6.3-volt winding is also used for the pilot or decimal-point lamps. Resistor *R2* is in series with this supply to reduce the voltage on the lamps so that they do not glow brighter than the counting lamps.

Most of the power supply components can be mounted on terminal strips or a component board as shown in Fig. 10. The rest of the components are mounted on the chassis.

GATE MODULE PARTS LIST

C1—1-μF, 25-volt electrolytic capacitor
C2—100-μF, 10-volt electrolytic capacitor
C3—0.1-μF, 10-volt ceramic disc capacitor
C4—0.005-μF, 50-volt Mylar capacitor
C5—0.1-μF capacitor
D1—1N914 silicon computer diode or equivalent
I1-I3—6.3-volt, 50-mA pilot lamp and lens assembly, two orange and one red (Southwest Technical Products #0-6.3 and #R-6.3 respectively, or equivalent)
IC1—Integrated circuit (Motorola MC789P)
IC2, IC5—Integrated circuit (Motorola MC790P or MC791P)
IC3—Integrated circuit (Fairchild μL914)
IC4—Integrated circuit (Fairchild μL900)
Q1-Q3—2N5129 transistor or Motorola MPS2923
R1—220,000-ohm, ½-watt resistor
R2—1000-ohm, ¼-watt resistor
R3—3300-ohm, ¼-watt resistor
R4-R6—470-ohm, ¼-watt resistor
Misc.—PC board, 3" x 3-¼", PC terminals or eyelets (7) (optional), #24 jumpers (2), solder, lamp bracket (see Fig. 12), mounting bracket and hardware (see Fig. 11).
Note:—The following Gate module parts are available from Southwest Technical Products, 219 W Rhapsody, San Antonio, Texas 78216: etched and drilled printed circuit board #155G, $3; complete kit of all necessary parts #CG-155, $10.85 postpaid in USA.

Assembly. To mount the modules in the chassis, aluminum support brackets such



HOW IT WORKS

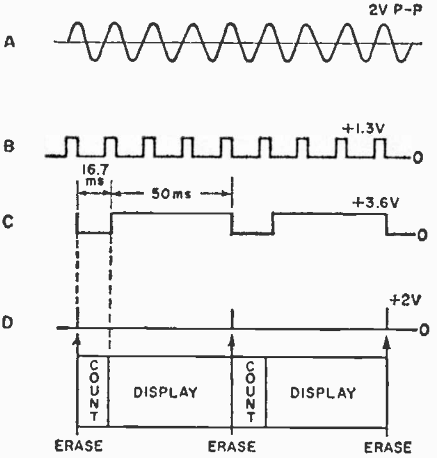
GATE MODULE

This module is a three-in-one board. First, it's a gate generator that produces the on-for-one, off-for-three gating waveform used in the V/F; it's also a reset generator that automatically provides a short pulse the instant the V/F is told to start producing a new count; and finally, it contains an 0, 1, overrange counter used to complete the 0-199 digital display. The complete schematic is shown in Fig. 5.

The gate waveform is generated by filtering the 60-Hz supply to obtain a smooth sine wave. The filter removes any noise from the power line that might cause inaccuracies, while *IC1*, a hex inverter, produces a rectangular wave with a fall time sufficiently steep to trigger the next stage. Capacitor *C3* provides positive feedback to improve the square-wave form.

The next stage, *IC2*, is a divide-by-four counter consisting of two JK flip-flops connected as cascaded binary dividers. Dual-gate *IC3* is a 1-of-4 decoder producing a gating waveform that is grounded for 16.7 milliseconds (one 60-Hz period), and positive for the next 50 milliseconds (three 60-Hz periods). Since this process takes up four 60-Hz cycles, the frequency of the composite waveform is ¼ of 60 Hz, or 15 Hz; hence the 15 measurements per second.

The gate output is routed to the V/F converter and to a half-monostable reset generator consisting of *C4* and buffer *IC4*. This circuit generates a very brief (about 2 microseconds) reset pulse which erases the display before the V/F converter can produce its first output pulse. The reset pulse goes to the two decimal counters as well as resetting the 0, 1, overrange portion of this module.



The 0, 1, overrange counter, *IC5*, has two flip-flops. One is a binary divider; the second is a latch that goes on when full scale is reached, regardless of how many more counts arrive. This counter takes the output of the ten's DCU and converts what would be an 0-99 display into an 0-199 plus overrange capability.

A power-line gate may be expected to be accurate to ±0.05%, while the digital 0-199 display used is only inherently accurate to ±0.5%. Thus, the instrument accuracy is determined by the display and the V/F accuracy. Without a far more expensive V/F circuit, extra decade modules or a more precise time base will not increase the instrument's accuracy.

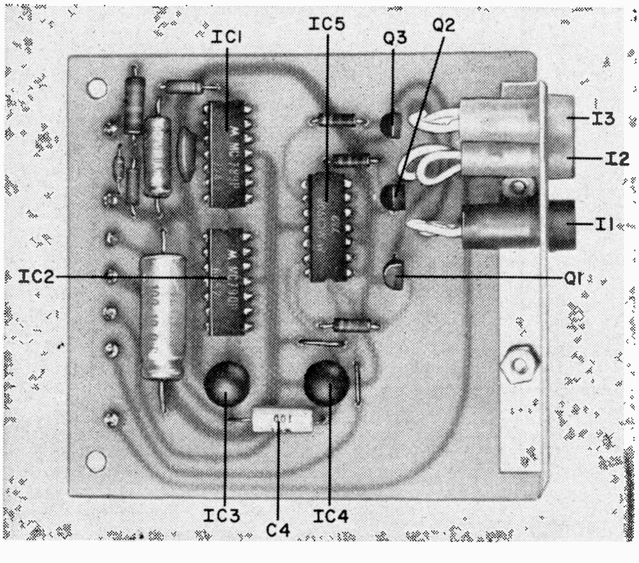


Photo of author's prototype shows properly wired Gate module board with indicator lamps and bracket in place and optional solder terminals at left; external wiring can be soldered directly to board.

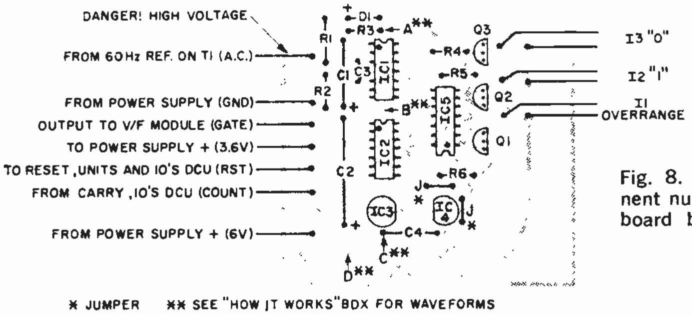


Fig. 8. Double and triple check component numbers, values, and orientation on board both before and after soldering.

as those shown in Fig. 11 can be used. The photos show how these brackets are used for support.

A three-hole bracket is required for the indicator lamps of the gate module. This can be fabricated as shown in Fig. 12. (One of the brackets supplied with the DCU kit can be used as a guide.) Use orange plastic covers for the 0 and 1 bulb, and a red one for the overrange indicator.

The complete schematic for the DVM is shown in Fig. 13. The photos show the assembly used by the author, although any other similar neat arrangement can be used. While layout is not critical, be sure to keep the instrument neat and compact to minimize the chance of wiring error. Be sure to use very short, heavy ground connectors. A ground buss of #12 solid wire between modules is strongly recommended.

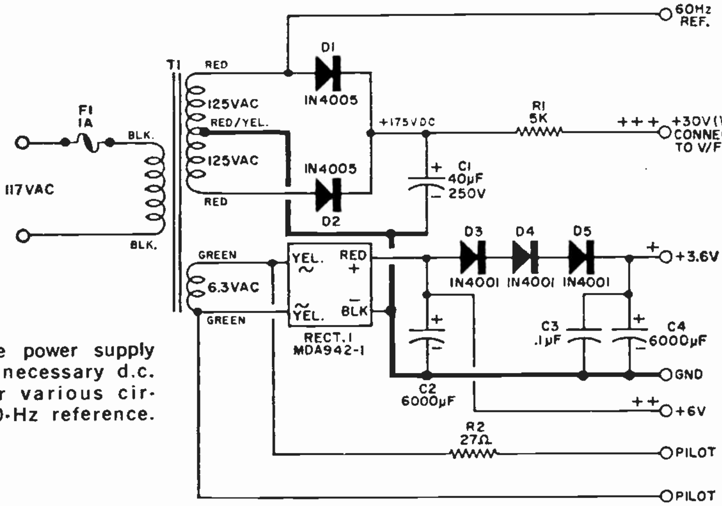


Fig. 9. Single power supply provides all necessary d.c. voltages for various circuits and 60-Hz reference.

NOTE: 1-DO NOT CONNECT CASE TO POWER SUPPLY COMMON
2-USE HEAVY GAUGE WIRE WHERE SHOWN

POWER SUPPLY PARTS LIST

C1—40-μF, 250-volt electrolytic capacitor
C2, C4—6000-μF, 10-volt electrolytic capacitor
C3—0.1-μF, 10-volt ceramic disc capacitor
D1, D2—1-ampere, 600-volt silicon diode (Motorola 1N4005 or similar)
D3-D5—1-ampere, 50-volt silicon diode (Motorola 1N4001 or similar)
RECT1—1.5-ampere, 50-volt, full-wave silicon molded bridge assembly (Motorola MDA942-1 or similar)
F1—1-ampere fuse and fuseholder
R1—5000-ohm, 10-watt resistor
R2—27-ohm, ½-watt resistor
T1—Power transformer, secondary 250 volts CT @ 25 mA, 6.3 volts 1 ampere (Knight 54E-2008, Stancor PS8416, Thordarson 22R39 or similar)
Misc.—16-point (8 on each side) terminal board assembly with mounting hardware, a.c. line cord, strain relief, mounting hardware for T1 and F1, wire, solder, mounting clips for capacitors, etc.
Note:—Complete kit of all power supply parts available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216. #CS-155, $10.70 postpaid in USA.

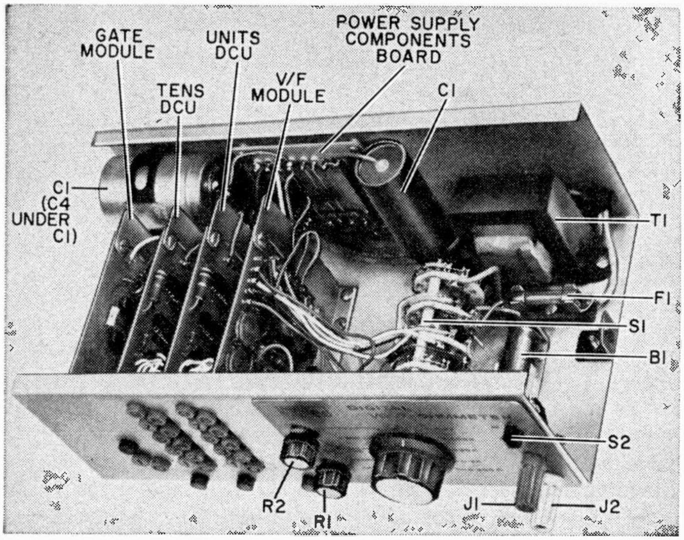


Fig. 10. Power supply circuit is located along rear apron of chassis. Modules are at left, while CAL and ZERO controls, range/function switch, polarity selector are at right.

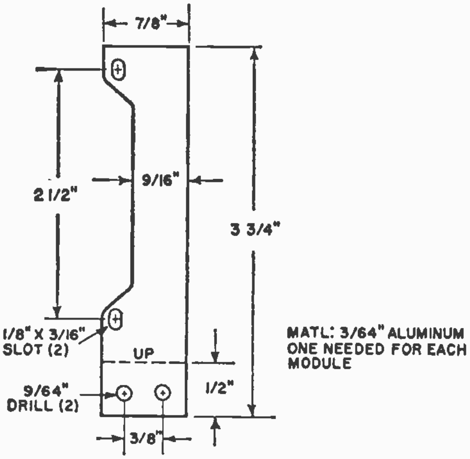


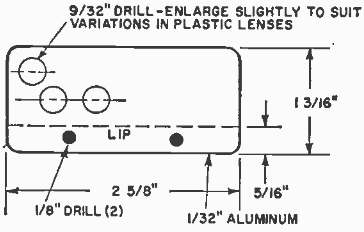
Fig. 11. If necessary, to avoid interference with components or wiring, deepen the notched cutout.

It is best to use color-coded wiring to minimize wrong connections and facilitate any possible troubleshooting. The resistors associated with *S1* may be assembled directly on the switch before installation. Also, use green-colored lenses on the decimal-point indicators.

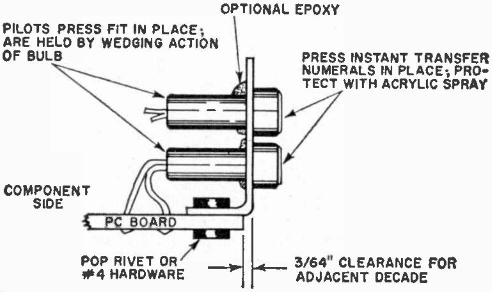
The 1.35-volt reference cell (*B1*) is mounted wherever convenient within the chassis. Note that there are two types of mercury cell: those for general-purpose use and those for standard or voltage-reference purposes. Make sure that you get the latter. The accuracy of the DVM will be no better than the accuracy of the calibration standard.

Setup and Calibration. After a careful wiring check, the DVM may be plugged in and *S1* placed in the ZERO position. One digit in each column should light brightly and continuously. Turning the ZERO control through its entire range should change the display from 000 to 030. At about the mid-point of the control, the reading should be 001.

The proper setting of the ZERO control is the position immediately before



(A)DRILLING GUIDE



(B) MOUNTING DETAILS

Fig. 12. Arrange lamp mounting holes in two closely spaced, staggered columns to obtain small size.

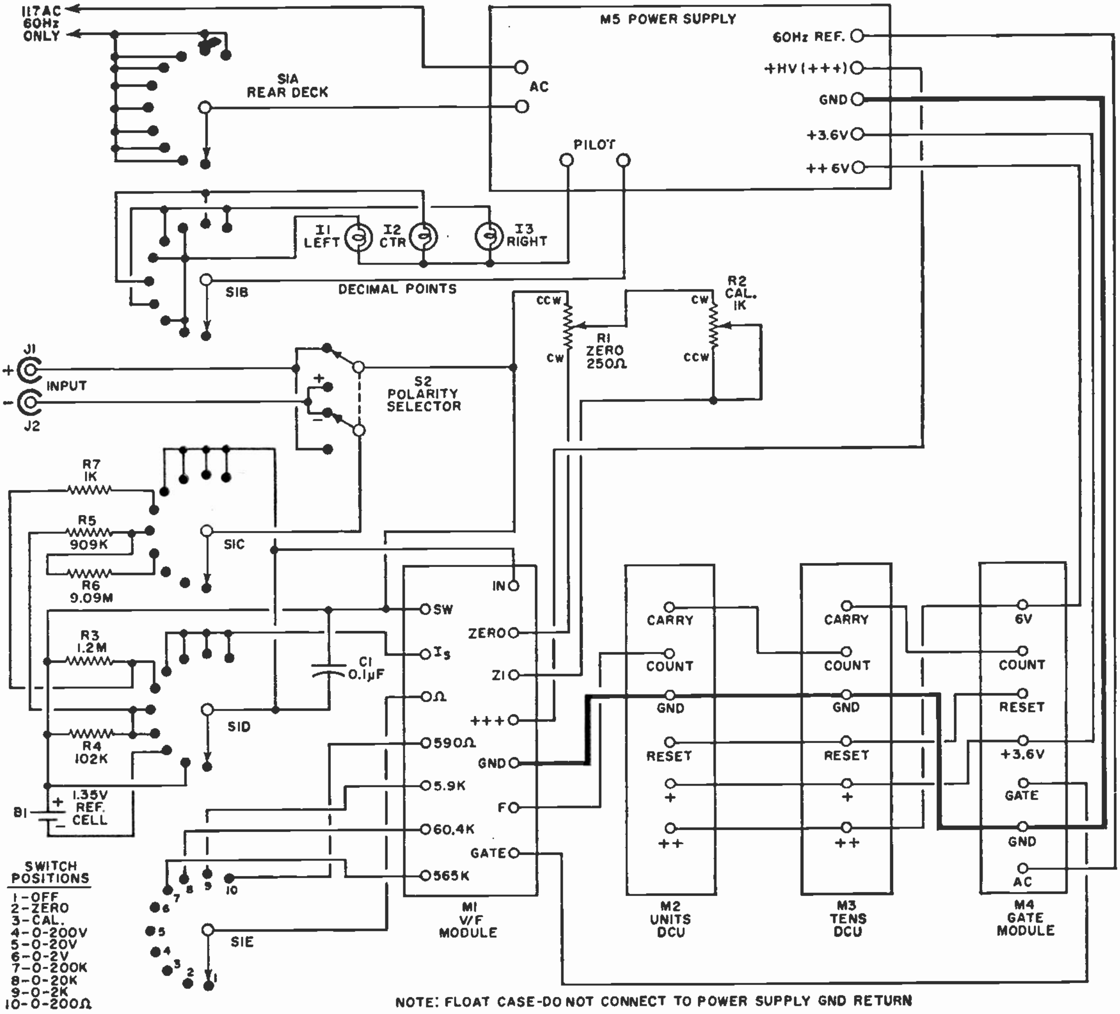


Fig. 13. The heavy line connecting the GND terminals in this overall wiring diagram is NOT a chassis ground; it is a convenient floating common bus.

COMPLETE DVM PARTS LIST

B1—1.35-volt AA mercury reference cell
C1—0.1-µF, 50-volt Mylar capacitor
I1-I3—6.3-volt, 50-mA pilot lamp.
J1, J2—5-way binding post, (red and black)
M1—V/F module (see text)
M2, M3—Decimal counting unit. See POPULAR ELECTRONICS February 1968 or Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK
M4—Gate module (see text)
M5—Power supply (see text)
R1—250-ohm, 2-watt linear potentiometer
R2—1000-ohm, 2-watt linear potentiometer
R3—1.2-megohm, ¼-watt resistor
R4—102,000-ohm, ¼-watt, 1% precision resistor
R5—909,000-ohm, ¼-watt, 1% precision resistor
R6—9.09-megohm, ¼-watt, 1% precision resistor or series resistor combination
R7—1000-ohm, ¼-watt resistor
S1—Five-deck, five-pole, ten-position, nonshorting rotary switch
S2—D.p.d.t. slide switch
Misc.—Vinyl clad aluminum case and support assembly, ¾" knobs (2), 1-½" knob (1), backup plate for controls, dialplate (optional), mounting hardware, brackets for M2, M3, (see Fig. 11), wire, solder, 1300- to 1500-ohm precision resistor, green jewels (2), etc.
Dialplate:—Hard anodized aluminum dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Ariz. 85014. In black and silver, $3.00; in red, gold, or copper, $3.45, postpaid in USA. Stock #DVM-1.
Note—Kits for the decimal counting units are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216 for $12 each, postpaid in USA. A complete kit of all above parts, including a punched and machined, vinyl-clad case and support assembly, but less dialplate and B1 is available from the same source for $79.50 plus postage for 6½ pounds.

HOW IT WORKS

OVERALL OPERATION

The function selector includes switch *S1* and its associated circuits. Here all input signals are converted to 0-2-volt d.c. voltages across a one-megohm resistance. When measuring 2 volts d.c. or less, the signal is applied directly to the remainder of the circuit. Above 2 volts, the signal is attenuated by 10 or 100. For ohms measurement, a calibrated and temperature-compensated current source supplies 0.01, 0.1, 1, or 10 mA to the input terminals. The voltage drop across the resistance (between 0 and 2 volts) is then an accurate measure of the resistance. For example, 1 mA of current through a 1600-ohm resistor produces a voltage drop of 1.6 volts. Because maximum ohmmeter current is only 10 mA on the lowest range (less on the higher resistance ranges), you can safely measure most current-sensitive devices without fear of damage.

For calibrating and zeroing the instrument, the function selector switch connects either a 1.35-volt mercury standard battery or a short circuit to the system.

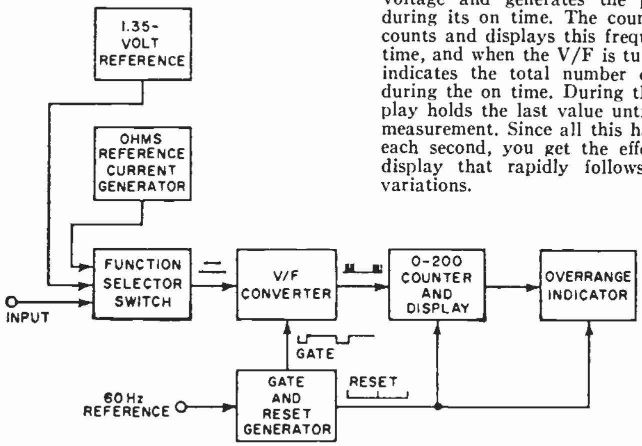
The 0-2-volt d.c. signal from the function selector is fed to a voltage-to-frequency (V/F) converter. This is a current-driven unijunction oscillator whose output frequency is proportional to the input voltage. Unlike industrial V/F converters, this one runs "open loop" and relies on calibration and inherent linearity rather than on complex and expensive feedback schemes for accuracy. Linearity, range, and resolution are more than adequate for the one-part-in-200 digital display used.

The output of the V/F converter drives a 0-199 counter/display (DCU's) and turns on a red overrange indicator when full scale is exceeded.

If this were the entire circuit, the digital display would be a blur of numbers that would just keep on adding up the output pulses from the V/F converter. Additional circuitry, called the gate-and-reset generator, continuously turns the V/F converter off and on and erases the old display before presenting an up-dated one.

In the gate and reset generator, the 60-Hz power from the line is used to generate a signal that turns the V/F converter on for one-fourth of the time and allows the display to show the results for three-fourths of the time. Immediately after the V/F converter is turned on, a very brief reset pulse is generated to erase the counter display before the new results can arrive at the DCU's.

The V/F converter then averages the input voltage and generates the pertinent frequency during its on time. The counter/display module counts and displays this frequency during the on time, and when the V/F is turned off, the display indicates the total number of pulses generated during the on time. During the off time, the display holds the last value until reset for the next measurement. Since all this happens fifteen times each second, you get the effect of a continuous display that rapidly follows the input-voltage variations.



you get the 001 reading. If you turn the control down all the way, you'll pick up some serious low-scale errors.

After zeroing, switch to the CAL 1.35 position. When the CAL potentiometer is turned through its entire range, the indicator should go from about 1.20 to about 1.50 with 1.35 at about the middle of the range. If you cannot get the readings low enough, or if 1.35 is at the *lower* end of the control, add one or two 680-pF mica capacitors across integrating capacitor *C3* in the V/F module till you get the proper range.

Very rarely, it may be necessary to change the value of *R11*. This occurs because of variations in the characteristics of *Q6*, the unijunction transistor. If the V/F converter oscillates but does not drive the counter, either increase or decrease the value of *R11* (in a range of 6.8 to 22 ohms) until proper operation is obtained.

Always rezero the instrument before calibrating. The settings will be remarkably stable after a few minutes' warmup. A slight interaction between the CAL 1.35 and the ZERO controls is normal, so always recheck the ZERO setting after calibrating.

To check zeroing, short test leads together, and misadjust zero control to get an 001 reading. Switch *S1* to 0-2 range. The reading should stay at 001. Remove the short. If the reading

(*Continued on page* 94)

BUILD A FET-QM

Improve selectivity with simplified Q-multiplier/amplifier

BY ROBERT N. TELLEFSEN, WØKMF

HAVE YOU BEEN THINKING of trading in your old communications receiver because its selectivity is about as broad as a barn door? If so, an expensive replacement receiver—even if it is a better model—may not be what you really need. Instead, the addition of a Q-multiplier to your present receiver may be just what the doctor ordered.

Now, for less than $10, you can build a Q-multiplier that incorporates a field-effect transistor stage to improve receiver selectivity and provide controlled regeneration. Called the "FET-QM," this device is completely self-contained (it even has its own line-independent power source), compact in size, and easy to use. A single coaxial cable connects the FET-QM to your receiver.

About the Circuit. The FET-QM incorporates a high-Q 455-kHz tuned circuit (*L1*, *C1*, and *C2* in Fig. 1). Additionally, amplifier stage *Q1* provides a facility for controlling regeneration.

Regeneration increases the Q of the tuned circuit and considerably improves receiver selectivity. Now, because the FET-QM is connected to the mixer plate, where the 455-kHz i.f. first appears in the receiver, its narrow passband determines the receiver's selectivity. As a result, broadcast signals as close together as 5 kHz can be easily separated (see Fig. 2).

With the FET-QM switched out of the receiver, signals A and B will be heard. If you wanted to listen to signal A, signal B would interfere. Ideally, signal B

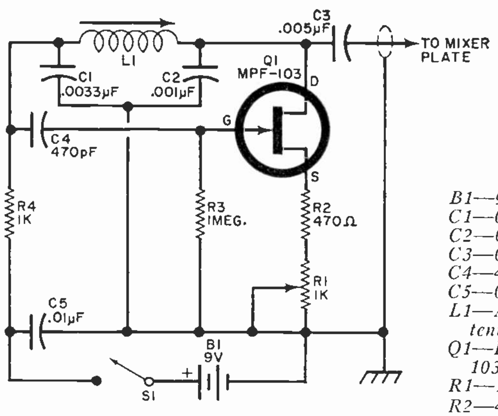


Fig. 1. High-Q 455-kHz tuned circuit (C1, C2 and L1) helps narrow passband of receiver, while R1 in source of Q1 provides means for controlling regeneration.

PARTS LIST

B1—9-volt battery
C1—0.0033-µF ceramic disc capacitor
C2—0.001-µF ceramic disc capacitor
C3—0.005-µF ceramic disc capacitor
C4—470-pF ceramic disc capacitor
C5—0.01-µF ceramic disc capacitor
L1—Adjustable slug-tuned broadcast band antenna coil
Q1—Plastic n-*channel FET (Motorola MPF-103)*
R1—1000-ohm linear taper potentiometer
R2—470-ohm
R3—1,000,000-ohm
R4—1000- to 1500-ohm (see text)
} *all resistors, ¼-watt*
S1—S.p.s.t. switch, part of R1
1—4" × 2¼" × 2¼" aluminum utility box
2'—RG-58A/U coaxial cable
Misc.—Knob for ¼"-diameter shaft; knob for ⅛"-diameter shaft; 2 four-lug terminal strips; battery clip; hookup wire; hardware; solder; etc.

should be eliminated or at least considerably suppressed. So, the FET-QM is switched in, with the result that the passband narrows, and signal B is now to all means and purposes rejected. The FET-QM passes signal A and suppresses signal B, making the desired signal stand out.

Potentiometer *R1* controls the amount of regeneration produced by the FET-QM. With too much regeneration, the Q-multiplier goes into oscillation, and a steady squeal is heard from the receiver. Therefore, the optimum setting for selectivity is when *R1* is set just below the point of oscillation.

Construction. The circuit of the FET-QM should be housed inside a compact aluminum utility box. The TUNE control, *L1*, and the PEAK control, *R1*, should be mounted on the front of the box as shown in the photos.

Two terminal strips can be used for the mounting of the remaining parts, except for battery *B1*.

The battery can be mounted with a battery clip in a location where it will not interfere with the other components in the circuit.

When all parts are mounted, wire them together. Drill a hole in the rear of the box to accept a rubber grommet, pass one end of the coax through the grommet, and solder the coax into the circuit as shown in Fig. 1.

Assemble the metal box, and letter the two panel controls. Finally, mount a knob designed for ⅛"-diameter shafts over the coil's adjustment screw; a ¼" knob goes onto the shaft of *R1*. This completes the construction of the FET-

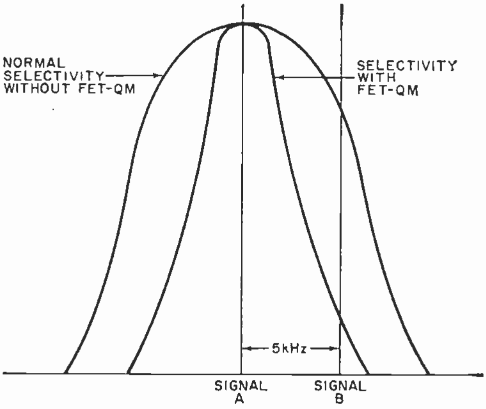


Fig. 2. Broadcast signals 5 kHz apart can be easily separated with the FET-QM in the receiver's circuit; unwanted signal B is greatly attenuated.

QM, and all that is left is to connect it to the receiver.

To connect the FET-QM to your receiver, first locate the plate lug of the mixer stage and solder one lead of a 0.005-μF capacitor to this lug. The other lead of the capacitor is then soldered to the center conductor of the coax. Ground the braid of the coax to the chassis near the tube socket. (In a.c.-d.c. receivers, ground the braid through a 0.005-μF capacitor to eliminate shock hazard.) If desired, phono jacks and plugs can be used to simplify connecting the FET-QM to the receiver.

WHAT IS Q-MULTIPLICATION?

The high selectivity provided by the FET-QM is the result of positive feedback (regeneration). The idea of attaching this circuit to the i.f. channel was proposed in 1952 by O. G. Villard and W. L. Rorden. In the circuit shown, the impedance at resonance of *C1*, *C2*, and *L1* is very high, and signals at this frequency pass through the i.f. strip unhindered. A Q-multiplication of 20-30 is not uncommon. Possibly, the phrase "Q-multiplication" is a misnomer since the actual Q of the i.f. strip remains unchanged, but signal frequencies slightly off-resonance in the strip are sharply attenuated.

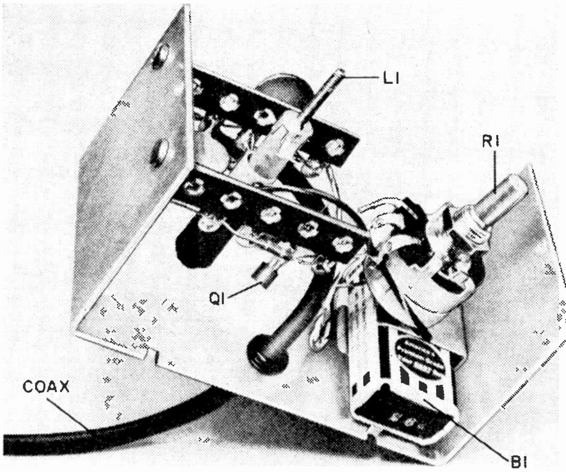


Fig. 3. Due to simplicity of circuit, two terminal strips can easily accommodate all small parts.

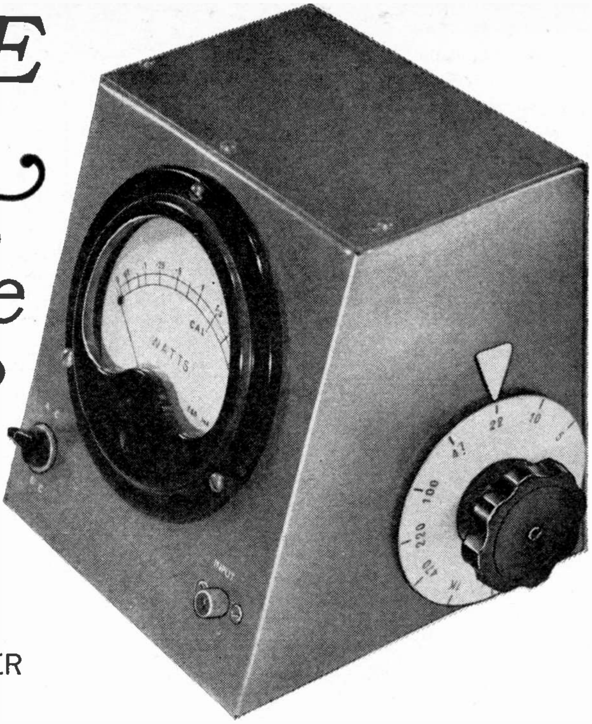
After the interconnection between the FET-QM and the receiver is accomplished, repeak the i.f. transformer. Be sure the FET-QM is turned off when touching up the transformer.

How To Use. Turn on your receiver, and tune in a weak, interference-free signal with the Q-multiplier turned off. If your receiver has an r.f. gain control, back it off a bit from maximum to prevent strong signals from forcing their way through the receiver and reducing the effectiveness of the FET-QM.

Turn on your BFO and adjust it for a beat note. Now, switch on the FET-QM, and set the PEAK control fully clockwise. Rotate the TUNE control until you hear a strong whistle; then back off on the PEAK control until the whistle disappears. Slowly adjust the setting of the TUNE control until the desired signal suddenly peaks. If necessary, the PEAK control can be advanced until the FET-QM almost goes into oscillation. This is the point of maximum selectivity, and any signals coming through the receiver will ring like a struck bell. The best setting is just below the point where the extreme ringing stops but where the desired selectivity is still present.

Even an inexpensive receiver can do surprising things with the addition of a Q-multiplier. When you build and use the FET-QM, you will probably find that the ideas you had about trading in your receiver for a better model were rather drastic. -30-

UNIQUE POWER & Impedance METER



READ MAXIMUM OUTPUT OF AMPLIFIERS, SIGNAL GENERATORS AND LOW-POWER TRANSMITTERS

BY ROY HARTKOPF

MEASURING VOLTAGE, current or resistance is relatively easy; all you need is a VOM or VTVM. However, when it comes to measuring power, most experimenters run into trouble. One difficulty is that two independent variables must be measured at the same time: either voltage and current, voltage and resistance, or current and resistance. This may not be too difficult, but if you want to measure *maximum* output power of an amplifier, signal generator, or low-power transmitter, the problem is complicated by the fact that, when making the measurement, the load impedance must match the output impedance of the device being tested.

The "Power and Impedance Meter" described here is a low-cost, signal-powered instrument that measures power output from a few milliwatts to 3 watts and simultaneously (and automatically) matches the output impedance from 4.7 to 10,000 ohms. What is more, the meter has a frequency range from d.c. to about 150 MHz! It has no power supply or semiconductor circuitry; and does not require alignment or maintenance.

The power meter is very easy to use: simply connect it to the output to be measured and rotate a single switch until a meter calibrated in watts indicates a maximum value. This is the maximum power output and the switch position indicates the approximate output impedance of the circuit being tested. The test set can be modified easily to indicate output impedance almost exactly.

Construction. The Power and Impedance Meter is constructed in an enclosed metal case to prevent excessive radiation when the test set is used with a low-power transmitter. A sloping front panel is convenient but any other shape is satisfactory.

The load resistors associated with switch *S1A* (*R1* through *R11* in Fig. 1) should be 2-watt, non-inductive units whose tolerances are chosen for the amount of reading accuracy desired, keeping in mind that the ultimate accuracy depends on the meter movement itself. The ohmic values of the resistors shown in the Parts List were selected to cover most loading cases.

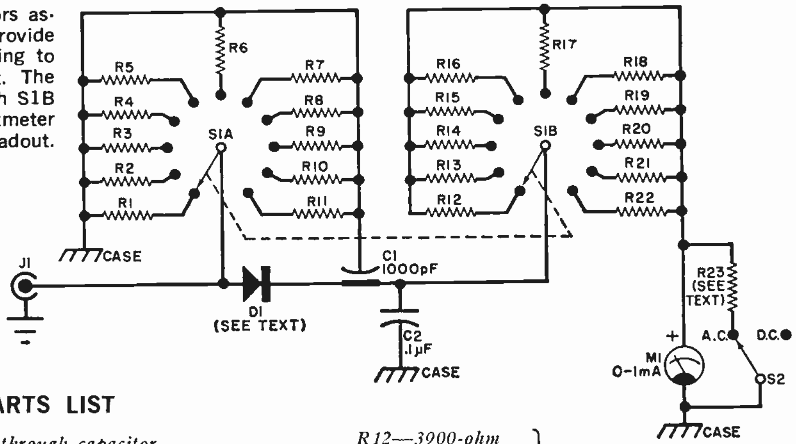
The switch can be assembled outside the case. Although only two 11-position decks are required, the author used a three-deck switch with the third one serving as support for one end of the meter resistors (*R12* through *R22*). Disassemble the switch and make up a U-shaped, tin-plated metal shield that covers the front deck of the switch (see photo). The front end of the shield is clamped (and grounded to the chassis) with the switch mounting hardware. Drill holes in the rear of the shield for the rear leads of the load resistors (which are soldered to the shield). The front leads of the load resistors are soldered to the appropriate terminals on the front deck of *S1*. Resistors *R12* through *R22* are mounted between the center and rear decks of the switch. Remove the rotor segment of the rear deck to prevent accidental shorting of resistors.

Drill a hole in the corner of the shield that will be closest to input jack *J1*. This hole should be capable of accepting feedthrough capacitor *C1*, which is soldered to the shield. One end of *C1* is used as a support for diode *D1*. Capacitor *C2* is then soldered in position, and the completed switch assembly is mounted in the chassis. Mount switch *S2* and input receptacle *J1* on the panel.

Almost any diode will suffice for *D1*, but there are two factors which must be considered. With three watts (d.c.) across a 10,000-ohm load, there are 173 volts across the diode. With the same power and impedance, the a.c. voltage is about 250 volts peak. All germanium signal diodes will fail at this voltage level. At the other extreme, 30 mW across a 5-ohm load produces less than half a volt across the diode, which is below the threshold of conduction for a high-voltage silicon diode. In practice, these two extremes are seldom encountered, and the author has found that a germanium rectifier having a 120-volt PIV rating will suffice for almost all conditions.

To calibrate the meter scale for indicating power in watts, gently remove the meter-face protective covering, and

Fig. 1. The resistors associated with S1A provide impedance matching to circuit under test. The resistors used with S1B make up a voltmeter using M1 as the readout.



PARTS LIST

C1—1000-pF, feedthrough capacitor
C2—0.1-µF capacitor
D1—Germanium rectifier diode (see text)
J1—Phono jack or other coaxial fitting
M1—0-1-mA meter
R1—4.7-ohm
R2—10-ohm
R3—22-ohm
R4—47-ohm
R5—100-ohm
R6—220-ohm
R7—470-ohm
R8—1000-ohm
R9—2200-ohm
R10—4700-ohm
R11—10,000-ohm
These resistors 2-watt non-inductive
R12—3900-ohm
R13—5600-ohm
R14—8200-ohm
R15—12,000-ohm
R16—18,000-ohm
R17—27,000-ohm
R18—39,000-ohm
R19—56,000-ohm
R20—82,000-ohm
R21—120,000-ohm
R22—180,000-ohm
R23—see text
These resistors ½-watt
S1—3-pole, 11-position rotary switch (see text)
S2—S.p.s.t. switch
Misc.—tin-plated shield material, metal enclosure, large knob with pointer, hookup wire, solder, hardware, etc.

recalibrate the scale in accordance with Table I. When this is done, mount the meter in the case.

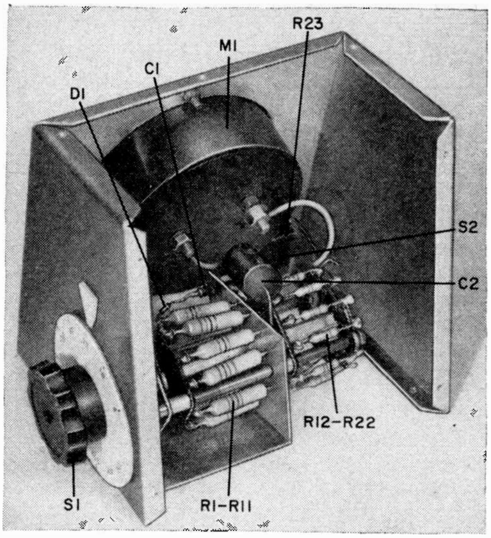
Because the r.m.s. value of an a.c. signal (assuming it is a sine wave) is only 0.707 of the peak value, it is necessary to have a shunt resistor in parallel with the meter during a.c. measurements. Since meters vary considerably in their internal resistance, the choice of this shunt resistor *R23* must be made to suit the meter you are using. To do this, connect a high-voltage supply and a potentiometer with a resistance of several thousand ohms in series with the meter. Adjust the potentiometer until the meter indicates exactly full scale (3 watts). Then connect various values of resistors across the meter terminals until the meter reads 1.5 watts (the CAL position on the scale).

TABLE I—METER CALIBRATION

WATTS	mA
3	1.0
2.5	0.91
2	0.82
1.5 (CAL)	0.707
1	0.57
0.75	0.5
0.5	0.41
0.25	0.29
0.1	0.185
0.05	0.13
0.01	0.057

Since the meter now indicates peak, rather than r.m.s., power, it cannot be expected to give exact results for inputs that are not sine waves. However, this method is used in most VTVM's and has proved to be quite satisfactory in practice, particularly at very high frequencies. Once *R23* has been selected, wire the test set in accordance with Fig. 1.

Operation. Connect input receptacle *J1* to the amplifier, signal generator, or low-power transmitter to be tested. Set *S2* to the AC position, and turn on the system. Rotate *S1* until the meter indicates the highest power output and read the switch position. For example, if the test set indicates maximum power of 1.5 watts at 470 ohms, you know that the device under test has an output impedance of 470 ohms (or close to it) and an output of 1.5 watts. If, on the other hand, you find that the meter indicates 0.5 watts in both the 220- and 470-ohm positions, the correct impedance is about 350 ohms and the power output is a little over one watt.



Mount the resistors, shield, C1, and D1 before installing the switch in the chassis. Grounding, through switch mounting hardware, must be tight!

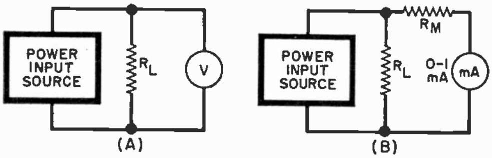


Fig. 2. Power measuring methods. (A) shows basic approach to measuring power, while (B) illustrates the method used in the Power and Impedance Meter.

Calibration Method. The Power and Impedance Meter uses the E^2/R approach to measuring power. The basic circuit is shown in Fig. 2(a). The power dissipated by R_L is E^2/R. Thus if R_L is 100 ohms and the voltmeter indicates 5 volts, the power is $5^2/100$ or ¼ watt. Because power is proportional to the square of the meter deflection, the scale is nonlinear. As an example, if the desired full-scale indication is 2 watts, then the 1-watt indication mark is $1/\sqrt{2}$ or 0.707 of full scale.

Assume that the meter in Fig. 2(a) indicated 10 volts full scale. With a 100-ohm resistor, the power is 1 watt. If the resistor is changed to 500 ohms, the

(*Continued on page* 72)

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POWER METER

(*Continued from page* 68)

power at 10 volts is $10^2/500$ or ⅕ watt. As a result, if the voltmeter were calibrated in watts, it would give the proper indication only with one particular value of load resistor.

The solution to the problem is to forget about voltage measurements and concentrate on the amount of current required to produce a full-scale meter deflection. With a 1-mA meter movement, all we have to do is arrange for 1 mA to flow through the meter whenever we want the meter to indicate full scale (1 watt, 3 watts, etc.). A simplified circuit for doing this is shown in Fig. 2(b).

For a full-scale meter deflection of 3 watts and with a load resistor of 100 ohms, the voltage across R_L would be W × R or 17.32 volts. To make a 1-mA meter indicate full scale, the total resistance in the meter circuit (R_M plus meter movement resistance) will have to be 17,320 ohms. Similarly, if the load resistor is 500 ohms, the voltage across it is 38.73 volts and the meter-circuit resistance must be 38,730 ohms.

TABLE II—METER RESISTOR VALUES

R_L (ohms)	E (volts)	R_M (calculated) (kohms)	R_M (used) (kohms)
4.7	3.742	3.7	3.9
10	5.48	5.5	5.6
22	8.12	8.1	8.2
47	11.87	11.8	12
100	17.32	17.3	18
220	26.67	25.7	27
470	37.42	37.4	39
1000	54.8	54.8	56
2200	81.2	81.2	82
4700	118.7	118.7	120
10 k	173.2	173.2	180

The values used to determine R_M for the Power and Impedance Meter are given in Table II. Note that in every case, the calculated value of R_M is close enough to a standard resistance value that it is not necessary to use special resistors. The use of 3 watts as the full-scale deflection makes possible this happy circumstance. Since the meter, in this case, had an internal resistance of only 100 ohms, its resistance was ignored. -30-

BIG SIX

(*Continued from page* 33)

Now, install the crossover networks, tweeter, and woofer on the speaker mounting board. Carefully observing polarity, complete speaker/crossover system wiring. If you plan to paint or stain the enclosure, now is the time to do so. And, while you're at it, apply a coat or two of flat black paint to the front of the speaker mounting board.

Set the speaker mounting board close to the enclosure, and thread the leads to the two L-pad controls and conducting bolts on the rear of the enclosure. Install the controls. The basic system is now ready for testing.

Temporarily set the speaker mounting board in place on the front of the enclosure, and hold it in place with four screws. Connect your amplifier, and start a record playing. Now, listening carefully, test the range of the controls. There should be more than enough range to allow adjustment of the sound reproduction to the acoustical environment of your listening room. When you are satisfied, turn off the power amplifier, and disconnect the feed cable.

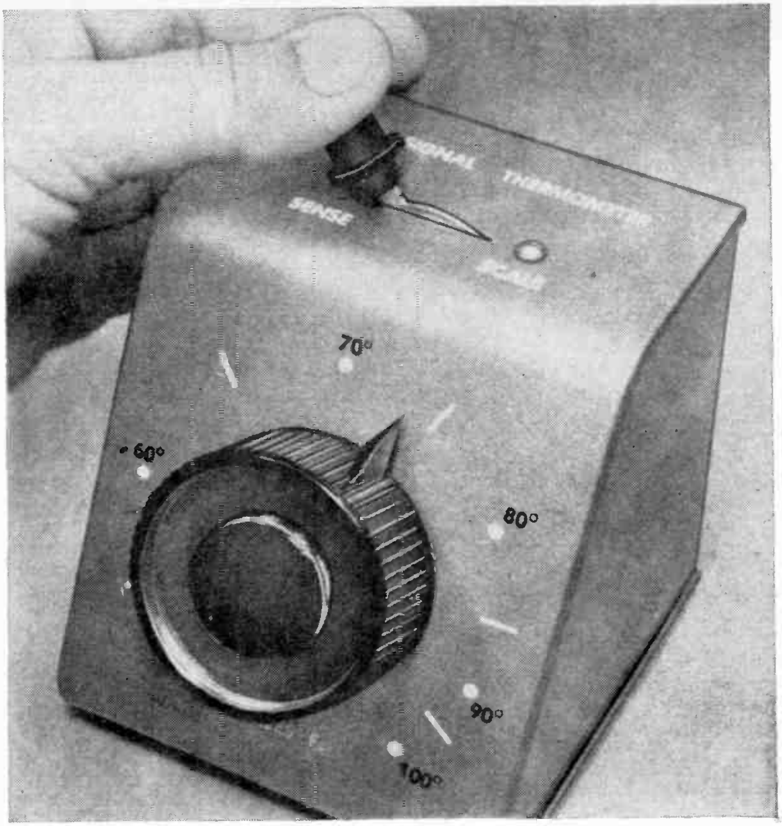
Complete construction by installing the rest of the screws for the speaker mounting board and the grille cloth and trim.

Stereo Setup. If you build two Big Six speaker systems for stereo reproduction, make the speaker mounting boards mirror images of each other. In this way, the sound will be balanced. A diagram of a mirror-image stereo system is shown in Fig. 4.

Because the midrange speakers are mounted off center and the two speaker mounting boards are mirror images of each other, the two speaker systems can be reversed to alter the stereo effect.

What is the sound reproduction like from the Big Six speaker system? As mentioned earlier, the bass is deep and smooth, but not obtrusive. (So use a turntable with negligible rumble). The midrange is full and smooth, with the column adding to the effectiveness of the sound distribution. And the treble is expansive. -30-

THERMISTOR-CONTROLLED TONE GENERATOR USED FOR AUDIBLE TEMPERATURE READINGS



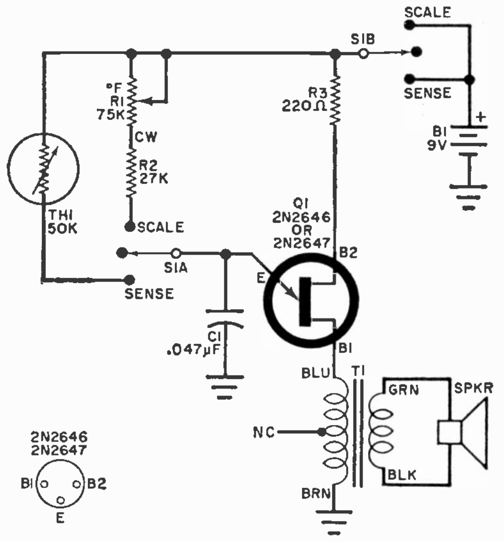
BUILD
Sound-Signal THERMOMETER

BY FRANK H. TOOKER

AIR TEMPERATURE CAN be measured in many ways—with a conventional mercury thermometer, a bimetal strip turning a pointer on a dial, or a thermocouple operating a digital readout. However, all of these systems have one thing in common—you have to be able to see the indicating device to be able to determine the temperature.

Some of us have friends or relatives who have difficulty seeing and who would welcome a device or technique to help them in going about their daily tasks. The "Sound-Signal Thermometer" is an electronic device that any experimenter can build and that will enable even a sightless person to tell the temperature. By flicking a switch and making a dial adjustment, he can "read" the temperature by comparing two sound signals. The range of the electronic thermometer is from 55 to 100 degrees Fahrenheit.

Construction. The layout of the components is not critical so any assembly arranged for convenience can be used. The author's version (see photos) is assembled in a small, sloping-panel metal cabinet. Switch *S1* is mounted on the top, potentiometer *R1* is on the sloping front, and battery *B1* is clip-mounted to the



PARTS LIST

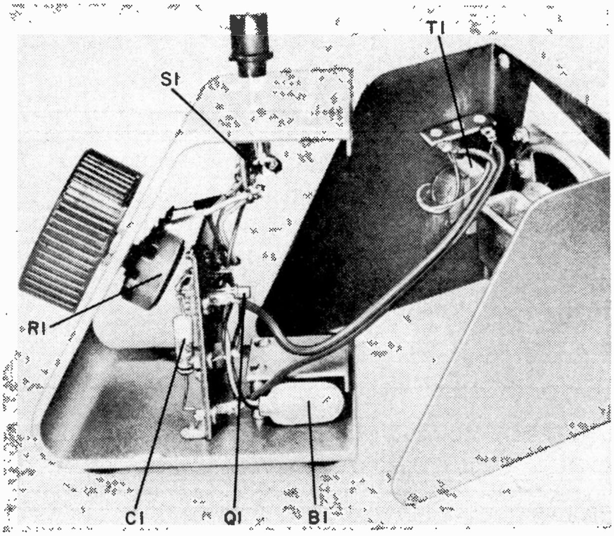
B1—9-volt transistor battery
C1—0.47-μF Mylar capacitor
Q1—2N2646 or 2N2647 unijunction transistor
R1—75,000-ohm potentiometer (Ohmite CU-7531, or similar)
R2—27,000-ohm, ½-watt resistor
R3—220-ohm, ½-watt resistor
S1—2-pole, 3-position lever switch with spring return from both sides to center (Centralab 1455, or similar)
SPKR—2½", 3.2-ohm speaker
T1—Transistor output transformer (Argonne AR-174, or similar)
TH1—Probe-type thermistor, 50,000 ohms at 25°C (Fenwal GA45P2, or similar)
Misc.—Sloping-panel cabinet 4" × 4" × 4¼" (Bud AC-1610-A, or similar), large-diameter pointer knob, 2½" × 2½" × 1⁄16" plastic mounting board, transistor socket, cambric tubing (to fit thermistor body), mounting hardware, wire, solder, etc.

The a.f. output of the UJT oscillator depends on emitter-circuit resistance—in SENSE mode, a function of the temperature acting on TH1.

bottom of the chassis. The output transformer *T1* and the loudspeaker are on the other half of the cabinet. The remainder of the components are assembled on a small piece of plastic mounted on L brackets within the cabinet. The dial knob used for *R1* should be large, with a distinct pointer, and the calibration marks can be either numerical (in degrees F) or in Braille.

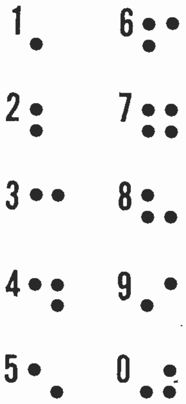
The most critical part of the assembly is the mounting and connecting of the thermistor. The probe-type component recommended for this unit is a small, very delicate device. It is easily damaged by both careless handling and excessive heat. The author found it expedient to mount the thermistor in a snug-fitting, short length of cambric spaghettic tubing, held in place on the plastic circuit board by a small metal clamp. Plastic insulation, slipped over the two thermistor leads, is cemented to the cambric tubing.

Keep the thermistor leads as long as practical in the assembly. Solder them



The entire electronic thermometer is contained within a small cabinet. The circuit is not critical, so any other mechanical arrangement can be used. If you wish to measure outside temperature, mount the thermistor out of a window in a weather-protected spot, and connect it to the thermometer via a twisted pair. This pair can enter the cabinet through a rubber grommet.

quickly, keeping the heat of the soldering iron well away from the thermistor at all times. Once overheated, a thermistor's characteristics may change and drift indefinitely. In this event, permanent accuracy of the instrument is impossible.



Braille numbers, in various combinations, can be embossed on front panel for use by a blind person.

Calibration. There are several ways of calibrating the thermometer, most of them are somewhat complex. However, there is one simple method that is accurate enough for almost all purposes.

Assemble the thermometer, except for the thermistor. Connect a pair of 15- to 20-inch leads between the thermistor and its terminals on the circuit board. Using a large container of water and an accurate mercury thermometer, adjust the water temperature consecutively (from 55 to 100 degrees F) to the various temperature values to be calibrated. With the thermistor placed two thirds of its length into the water, set *R1* until the frequency of the audible tone is the same in both the SENSE and SCALE positions of *S1*. Mark the *R1* dial in accordance with the thermometer readings. Calibration at 5° intervals is adequate. Do not allow the thermistor leads to get wet as this may produce inaccurate temperature indications.

When calibration is complete and has been checked, remove the auxiliary leads from the thermistor and reinstall it in the cabinet.

HOW IT WORKS

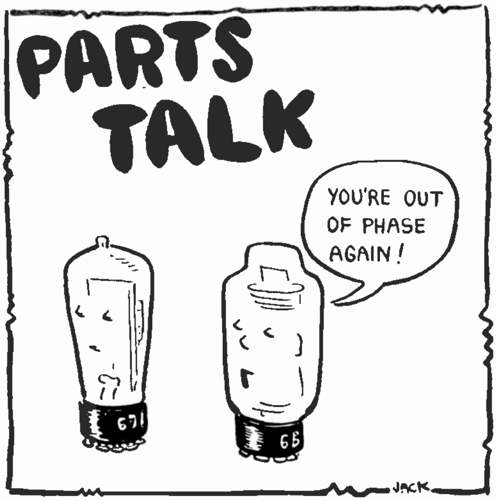
Unijunction transistor *Q1* is an oscillator whose frequency is determined by the combination of emitter capacitor *C1* and the resistance of either the thermistor *TH1* or calibration potentiometer *R1*. Audio output is obtained from B1 of *Q1* through transformer *T1*.

Switch *S1* is spring-loaded to return to its center position. If it is moved to either of its two other positions (SCALE or SENSE) and released, it will automatically return to the off position.

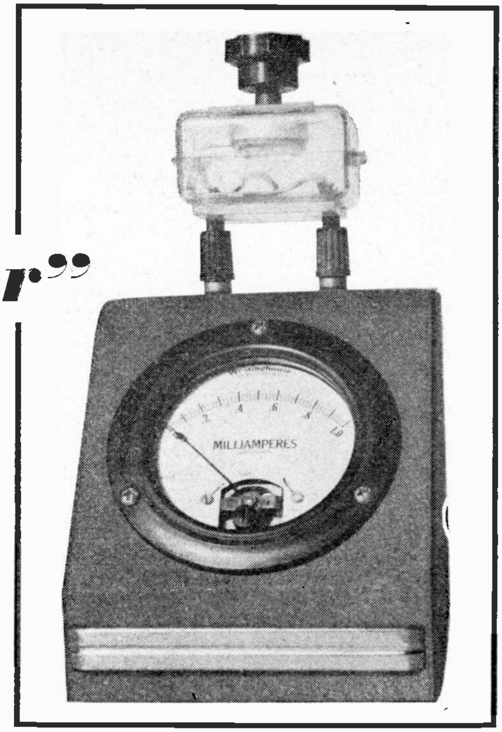
When *S1* is moved to SENSE, thermistor *TH1* supplies the resistance for the *RC* circuit which controls *Q1*. The transistor then oscillates at a frequency determined by capacitor *C1* and the resistance (at ambient temperature) of *TH1*. A thermistor is a semiconductor device whose resistance varies inversely with temperature; as the temperature goes up, the resistance goes down. Therefore, the audible output frequency is a function of thermistor resistance and, hence, the temperature.

The values of potentiometer *R1* and resistor *R2* have been selected so that, over the range of 55 to 100 degrees Fahrenheit, the resistance of *TH1* can be duplicated by adjustment of *R1*. Thus, when *S1* is in the SCALE position, *R1* can be adjusted to duplicate the tone generated by the thermistor.

Installation. The Sound-Signal Thermometer can be placed in any convenient place in the house and is always ready for immediate use. If desired, the thermistor can be mounted outside a window, with the cabinet on a window sill, ready to make outside temperature measurements within its range. When using external mounting, the thermistor leads must be waterproofed to prevent resistance changes caused by rain. -30-



Throw Together A "Quintupler"

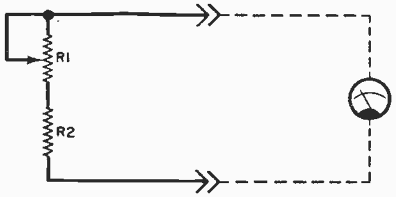


SHUNT UPS RANGE OF YOUR MILLIAMMETER

BY TOM GILBERT

HOW OFTEN has the pointer of your milliammeter been deflected off scale because the current through the meter was slightly too high? What did you do? Change meters or give up because you didn't have a suitable meter at hand? If your measurements can tolerate a modest inaccuracy, you need a "Quintupler."

The "Quintupler" is nothing more than a simple variable shunt that you temporarily place across the milliammeter. The shunt is made up of two resistances: a potentiometer (*R1*) equal to, or slightly greater in value than, the internal resistance of the meter movement; and a fixed resistor (*R2*) with a value of about 10-15% of the potentiometer's resistance.



Values of potentiometer R1 and resistor R2 depend on the internal resistance of the meter movement.

For example, if the meter has an internal resistance of 100 ohms, the potentiometer should also be 100 ohms, and the resistor between 10 and 15 ohms.

The following discussion assumes that your meter is a 0-to-1 mA unit; however, the same procedure applies to all current-measuring meters. Before using the variable shunt, adjust the current amplitude through the meter movement only for full-scale deflection. Plug the shunt into the meter's inputs, leaving the power connected. Now adjust the potentiometer so that the meter pointer deflects to 0.5 mA to obtain an *X2* range. For the *X3*, *X4*, and *X5* ranges, adjust the potentiometer so that the meter pointer deflects to 0.33 mA, 0.25 mA, and 0.20 mA, respectively. The *X1* range is obtained with the variable shunt out of the circuit. Record pot position for each range.

This setup allows you to measure up to 5-mA current amplitudes with only a 0-to-1 mA meter movement. Using a greater than five times multiplication factor for any given meter movement is not recommended since beyond this point the adjustment of the potentiometer is too critical. -30-

BUILD A
HART-65 TRANSMITTER

CLOSE TO THE LEGAL LIMIT NOVICE HAM TRANSMITTER CAN BE BUILT FOR 80 AND 40 USING ONLY ONE TUBE

By HARTLAND B. SMITH, W8VVD

OVER FIFTEEN YEARS AGO, the author wrote about a Novice transmitter with an input of 22-26 watts which cost about $20 to build.* Several months ago a new version of this single-tube transmitter was constructed. Through the use of a modern tube, the power input can be raised to 65 watts—but the construction cost remains just about the same—$20! Here is a Novice transmitter for 40 or 80 meters that is easy to build and provides just about the "mostest" for the very "leastest" investment.

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*POPULAR ELECTRONICS, *April, 1955, "The Hart-25," page 30.*

The "HART-65" was carefully constructed to minimize television interference (TVI). All r.f. carrying components, with the exception of the crystal, are shielded within an aluminum box. The key and power leads are bypassed to confine stray r.f. inside the case. A high-C pi-network plate circuit discriminates against harmonics that want to escape up the antenna feed line. In the unlikely event that a herringbone does appear on your family's favorite TV channel, a coaxial cable and low-pass filter can be connected between the transmitter and the antenna.

How It Works. The transmitter circuit is shown in Fig. 1. The tube, a 6HB5, was designed to be a TV horizontal amplifier, but it is also a highly efficient r.f. generator. A 3.5-MHz crystal is required for 80-meter operation and a 7-MHz crystal for 40-meter work. Pilot lamp *I1* indicates the r.f. current passing through the crystal. The brighter the bulb, the greater the current. Since too much r.f. energy will overheat the crystal, or possibly fracture it, trimmer *C1* has been included to provide a means of adjusting crystal current to a safe level.

The d.c. voltage to the plate of *V1* passes through an r.f. choke, *RFC2,* and any r.f. is blocked. However, the r.f. is passed by *C4* to *L1* and then on to output connector *J1*. Components *C5*, *L1*, and *C6* form a pi-network load and antenna circuit which can be tuned to the operating frequency. All of *L1* is used for 80 meters, while a portion of the coil is shorted by *S1* when 40-meter operation is desired. The output capacitor, *C6*, is adjusted to match the transmitter to a low impedance feed line. Capacitors *C7* and *C8* can be switched across *C6* to extend its impedance-matching range.

Although a telegraph key could have been wired directly in series with the cathode of *V1*, this arrangement was not used because it would have allowed a very dangerous 700 volts to appear across the exposed key terminals. Instead, 6.3 volts from the power transformer is applied to the coil of relay *K1* by the telegraph key. The relay, in turn, keys the

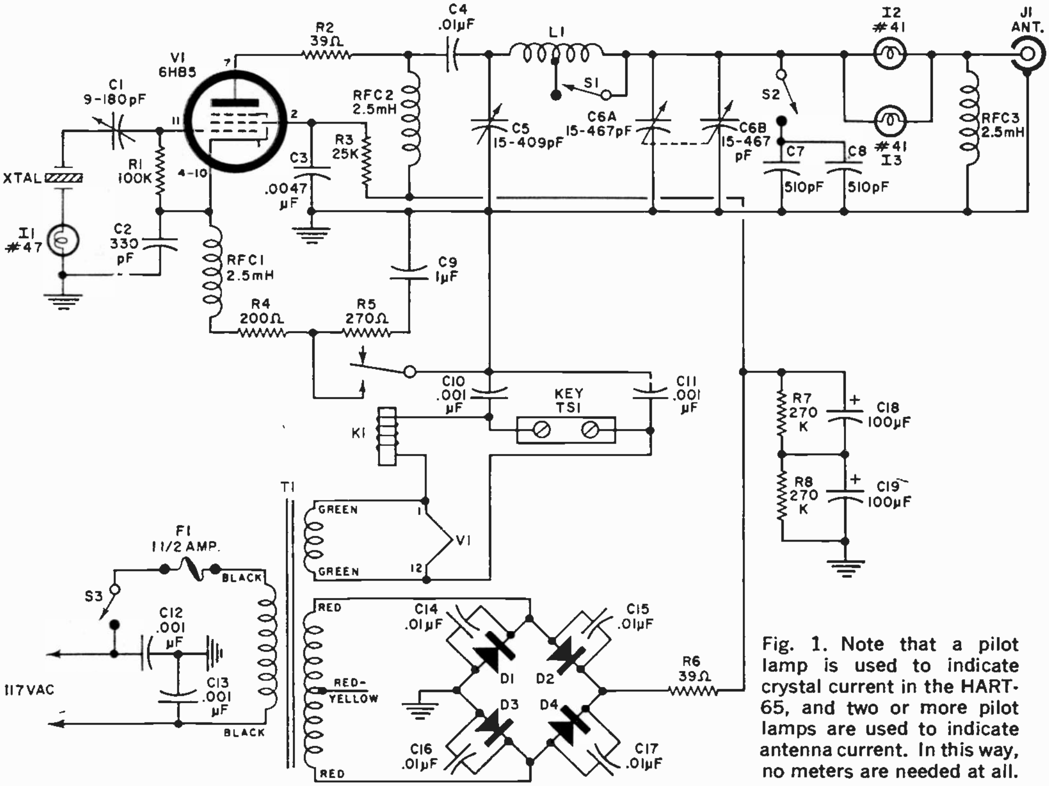


Fig. 1. Note that a pilot lamp is used to indicate crystal current in the HART-65, and two or more pilot lamps are used to indicate antenna current. In this way, no meters are needed at all.

transmitter. This arrangement keeps high voltage inside the transmitter, where it is less likely to attack a careless operator.

A built-in keying filter consisting of *R5* and *C9* minimizes key clicks to prevent undesirable interference to other fellows operating near your frequency.

Safety is one of the most important features of this unit. When the transmitter is properly buttoned up, there are no exposed high-voltage points to shock the unwary. Even across the key terminals, a danger spot overlooked in many transmitters, the voltage is only 6.3 volts.

Choke *RFC3*, connected between *J1* and the chassis, provides a d.c. path that will immediately blow the 1½-ampere line fuse, *F1*, should plate blocking capacitor *C4* fail, thus preventing a deadly voltage from ever appearing on the antenna or its feeder.

PARTS LIST

C1—9-180 pF mica trimmer capacitor (Allied Radio 43 C 3513, or similar)
C2—330-pF mica capacitor
C3—0.0047-µF disc ceramic capacitor
C4, C14, C15, C16, C17—0.01-µF, 1000-volt disc ceramic capacitor
C5—15-409 pF variable capacitor (Allied Radio 43 C 3524, or similar)
C6—15.5-467.8 pF two-gang variable capacitor (Allied Radio 43 A 3528, or similar)
C7, C8—510-pF mica capacitor (Aerovox 1464, or similar)
C9—1-µF, 600-volt paper capacitor
C10, C11, C12, C13—0.001-µF disc ceramic capacitor
C18, C19—100-µF, 350-volt electrolytic capacitor
D1, D2, D3, D4—750-mA, 1200-PIV silicon diode rectifier
F1—1½-amp fuse (3AG)
I1—#47 pilot lamp
I2, I3—#41 pilot lamp
J1—SO-239 coaxial chassis connector
K1—S.p.d.t. relay, 6.3-volt a.c. coil (Potter & Brumfield KA5AY-6AC, or similar)
L1—22¾ turns of #20 wire, 1" diameter, 1⅜" long, tapped 7 turns from C6 end (Barker & Williamson 3015 Miniductor, or similar)
R1—100,000-ohm, ½-watt resistor
R2, R6—39-ohm, 2-watt carbon resistor
R3—25,000-ohm, 12-watt wire-wound resistor
R4—200-ohm, 5-watt wire-wound resistor
R5—270-ohm, ½-watt resistor
R7, R8—270,000-ohm, 2-watt resistor
RFC1, RFC2, RFC3—2.5-mH, 125-mA r.f. choke (National R-50, or similar)
S1, S2, S3—S.p.s.t. slide switch
T1—Power transformer: primary, 117 volts, a.c.; secondary, 480 volts, CT @ 70 mA, and 6.3 volts @ 3 amperes (Allied Radio 54 C 1463, or similar)
TS1—2-screw terminal strip
V1—6HB5 tube
XTAL—See text
1—10" x 6" x 3½" aluminum box (Bud CU-2110A, or similar)
Misc.—Fuse clip; compactron tube socket (ceramic); 1-terminal insulated tie point; 2-terminal insulated tie strips (3); 4-terminal insulated tie strips (4); crystal socket, 0.095"-diameter pins, 0.487" spacing; ½" spacers for #6 screws (3); ⅜" to ¼" shaft extender (Allied Radio 47 A 1109, or similar); knobs (2); grommets, ½" mounting hole, ⅜" i.d. (6); grommet, ¼" mounting hole, 11/32" o.d.; 4-36 and 6-32 machine screws and nuts; line cord; plug; decals; wire; solder.

Since the HART-65 is strictly a CW rig, its power transformer need only supply plate current during the short intervals when the key is depressed. Between dots and dashes, as well as during standby periods, the transformer loafs along, merely furnishing a little heater power to the 6HB5. The intermittent nature of CW operation makes it possible to draw much more than rated transformer current under "key down" conditions without causing the transformer to overheat. Thus, a relatively small, low-cost transformer can be used.

A bridge rectifier utilizing the entire *T1* secondary, rather than half, as is the case with an ordinary center-tapped full-wave circuit, doubles the available d.c. voltage. Disc capacitors *C14* through *C17* in parallel with diodes *D1* through *D4* absorb stray voltage spikes which might otherwise ride in on the power line and destroy the diodes. In addition, the capacitors also bypass r.f. around the diodes to produce a clean signal in the shack. Without *C14* through *C17*, if you used your receiver as a monitor, the signal would sound disturbingly rough, even though it would be clear as a bell at a distance.

Resistor *R6* prevents a high current surge from ruining the diodes at the instant *C18* and *C19* first charge up when the a.c. power is switched on. Two filter capacitors in series are needed to withstand the "key up" voltage of the power supply. Equalizing resistors *R7* and *R8* divide the voltage drops across *C18* and *C19* so that one capacitor is not subjected to a significantly greater voltage than the other. These resistors also serve as bleeders to slowly discharge the capacitors after the power supply is switched off.

No plate meter is included in the transmitter. If the transformer specified in the Parts List is used, the input to *V1* will be between 60 and 70 watts, safely below the 75-watt Novice limit, when the

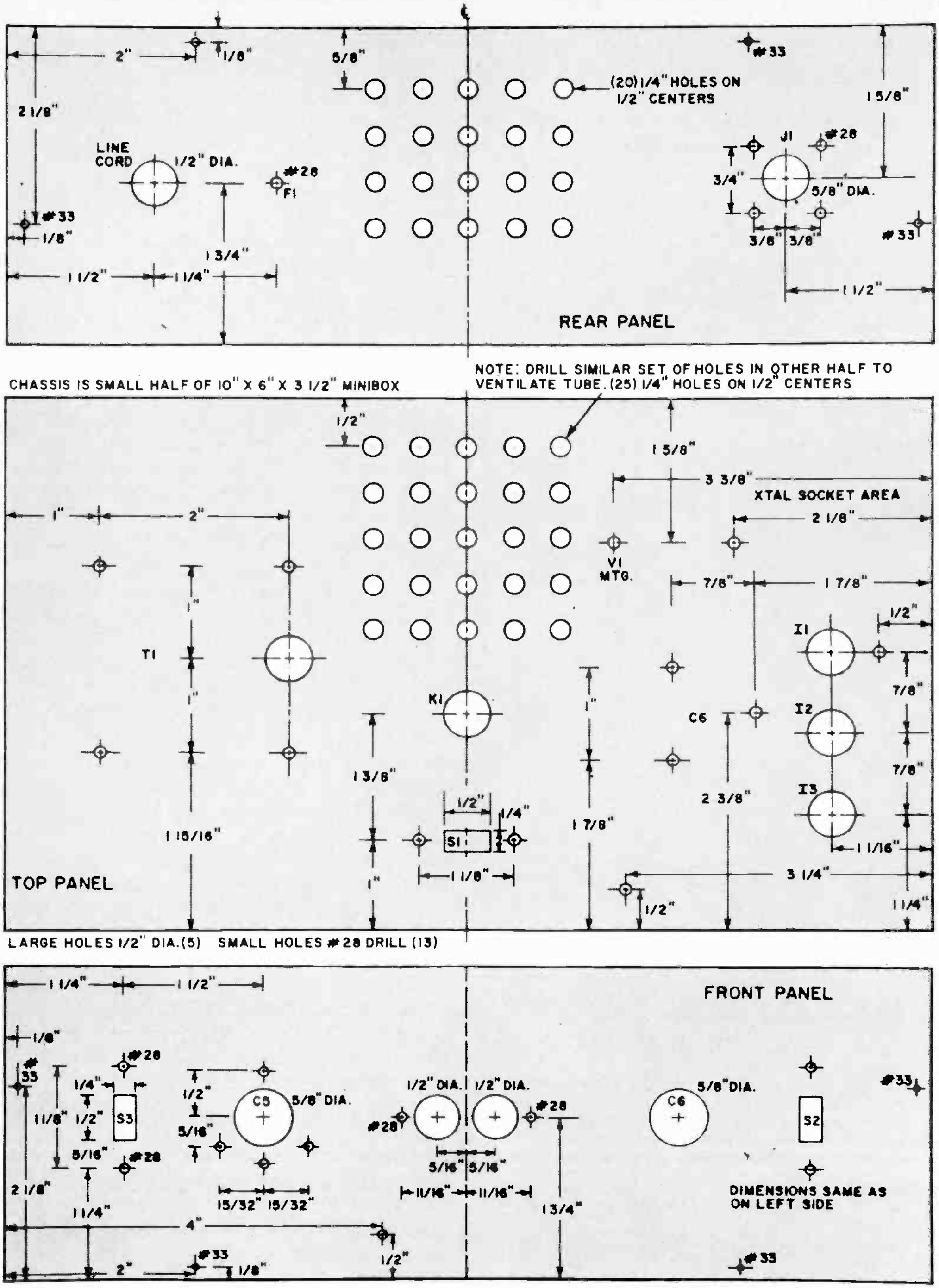


Fig. 2. Drilling specifications for the chassis. The three photos on the opposite page show the various holes and the location of all parts. Don't forget to drill 25 holes in the other half of the chassis, directly opposite the holes on the top panel. Crystal socket holes are drilled as required.

Top view of finished transmitter (right). Visible here are the top and rear panels with mounted components. In this transmitter, only the power transformer and crystal are mounted outside the chassis. Note that the three indicator lamps are mounted in ordinary rubber grommets fitted into drilled holes.

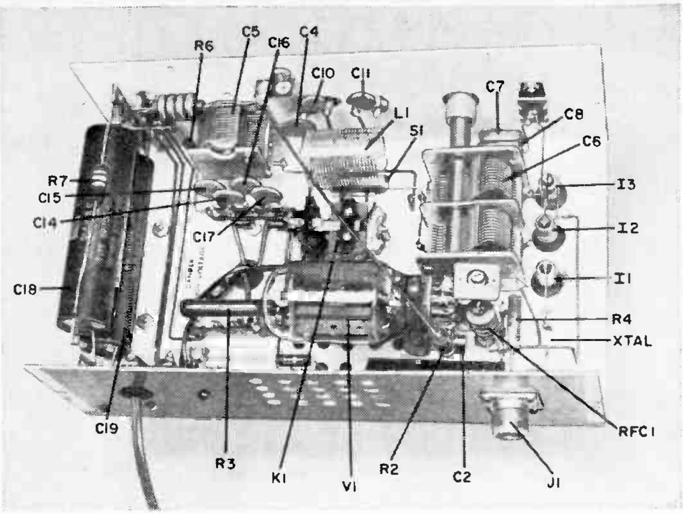
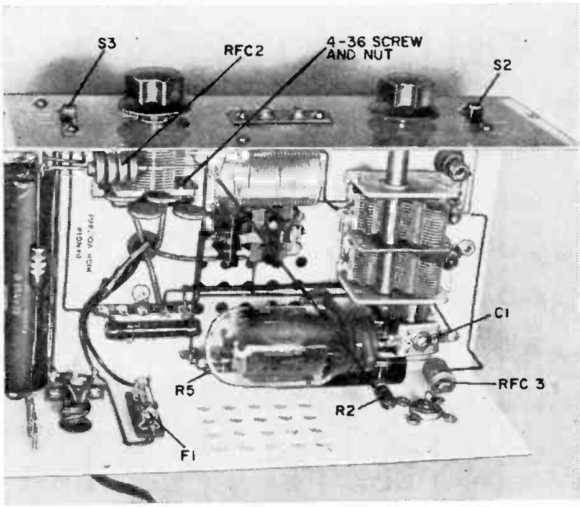


Fig. 3 (left and below). Views of the interior of the transmitter. Mounting details of certain components are shown enlarged on pages 82 and 83. Once the other half of the box is secured in place, the entire transmitter is shielded, and all high voltages are safe from accidental contact.



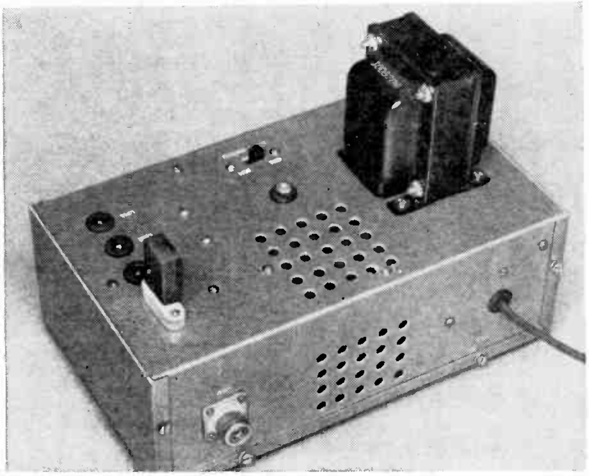
rig is tuned for maximum output as indicated by *I2* and *I3*.

Construction. A 10" x 6" x 3½" metal box serves as both cabinet and chassis for the transmitter. Major dimensions are shown in Fig. 2, while the photos on p. 77 and below show what the final unit looks like. A few of the small holes required for mounting the insulated tie strips have been omitted from the drawing because their exact positions will depend on the configuration of the mounting holes of the tie strips you buy. The crystal socket holes are also missing for the same reason.

It is very important that you drill all of the ¼"-ventilation holes visible in the photos and called out in Fig. 2. Otherwise, the considerable amount of heat generated by *V1* will be trapped within the chassis. Four rubber feet, at least ¼" thick, should be fastened to the bottom of the box so that it will clear the operating table sufficiently for air to circulate easily through 25 holes drilled in the bottom directly beneath the tube.

Indicator lamps *I1*, *I2*, and *I3* require no sockets. They are merely pressed into ½" grommets with ⅜" holes just far enough to assure a good friction grip (see photos). Appropriate leads are then soldered to the bases and tips of the bulbs.

Since relay *K1* is rather noisy, shock-mount it to prevent the chassis from act-



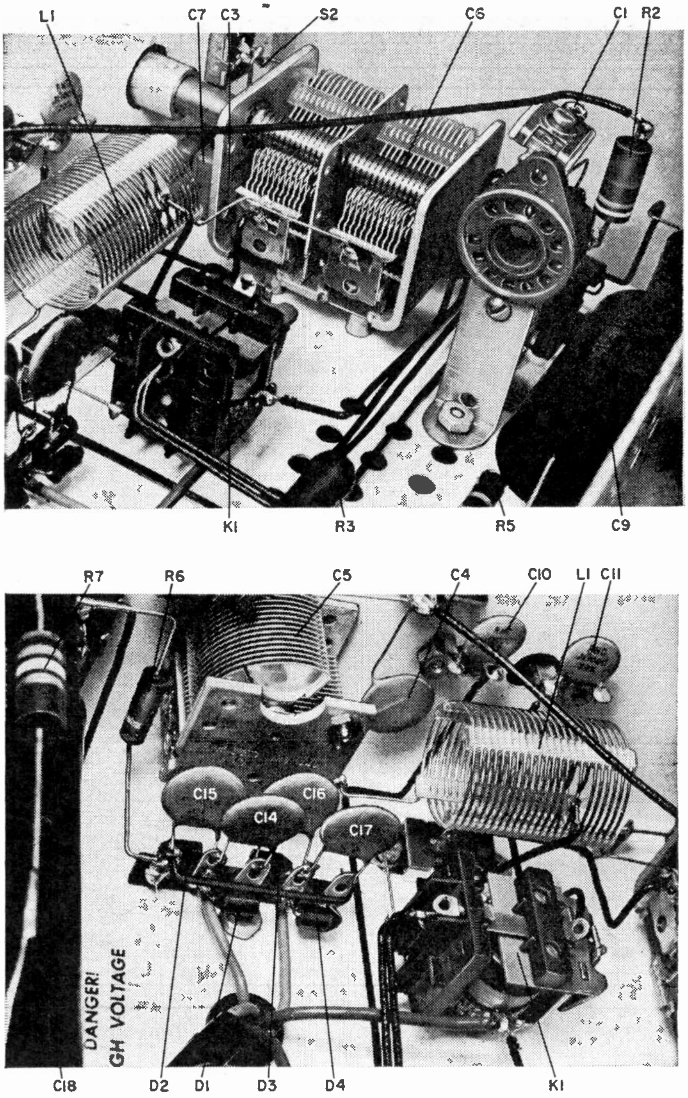
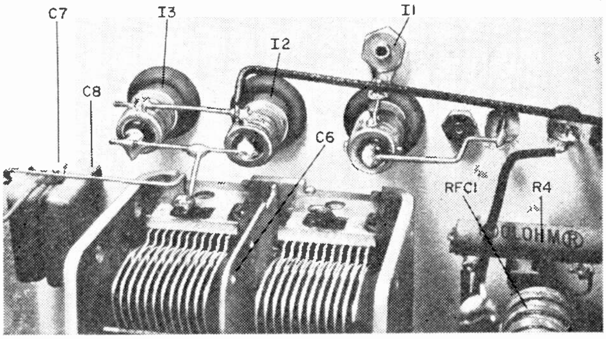


Fig. 4. Details of vacuum tube L-bracket (top) and rectifier and bypass capacitor mounting (bottom). The bracket is a narrow piece of scrap aluminum bent into an L-shape as shown with the vertical section about 1½″ long; mount the socket so that pin 4 faces the chassis. Also clearly shown in lower photo are the 4-36 screw and nut that prevents the rotor of C5 from opening fully to avoid accidental operation on 20 meters. Note method of "countersinking" L1's turns on both sides of tapped turn.

ing as a sounding board. In the prototype, the positioning lug on the base of the relay was cut off. Then, a ¼″ grommet was slipped over the *6-32* mounting bolt. This grommet was inserted in the ⅜″ hole of a ½″ grommet. A washer was placed over the short portion of the mounting bolt protruding above the chassis and the relay was secured in place with a *6-32* nut. These mounting details can be clearly seen in the photos between the *Band Switch* and ventilation holes on the top of the unit. An even quieter mount can be achieved by epoxy-cementing a 1″-square chunk of plastic sponge to the underside of the chassis and then epoxying the relay to the sponge.

Details of the underside of the chassis are shown in Fig. 3. Before mounting *C6*, remove and discard the trimmer adjusting screws, mica insulation, and trimmer plates located on the side of the capacitor. Since *C6* has a ⅜″ shaft, a ⅜″-to-¼″ shaft extender is required to adapt it for a knob having a ¼″ hole. Fasten capacitor to chassis using three ⅝″ long, *6-32* screws that pass through ½″ spacers and then into tapped holes in the bottom of the capacitor frame.

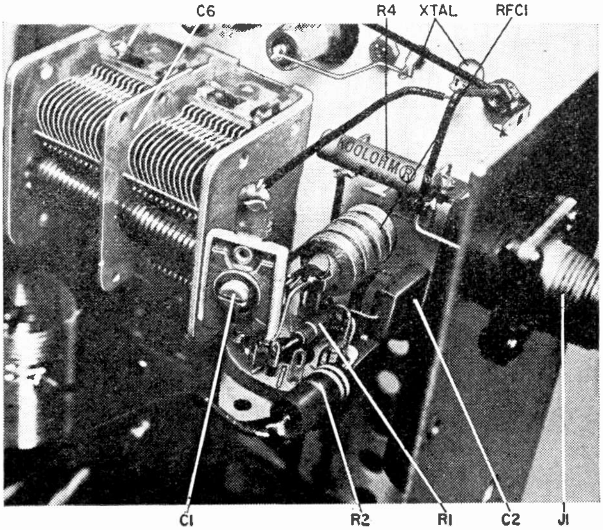
Attach *C5* to the front panel with three 1¼″ x *6-32* screws that have been cut down until they are long enough to hold



The three bulbs are press-fitted into ordinary rubber grommets. The crystal is mounted adjacent to I1. Note that I2 and I3 are connected in parallel.

the capacitor, but not so long that they extend through the frame far enough to touch the rotor. There are five holes in the rear of *C5*'s frame. Fasten a *4-36* screw in the upper right hole, as shown in Fig. 3, to prevent the rotor from opening fully. This action restricts the tuning range of the capacitor and will prevent you from accidentally resonating the transmitter at 20 meters when you're tuning up on 40.

Support *V1*'s socket on an L-bracket approximately 1½" high, as shown in Fig. 4, with the pin-4 side towards the chassis. When *V1* is plugged into the socket, the envelope of the tube should clear the bottom cover of the chassis by approximately ¾".



Details of the area around the tube socket. Trimmer C1 adjusts crystal current as indicated on lamp I1. Antenna output connector J1 is on the right panel.

Wiring. After mounting the major components, start wiring the power supply section. The red-yellow center tap of *T1* is not used. Snip it short and insulate the stub with electrical tape. When soldering diodes *D1* through *D4*, grip their leads with long-nosed pliers to drain away excessive heat.

While wiring *K1*, *TS1* and *S1*, keep in mind that you must leave room for *L1*, which will be installed after the balance of the circuit has been completed. Before installing *L1*, bend the turns on either side of the tapping point inward so that there will be plenty of clearance to prevent a blob of solder from creating an unwanted short.

Cut the leads of *R2* very short and solder the resistor directly to pin 7 of *V1*. A wire about 6" long can then be run diagonally across the chassis from the other end of *R2* to a one-terminal tie point supporting the junction of *RFC2* and *C4*. (See Fig. 3.)

Resistor *R1* is connected between pin 11 and pin 4 of *V1*'s socket; *C2* goes from pin 4 to a ground lug under the mounting nut that holds *V1*'s socket to the L-bracket; *C3* runs between pin 2 and the same ground lug; and *RFC1* goes from pin 10 to a two-terminal tie strip which also supports *R4*.

Solder the terminal of *C1* which is part of the capacitor's movable plate directly to pin 11. Run a wire from the other end of *C1* to the crystal socket.

When you have completed the overall wiring, apply the following words in a prominent spot on the underside of the chassis: "DANGER! HIGH VOLTAGE. CLOSE RELAY. SHORT B PLUS." These will remind you that after pulling the a.c. plug you should close the relay momentarily with an insulated prod to discharge *C9* and you should ground the positive end of *C18* with a shorting stick or the blade of a screwdriver with an insulated handle before working on any below-chassis component. *Don't neglect these warnings.* The bleeder on *C18* and *C19* works quite slowly, and the large value of capacitance in *C9* can hold a nasty charge for several days!

Crystals. Use a 3.5-MHz crystal for the 80-meter band, or a 7-MHz crystal for 40 meters. Although the transmitter will put out a 40-meter signal with an 80-meter crystal if *C5* is inadvertently set near minimum capacitance, NEVER operate the rig in this manner because it will radiate a strong subharmonic at the fundamental frequency.

Use only FT-243 type crystals, which are furnished in Bakelite cases that measure approximately 9/16″ wide, 1 1/8″ high, and 7/16″ thick. They are widely available on the surplus market at prices ranging from $1 to $1.50. Smaller HC6/U hermetically sealed crystals cannot be used in the HART-65 because they will overheat, drift, and possibly shatter.

The transmitter will not function satisfactorily on the 20-, 15-, or 10-meter bands. Don't attempt to modify it for such service.

Testing. *The power supply delivers up to 700 volts. Consequently, while performing the following tests, you must be sure to keep your fingers out of the works!*

After double-checking for wiring errors, plug in the power cord, attach a 100-watt bulb to *J1*, plug in an 80-meter crystal, and connect a telegraph key to *TS1*. Tighten *C1* for maximum capacitance. Set *C5* (*Tune*) and *C6* (*Ant. Loading*) at maximum capacitance, place *Band Switch S1* in the 80M (meter) position, and place the *Pad* switch (*S2*) in the IN (closed) position. Turn on the a.c. power. After a one-minute warm-up, close the key. Relay *K1* should click shut. Slowly reduce the capacitance of *C5* until the 100-watt lamp glows brightest. Mark the position of *C5*'s knob with "80M". In the future, whenever you work 80 meters, *C5* should always be set to approximately this point.

Plug in a 40-meter crystal. Place the *Band Switch* (*S1*) in the 40M (meter) position, and set the *Pad* switch (*S2*) in the OUT (open) position. Adjust *C5* for maximum lamp brilliance, and mark the position of the tuning knob with "40M".

Remove the antenna from your ham receiver and tune in the transmitter's signal. Send a series of rapid dots while slowly opening *C1* (reducing capacitance) with an insulated screwdriver. Use only enough capacitance to assure reliable, chirp-free starting of the crystal every time the key is operated. When *C1* is properly adjusted, indicator lamp *I1* (marked *XTAL*) will barely glow. If it lights up brightly, too much current is flowing through the crystal.

Bear in mind, too, that *T1*, *V1*, the r.f. chokes and several resistors are operated above their continuous-duty ratings. Therefore, when you're tuning the rig, never hold the key down for more than 10 seconds at a time. Always allow a 15-second cooling interval before operating the key again.

Antennas. For maximum performance and minimum harmonic radiation, separate center-fed half-wave antennas for 80 and 40 meters are recommended. Do not attempt to get by with a multiband radiator or a random-length wire.

If an 80-meter dipole is too long for your piece of real estate, don't hesitate to bend it around corners, or even droop the ends. Whatever the final arrangement, though, make certain that you have a total of 125′ of wire in the air.

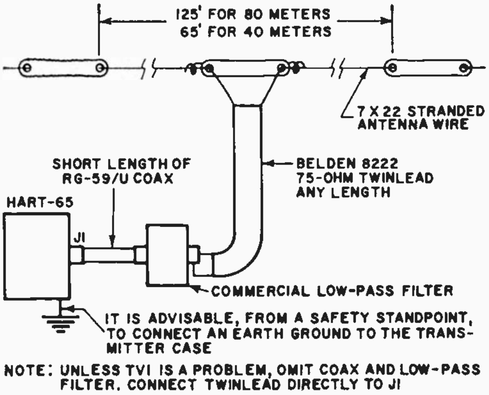


Fig. 5. Suggested antenna system for the HART-65. The commercial TVI filter is an optional feature.

Although the antenna itself must be cut to the dimensions given in Fig. 5, the feeder can be of any convenient length. RG-59/U coaxial cable can be used if you want a fancy installation, but Belden 8222 75-ohm receiving-type twin lead, at $1.65 per hundred feet, will cost a lot less and will perform quite satisfactorily.

On The Air. Plug in the appropriate

(*Continued on page* 94)

Getting To Know The Zener Diode

Unique Component Disregards Ohm's Law

BY NORMAN CRAWFORD

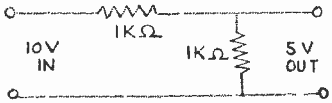
AMONG THE SCORES of semiconductor devices available to the modern electronics enthusiast, none seems to be more underestimated and misunderstood than the zener diode. Since the zener diode has the unique ability to regulate voltage within precise limits, regardless of changes in load impedance or supply voltage, this is indeed a strange situation.

The zener diode is not only unique among solid-state devices: it is also one of the most important in terms of circuit efficiency and safety. The experimenter or hobbyist who fails to take advantage of its properties works under a handicap. Even so, its relatively uncommon usage suggests that many experimenters do not fully understand how the zener diode works—or they dismiss it as being of dubious value.

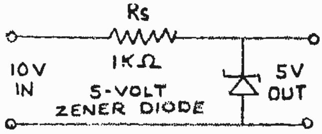
While there are several good books on the market dealing with zener diodes, most of them are written for engineering-level readers. The few books that are less technical rarely do more than inform the reader that such devices exist. This article bridges the gap between little or no useful information and information that is unnecessarily top-heavy with technical details.

Voltage-regulator circuits are most commonly employed in electronic power supplies, but they are applicable to any circuit in which a constant-level voltage is required. To understand why voltage regulation is so important, it is necessary to review the conditions that exist when there is no regulation.

Consider the output circuit of an unregulated electronic power supply. In its simplest schematic representation, the circuit consists of an input voltage, a supply resistance, and an output resistance. The input "sees" the two resistances as a voltage-divider network. If both resistances are of equal value—say, 1000 ohms—the output voltage is just half of the input. Therefore, with 10 volts input, the output is 5 volts; for 15 volts input, the output is 7.5 volts, and so on.



The important point to bear in mind here is that these output voltages are ideal; no load has been connected across the output. Now, replace the output resistor with a 5-volt zener diode, and apply 10 volts to the input.

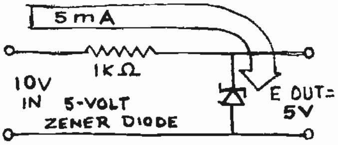


As before with the two 1000-ohm resistors in the circuit, the voltage divides exactly in half so that 5 volts appears at the output. What happens when the input potential is raised to 15 volts? Oddly enough, the output remains at 5 volts as a result of the regulatory ability of the zener diode.

In the voltage-divider circuit, according to Ohm's law ($I = E/R$), current flow through the circuit is 5 mA when the input is 10 volts. Therefore, the output potential must be $E_{out} = I \times R = 0.005 \times 1000 = 5$ volts.

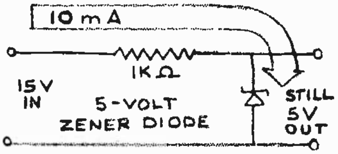
By applying Ohm's law for a 15-volt input, it can be determined that the current flow becomes 7.5 mA and output voltage jumps up to 7.5 volts.

When a 5-volt zener diode is substituted for the output resistor, however, a strange phenomenon takes place when the input voltage is increased. With a 10-volt input, 5 mA must circulate to produce a 5-volt output.



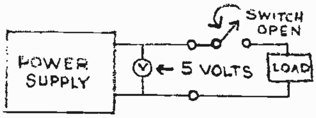
Thus, the same current-voltage relationship as in the voltage divider network exists when the zener diode is substituted and a 10-volt potential is applied to the input.

Raising the input to 15 volts causes the zener diode to conduct more current (10 mA), but it maintains a 5-volt output in spite of the increased current.

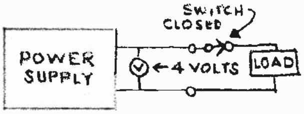


This shows that, while a resistor behaves according to Ohm's law, the zener diode disregards it, changing its effective resistance as needed to provide a constant output voltage.

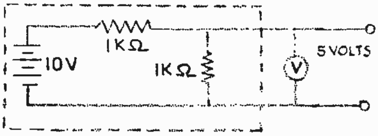
To see how this unique ability of the zener diode can be put to good use, consider a hypothetical power supply whose 5-volt output (unloaded) is unregulated.



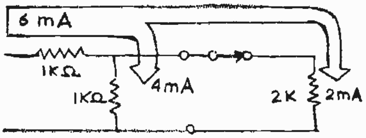
When the load is switched into the output circuit of the power supply, its output drops to 4 volts.



Now, give a few values to the hypothetical components inside the power supply: 1000 ohms each for the supply and output resistances, and 10 volts for the source. To keep the example simple, assume that the load is an ordinary 2000-ohm resistor.

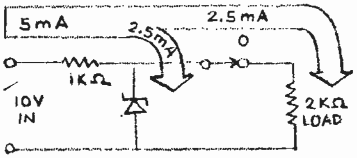


With the switch open and the load disconnected, the output is 5 volts with 5 mA in the output resistor. Closing the switch puts the 2000-ohm load in parallel with the output resistor so that the 6 mA now drawn from the source divides: 4 mA through the output resistor and 2 mA through the load resistor.



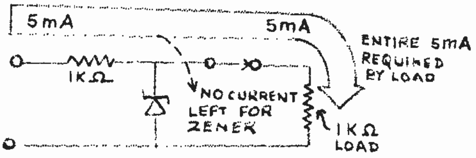
Using Ohm's law, $E_{out} = 2000 \times 0.0002 = 4$ volts. What happens is that the load resistance shunts the output resistance, decreasing the total resistance "seen" by the source and reducing the voltage drop across the load.

How can the zener diode help? Well, first, substitute a 5-volt zener diode for the output resistor. With the switch open, there is a 5-volt drop across the diode as in the example discussed earlier. The difference is that, when the switch is closed and the load is connected to the output of the power supply, the current still divides—2.5 mA going to the zener diode, and 2.5 mA going to the load.



The reduction in current through the zener diode has little or no effect on it (up to a certain point), and the diode maintains a constant 5-volt output. As a result, the 2000-ohm load has 5 volts across it. Because the load is a resistor (it can be any other type of load for that matter), it cannot ignore Ohm's law, so it draws current: $I_{load} = E/R = 5/2000 = 2.5$ mA.

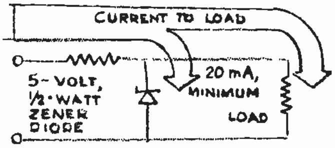
At this point, you might well ask what would happen if the load were to drop to 1000 ohms. To find out, simply apply the above formula again, substituting 1000 ohms for the 2000 ohms in the denominator. Thus, the current now required by the load is 5 mA; but with this new drain, the zener diode is completely deprived of current.



With no current available for the zener diode, it ceases to conduct, and the voltage across the load begins to decrease with further decreases in load resistance.

Even before complete current starvation, however, most zener diodes indicate their inability to maintain regulation by allowing the output voltage to sag.

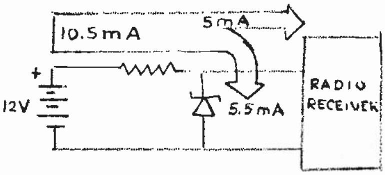
A good rule of thumb is to keep about 20% of the zener diode's maximum current flowing through it when the load is heavy. To determine maximum current handling ability, you need only apply the power formula: P = IE. Let us assume you have a 5-volt, ½-watt zener diode and you want to know its maximum current handling ability. Since P = IE, I = P/E = 0.5/5 = 100 mA. The current through the diode should not be allowed to fall below 20 mA.



All of the foregoing may be very interesting, but what practical applications are there for zener-diode regulation?

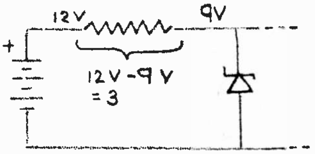
One of the more common uses for the zener diode is in reducing and maintaining voltages to and at a safe level. To demonstrate, let us say that you have a portable radio receiver that requires a 9-volt d.c. supply and you wish to operate it from the 12-volt cigarette lighter accessory in your car. Obviously, you need a 9-volt zener diode.

Designing the regulator circuit is relatively easy. If the radio receiver draws 5 mA of current, and the battery potential is 12 volts, you must first determine the maximum zener diode current allowable. Let's take a guess and start with a ¼-watt zener diode. Using the power formula, $I_{max} = P/E = 0.25/9 = 27.8$ mA. Twenty percent of 27.8 is 5.56 mA. Hence, 10.5 mA must be drawn from the voltage source—5 mA for the load, and 5.5 mA (minimum) for the diode.



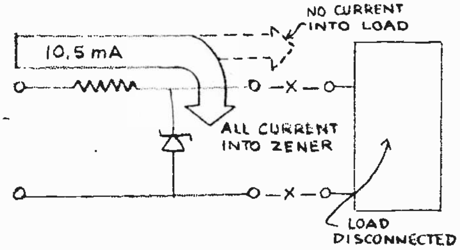
We know now that 10.5 mA must flow

through the resistor, that the battery is holding 12 volts on one side of the resistor, and that the drop across the diode is 9 volts.

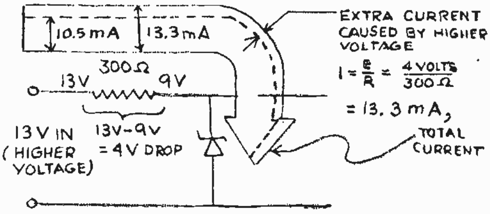


The result is that 3 volts is dropped across the resistor. Ohm's law now tells us the value of the resistor: R= E/I = voltage drop/current = 3/0.0105 = 286 ohms. Because 286 is not a standard ohmic value, we would use a 300-ohm resistor. Next, we use the power formula to determine the power rating required: P = 0.0105 × 3 = 31.5 mW. Almost any commercially-made 300-ohm resistor can be used; it just has to dissipate more than 31.5 mW.

While the circuit components thus selected will almost certainly work, let's find out how they will bear up under "worst-case" conditions. First, assume that power is suddenly disconnected from the receiver.



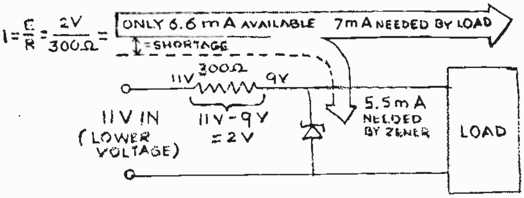
Just as suddenly, the entire 10.5 mA is now diverted to the zener diode—and while we're at it, let's assume that the input voltage chooses this instant to jump up to 13 volts.



As you can see, the current through the diode jumps to 13.3 mA. Back to the power formula; P = 0.0133 × 9 = 119.7 mW—still well below the ¼-watt (250 mW) maximum for the zener diode.

But we're not finished yet. We still have to check on what is happening to the resistor; P = 0.0133 × 4 = 53.2 mW—again well within the maximum ¼-watt rating. Everything checks out.

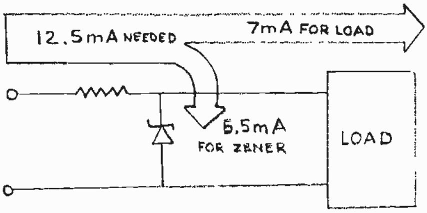
Now, assume that 1 or 2 mA more current is drawn (as a receiver with a class-B output circuit is likely to do on high-volume settings) and that the source suddenly decides to drop to 11 volts.



This leaves only 2 volts, dropped across the source resistor, to drive the current through the resistor. As a result, current drops to about 6.67 mA.

Unfortunately, the receiver requires 7 mA to operate properly. Deprived of current, the zener diode stops regulating, and the output voltage drops until there is enough of a drop across the resistor to supply the receiver's needs. As the supply voltage drops, the receiver will probably operate less than satisfactorily. The regulator circuit is a failure, and something has to be done to rectify the problem.

All is not lost, and because of the simplicity of the circuit, the solution is also simple. Something must obviously be done about the resistor. Since we know that the zener diode requires 5.5 mA of current to operate and the receiver requires an additional 7 mA, 12.5 mA must come through the resistor.



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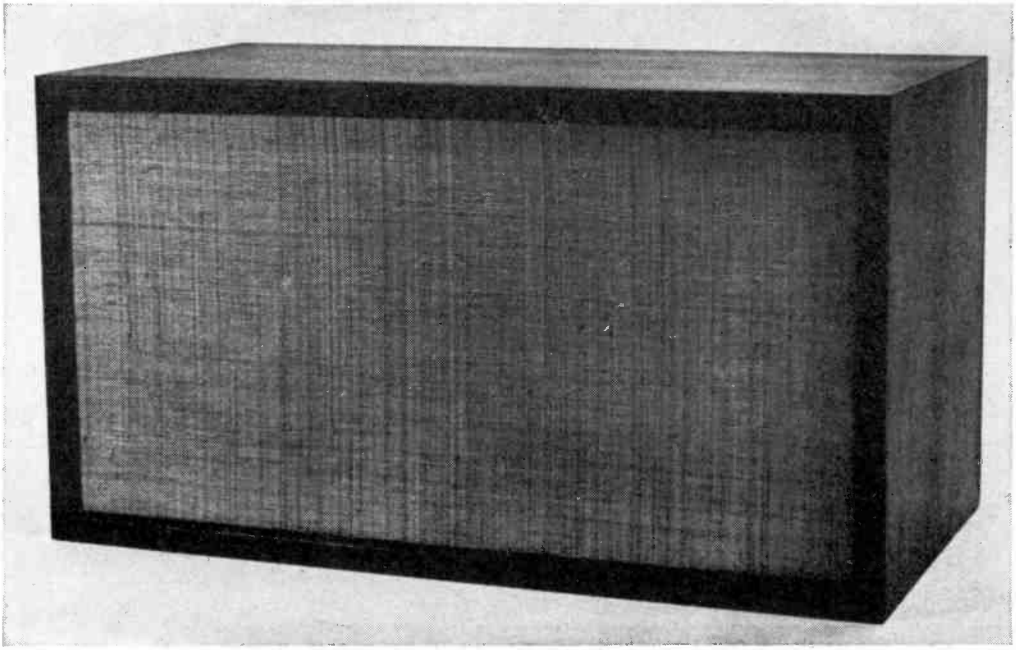
SEALED-REFLEX



SPEAKER SYSTEM

Build something new in hi-fi—a passive radiator system that provides better bass, dynamics, and efficiency

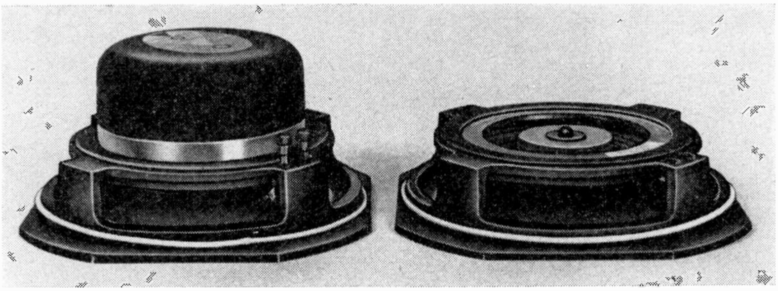
BY DAVID B. WEEMS

IF YOU'VE BEEN PLANNING to build a compact speaker system but can't decide between using a bass reflex or a sealed enclosure, why not build a sealed reflex? By adding an extra "speaker cone" to your enclosure, you can obtain increased bass performance without using ducts or ports.

Experiments to add "free" bass performance have been going on for more than 15 years in projects called by such names as "drone cone," "auxiliary bass radiator," and "passive radiator." The common denominator of each of these projects has been the addition of a freely suspended speaker cone (speaker minus its magnet assembly and voice coil) to a sealed enclosure. Some of the results obtained from these experiments have given rise to the sealed-reflex speaker system described here. The system consists of a full-range 8″ loudspeaker and a complementary cone which the manufacturer, James B. Lansing, terms a "passive radiator."

About the System. The sealed reflex offers several advantages over the conventional compact speaker system. Noticeably improved bass response is possible in the sealed enclosure with the use of a passive radiator. While an ordinary bass reflex will provide approximately the same results, there are a few differences.

The air in the port of a bass-reflex system does not necessarily move in phase with the movement of the speaker cone at all frequencies nor even at all



The PR8 (right) is nothing more than heavy speaker cone without voice coil and magnet. Cone is tuned by adding circular weights.

points across the port. The passive radiator, on the other hand, maintains an in-phase movement of air over its entire surface and throughout its effective range. Thus the possibility of unwanted mid-range reflections through an open port is eliminated. Proponents of the sealed-reflex system claim that it gives a "warmer" tonal quality to the sound than does the bass-reflex system.

Any cone mounted inside a sealed enclosure produces extra bass at some frequencies, but its range and freedom from distortion are determined by the mass and suspension of the cone. The suspension must be linear and compliant because the passive radiator, having no electromagnetic control, moves much farther than a driven speaker's cone. The JBL passive radiator, Model PR8, used in this system, was designed for free movement and is tunable to various enclosure sizes by a change in its mass. When used with the JBL Model LE8T complementary 8″ loudspeaker it is possible to obtain low-distortion wide-range response with greater efficiency and dynamic range than with the usual compact speaker system.

Construction. The enclosure for the passive radiator system features unitized construction; each wall of the enclosure is permanently bonded and sealed to the other walls. This procedure is possible because the speakers are front mounted. The hardware (T-nuts and machine screws) for the speakers is supplied.

To achieve a clean professional appearance when assembling the enclosure, bevel the mating edges of the top, bottom, and two side panels at a 45° angle. Leave the front and rear edges of these panels square. If you have no facilities in

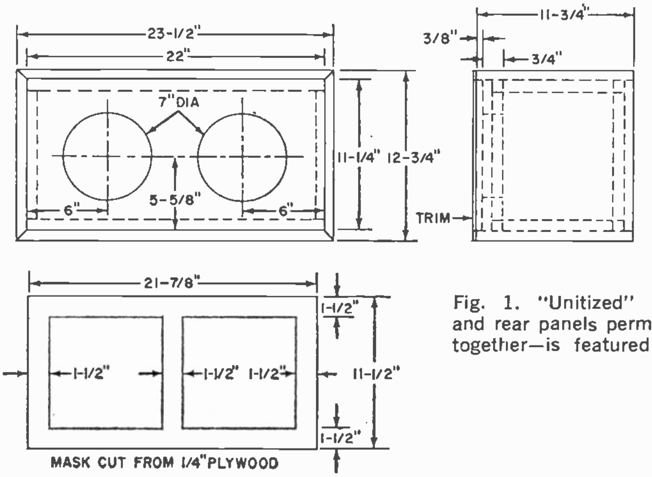


Fig. 1. "Unitized" construction—sides, front, and rear panels permanently glued and screwed together—is featured in the enclosure design.

your workshop for making the beveled edges, be sure to adjust the sizes of the panels used so that the enclosure has the same inside dimensions called out in Fig. 1.

After cutting the lumber to size, prepare the speaker mounting board as follows. First cut the two 7″-diameter speaker holes. Then drill 11/64″ guide holes every 4″ apart and ⅜″ in from the edges of the mounting board. Temporarily set the speakers into the holes from the *front* of the board and mark the location of the mounting holes. Remove the speakers.

Now, carefully drill the mounting holes at 90° angles to the surface of the board (if you have a drill press, use it) with a 7/32″ or 15/64″ drill. Install the T-nuts by driving them into the holes from the *inside* surface of the board.

Replace the speakers into their respective holes, and temporarily screw in the machine screws to check for proper fit. Finally, remove the hardware and speakers and set the speakers aside in a safe place. When handling the speakers, be careful not to touch the cones or aluminum domes.

Prepare the rear panel by drilling 11/64″ guide holes every 4″ around the edges, recessing them ⅜″ in from the edges as done with the speaker mounting board. Drill two small holes near the center of this panel, and insert two tight-fitting bolts to serve as terminals for connection to the speaker. Code the bolts by using one brass and one steel bolt, or by some other method so that you can identify the polarity of the speaker. Connect a 24″ length of twin-lead cable to the screws.

BILL OF MATERIALS

*1—James B. Lansing Model LE8T 8″ loudspeaker**
*1—James B. Lansing Model PR8 8″ passive radiator**
2—23½″ x 11¾″ x ¾″ pieces of interior-grade plywood for sides
2—12¾″ x 11¾″ x ¾″ pieces of interior-grade plywood for top and bottom plates
2—22″ x 11¼″ x ¾″ pieces of interior-grade plywood for speaker mounting board and rear plate
1—21⅞″ x 11⅛″ x ¼″ piece of plywood for mask; see text
4—22″ x ¾″ x ¾″ pieces of pine for side cleats
4—9¾″ x ¾″ x ¾″ pieces of pine for top and bottom cleats
4—8⅜″ x ¾″ x ¾″ pieces of pine for corner blocks
Misc.—¾″-wide trim cut to size; 6-doz. #8 flat-head wood screws; glue; fiberglass wool; carpet tacks; grille cloth; two-conductor cable; stain; etc.

**James B. Lansing loudspeaker and passive radiator are available from most well-stocked hi-fi centers or can be ordered through franchised JBL retailers.*

Next, cut the cleats and corner blocks to size, and drill 11/64″ holes, along their center lines, in one direction every 4″ apart. Set the cleats aside, and drill the same size holes through the corner blocks in the other direction every 4″ apart; alternate these new holes with those already drilled. (The 11/64″ guide holes should be used only in a construction member that holds the head of the screw. Use 7/64″ or ⅛″ guide holes for the part receiving the threads. Also, countersink all 11/64″ holes to provide a flush surface over the screw heads.)

The quickest and most efficient way to obtain a good seal is to use glue liberally between all surfaces to be joined. Therefore, glue and screw the long cleats to the long sides, leaving a margin of ¾″

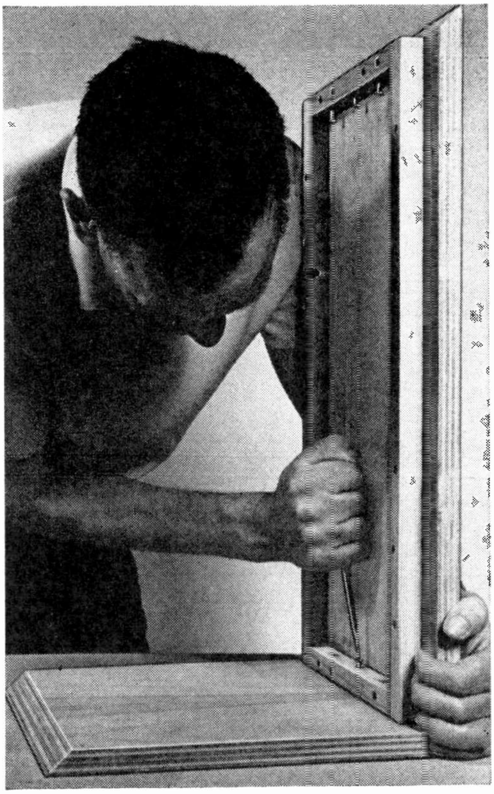


Fig. 2. Corner blocks, drilled in two directions, must be used to anchor sides to top and bottom.

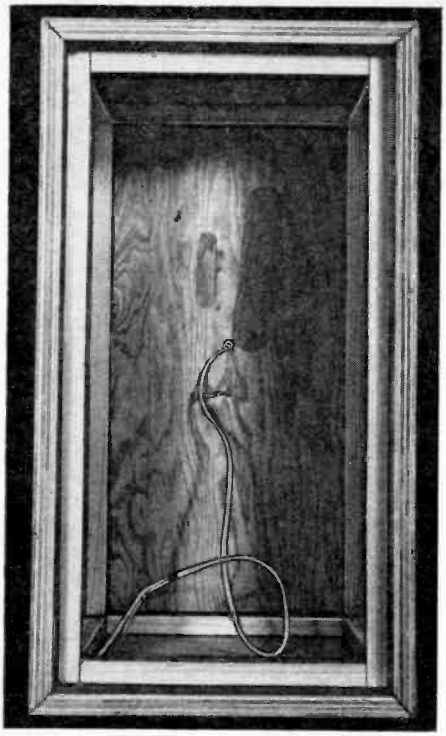


Fig. 3. Two screws, inserted through rear of enclosure, serve as electrical connections.

at the rear and 1⅛" at the front. Do the same with the corner blocks.

Set up a long side and either the top or bottom panel with the beveled edges matching. Mark the points where the screws from the corner block will enter the top or bottom panel. Drill the small guide holes about ⅜" deep at these locations. Glue and screw the two pieces together (see Fig. 2), and repeat this process until both sides and top and bottom are assembled.

Now glue and screw the 9¾" cleats to the top and bottom panels. These cleats must fit snugly between the longer cleats to prevent air leaks when the enclosure is fully assembled. Glue and screw the rear panel in place as shown in Fig. 3.

PASSIVE RADIATOR TUNING TABLE

0.75-1.0 cu. ft.	use two discs
1.0-1.5 cu. ft.	use one disc
1.5-2.0 cu. ft.	use no discs

Line the top, bottom, sides and rear wall of the enclosure with a 2"-thick layer of acoustical fiberglass. Glue and screw the speaker mounting board to the front of the enclosure. This board should be recessed from the front edges of the enclosure by approximately ⅛" at this time.

Cut four pieces of ¾"-wide wood trim to size, and frame the front edges of the enclosure; use glue to hold the trim in place. Sand and stain all outer surfaces—except speaker mounting board. If you use wider trim, it should be secured as the final step in assembly when the grille cloth is in place.

Before mounting the passive radiator, remove the screw that anchors the discs at the rear of the radiator. Remove one of the discs. Then reassemble one disc, the large washer, the small lock washer, and the screw in proper sequence, and tighten the screw back in place—but don't over tighten. The passive radiator is now tuned to the enclosure.

Connect the speaker cable to the speaker, taking care to note polarity. Mount the passive radiator and speaker in their respective holes as shown in Fig. 4. You will notice that the edges of the speakers protrude about ¼" in front of the speaker mounting board. For this reason it is necessary to fabricate a mask from ¼"-thick plywood, following the dimensions provided in Fig. 1. This mask should be slightly smaller than the speaker mounting board—how much smaller will be determined by the thickness of the grille cloth.

Drive several ⅝" carpet tacks through the front of the mask. Set the side of the mask with the tack heads showing over the grille cloth, fold the edges of the grille cloth over the edges of the mask, and staple. Set the mask over the speakers, pushing the tacks into the speaker mounting board to anchor it solidly. If you are using larger than ¾"-wide trim, now is the time to glue it in place.

Conclusion. This enclosure offers a good compromise between space and performance requirements. The LE8T/PR8 combination can be used in any enclosure from less than one cubic foot to two cubic feet in volume. It is estimated that a two-cubic-foot passive radiator system

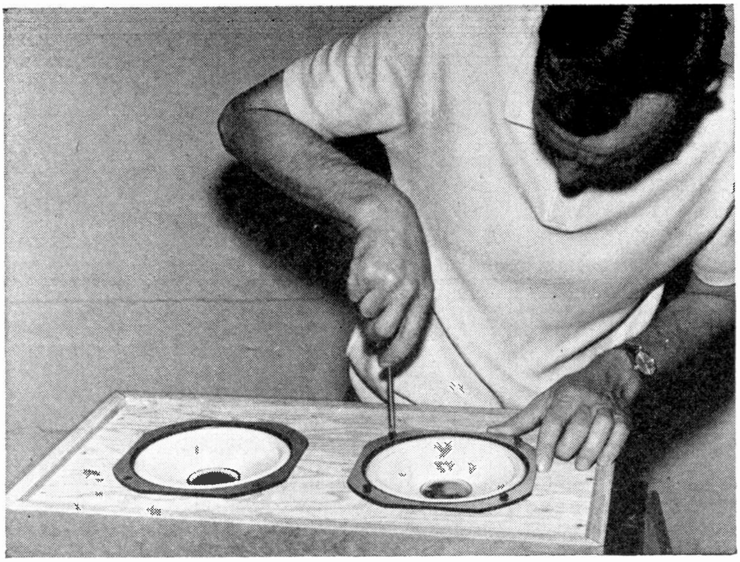


Fig. 4. T-nuts and machine screws are provided to facilitate passive radiator and loudspeaker mounting. Note that the LE8T and PR8 are designed for mounting through the front of the speaker mounting board.

HOW DOES IT SOUND?

This is probably the most expensive hi-fi speaker-system construction project published in the EE HANDBOOK. The author and his colleagues all report that the sound from the JBL LE8T-PR8 combination is "pleasing." The bass may be less heavy than in certain other compact systems (selling at about the same price this system costs to build), but it seems natural. Transient response is particularly good and there is little doubt this system has the "edge" in dynamic range. In fact, this combination is thought to be more lively than a well-known system selling for $25 more than construction costs. There is a feeling of "warmth" of tone in the sound—especially in the reproduction of the lower string notes.

will equal the performance of a four- or five-cubic-foot bass reflex system. If you wish to use a different size enclosure, tune the passive radiator according to the table shown on page 92.

Although the tuning specifications specified are those recommended by JBL, you can vary them to match your own tastes. You might also want to experiment with more or less fiberglass padding. When you obtain the quality of sound you want, you're in business. The sealed reflex system will handle up to 20 watts of power but it is efficient and may be used with a low-power amplifier. -30-

---

GADGET BOX

(*Continued from page* 28)

for the interconnections. You can anchor the 9-volt battery to the perf board with a length of wire as shown in the photo on page 28.

As far as controls are concerned, you can select almost any type that suits your fancy. The d.p.s.t. push-button switch designated for *S2* in the Parts List requires some preparation before installation. First decide which set of contacts you will use as the power switch for the siren assembly. Then, bend these contacts so that they are the first to close and the last to open when *S2* is depressed.

For the ticker circuit, two controls were used—the on/off switch, *S1*, is a switched potentiometer, but the potentiometer section is not used; and a separate pot was used for *R3*. If you wish, you can use just one switched pot to control the tick rate and power. Almost any general-purpose unijunction transistor can be used for *Q1*.

If you're going to paint the cigar box or decorate it with adhesive-backed vinyl, do so after drilling but before mounting any of the parts. Then, when you're finished with construction, show your child once or twice how the controls work and the functions of the Gadget Box. Then, quietly back out of the room and leave him to his own devices. -30-

HART-65 TRANSMITTER

(*Continued from page* 84)

crystal and antenna. Place the *Band Switch* (*S1*) in the appropriate position. Set *C5* (*Tune*) at the correct band mark, then place the *Pad* switch (*S2*) in the IN position. Slowly reduce the capacitance of *C6* (*Ant. Loading*) while slightly readjusting *C5* for brightest indication on *I2* and *I3* (marked *Line*). On 40 meters, you may find it necessary to place the *Pad* switch in the OUT position to obtain the most power from the transmitter.

If lamps *I2* and *I3* are very dim, or don't glow at all, disconnect one of them. This will double the current through the other and you should then get a usable indication. On the other hand, if the bulbs are very bright, you may find it necessary to add a third—similar—bulb, one in parallel with the other two to prevent them from burning out. Bulb brightness is dependent on feed line length and the amount of standing wave present in your particular installation. Since *I2* and *I3* are relative indicators only, just tune for the best indication and forget about how bright or dim they are at maximum output.

When you've completed the tuning process, the knob of *C5* should be fairly close to the band marked on the panel. If it isn't, your antenna is not properly constructed, the *Band Switch* is in the wrong position, or *C6* has been set at too low a capacitance with the *Pad* switch in the OUT position. In any case, don't work 80 meters with *C5* at less than half capacitance, because the nearer *C5* approaches minimum capacitance, the more likely the transmitter is to put out an unwanted 40-meter harmonic.

While testing the prototype, Novices and Generals were worked throughout the U.S. and Canada on both 80 and 40 meters. The little rig has a click-free pure d.c. note that is a joy to copy. It is rock-steady on 80, and its 40-meter stability compares favorably with that of many low-cost VFO transmitters presently on the market.

If you're looking for an inexpensive way to put out a truly effective signal, the HART-65 is a construction project well worth considering. -30-

VOLT-OHMMETER

(*Continued from page* 62)

changes, adjust *R2* on the V/F module to get an identical 001 reading with the input test leads either open or shorted. Center the adjustment on the 001 reading and then adjust it slightly lower, favoring the 000 reading.

DIGITAL VOLTMETER SPECIFICATIONS

Ranges: D.c. volts: 0-2, 0-20, 0-200. Ohms: 0-200, 0-2000, 0-20,000, 0-200,000. Range extendable to anything that can be represented by a variable 0-2-volt d.c. signal.

Input Impedance (Voltmeter): 0-2, 1 megohm; 0-20, I megohm; 0-200, 10 megohms.

Maximum Ohmmeter Current: 0-200,000 ohms, 10 μA; 0-20,000 ohms, 100 μA; 0-2000, 1 mA; 0-200, 10 mA.

Resolution: One part in 200, any range. ±5 millivolts on 0-2-volt range, ±0.5 ohms on 0-200-ohm range.

Accuracy: Better than ±1% of full scale, ±1 count over most portions of most ranges. Internal calibration with 1.35-volt secondary mercury standard.

Stability: Less than 1 count drift per 20 minutes after 15-minute warmup.

Noise Rejection: Instrument is a fully integrating, multiple slope type and is essentially "blind" to any 60-Hz line-borne hum or noise and has a high degree of rejection to all other high-frequency noise.

Update Time: 15 measurements per second; instrument integrates input for 16.7 milliseconds and displays for 50 milliseconds.

Miscellaneous: Automatic overrange indicator, floating decimal points for "actual value" indication; zener input protection; polarity reversal switch; internally self-calibrating; useful accuracy to 200% of full scale.

To calibrate the ohmmeter portion, ZERO and CALibrate the DVM as described above. Then place the test leads across a precision 1% resistor between 1300 and 1500 ohms (do not use higher or lower values) and switch to the 0-2K resistance range. If the DVM does not read exactly the resistance being measured, adjust *R13* on the V/F module till it does. The instrument is now fully calibrated on all scales.

Readjust the ZERO and CALibrate 1.35 front-panel controls any time you like. This gives you an instant check on how the DVM is doing. The internal trimmers will rarely need readjustment. -30-

BUILD THE SPORTS TIMER

Get thousandths-of-a-second accuracy up to 10 minutes—useful for a variety of sports events

THE AVAILABILITY OF LOW-COST decimal-readout counting units has created an entirely new "ball park" of experimentation for the advanced electronics hobbyist. This new area is digital-readout instruments and we will be publishing several articles on such projects in the issues to come. The first is the "Sports Timer," a real-time clock, described here.

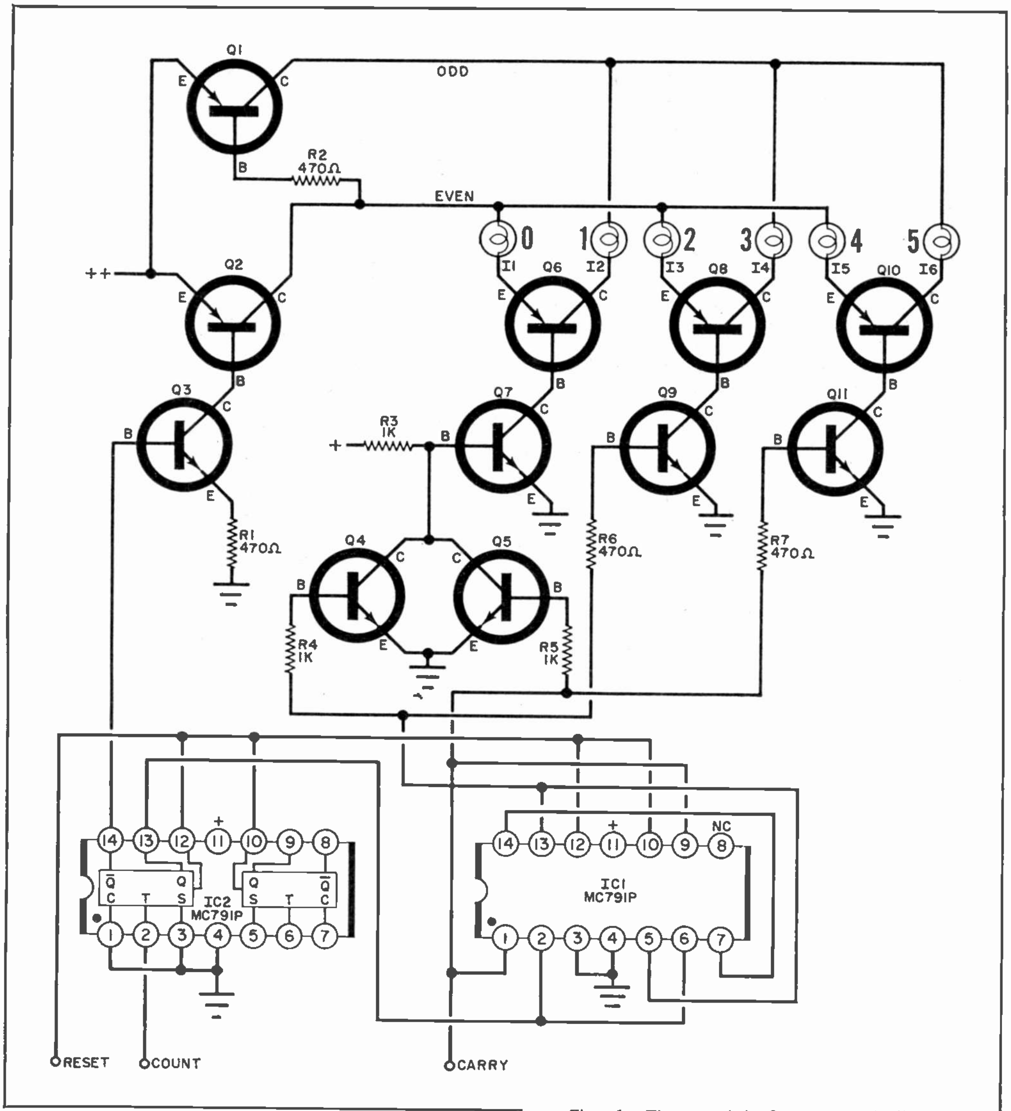


Fig. 1. The modulo-6 counter indicates only up to five, then returns to zero. Simultaneously, it passes a carry (trigger) pulse to the next decade counter.

PARTS LIST

I1-I6—6.3-volt, 50-mA pilot light and cap assembly (Southwest Technical Products #0-6.3 or similar)
IC1, IC2—MC791P dual JK flip-flop integrated circuit (Motorola)
Q1, Q2, Q6, Q8, Q10—MPS3638 or 2N5139
Q3, Q4, Q5, Q7, Q9, Q11—MPS2923 or 2N5129
R1, R2, R6, R7—470-ohm, ½-watt resistor
R3, R4, R5—1000-ohm, ½-watt resistor
A complete kit of parts for the modulo-6 counter is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, for $10.00, postpaid in U.S.A.

The clock is basically a combination of two previous projects ("Low-Cost Counting Unit," and "Ultra-Fast Electronic Stopwatch," 1969 Winter Edition, ELECTRONIC EXPERIMENTER'S HANDBOOK, with the addition of a modulo-6 counter that counts, and indicates, to 5 and then returns to zero. This counter is required in real-time measurements in order to get the 5 needed in measuring 59 seconds or 59 minutes before switching to the next register. (The original counter reads out to 9 before returning to zero.)

The "Sports Timer" is designed to read out to 9 minutes and 59.999 seconds,

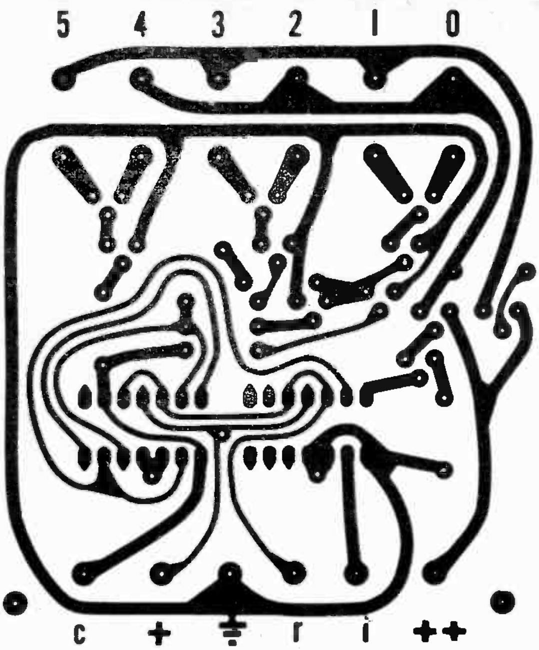


Fig. 2. Actual-size foil pattern for the modulo-six counter. It is the same size as the boards used for the other circuits (see text) simplifying construction of timer.

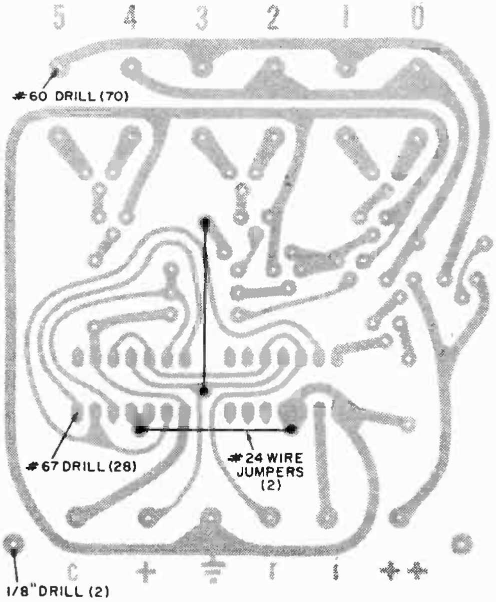


Fig. 3. Drill the PC board as shown here, and add the two insulated jumpers on component side of board.

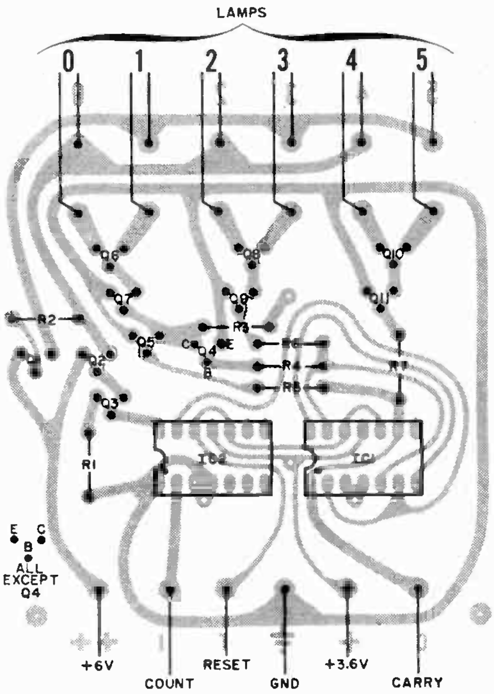
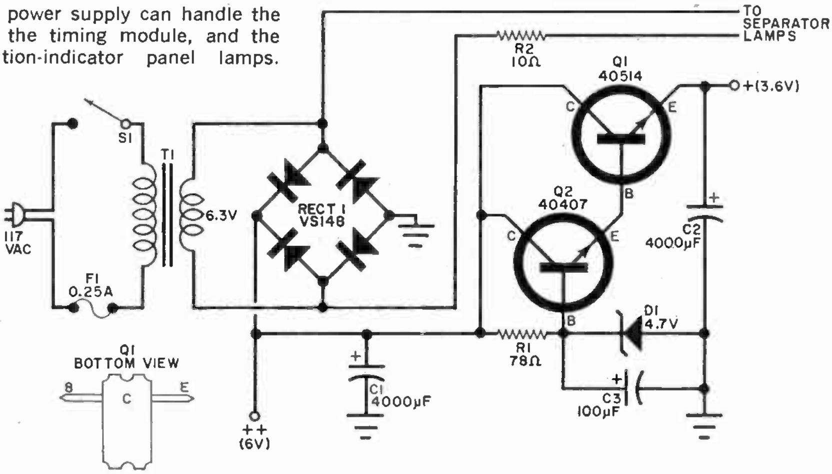


Fig. 4. Mount the components as illustrated here making sure that you orient the semiconductors properly. Note Q4 is not installed in same way as Q1-Q11.

Fig. 5. The power supply can handle the six DCU's, the timing module, and the three position-indicator panel lamps.

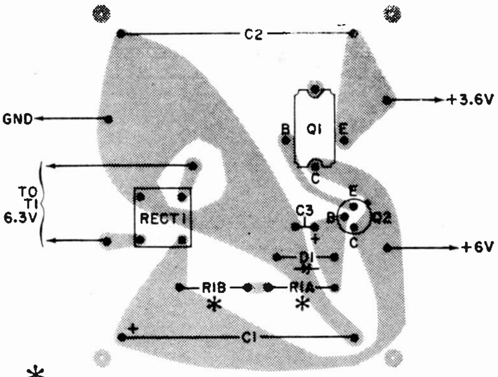


PARTS LIST

C1, C2—4000-µF, 6-V electrolytic capacitor
C3—100-µF, 15-V electrolytic capacitor
D1—4.7-V zener diode
F1—0.25-A fuse
R1—78-ohm, 1-W resistor (two 39-ohm, 1-W resistors in series)
R2—10-ohm, ½-W resistor
RECT1—Full-wave bridge rectifier (Varo VS148, or similar)
S1—S.p.s.t. switch
T1—Filament transformer; secondarys 6.3 V, 2 A
Q1—40514 power transistor (RCA)
Q2—40407 transistor (RCA)
Misc.—Heat sink for Q1, fuse holder, silicone grease, wire, solder, four standoffs, etc.

A complete kit of parts is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, for $9.75, postpaid in U.S.A.

Fig. 6. Actual-size foil pattern for power supply. Like all the other PC boards, this one is also available etched and drilled (see Parts List for ordering details).



*SEE PARTS LIST

Fig. 7. Component installation on the power supply PC board. Note that R1 is two resistors in series.

which should be sufficient for the majority of track events, auto races, swimming contests, ski runs, etc. If desired, however, the maximum time can be extended to read up to 9 hours, 59 minutes and 59.999 seconds. Besides sporting events, the clock can be used to time tape recordings and speeches and has applications in laboratories, photo darkrooms, or any other activity where an illuminated readout clock capable of measuring to small parts of a second can be used.

The clock can be started and stopped in a variety of ways. A photoelectric start-and-stop circuit (described in this article) is one way; others include the operation of mechanical contacts, such as pushbutton switches or step-on doormat switches. If desired, the clock can be started from a microphone and amplifier system adjusted to pick up the crack of the starter's pistol. The number of triggering methods possible is limited only by the imagination of the user.

Construction. Because the decade counting units and the crystal-controlled timing circuit have already been described in detail (see the 1969 Winter ELECTRONIC EXPERIMENTER'S HANDBOOK) only the modulo-6 counter is covered here.

The basic modulo-6 counter (schematic shown in Fig. 1) uses two low-cost IC's, eleven transistors, 7 resistors, and six incandescent bulbs. Cost of this counter is $10 (see Parts List). An actual-size printed-circuit-board foil pattern is shown in Fig. 2, while Fig. 3 shows how the board is to be drilled and the location of the two jumpers required. These jumpers are made from #24 solid wire and are added on the component side of the board.

When mounting the components, as shown in Fig. 4, be sure to observe the correct positioning of all semiconductors, noting that the IC's are identified by a notch and dot code at one end. Use a low-wattage soldering iron and fine solder to make all connections.

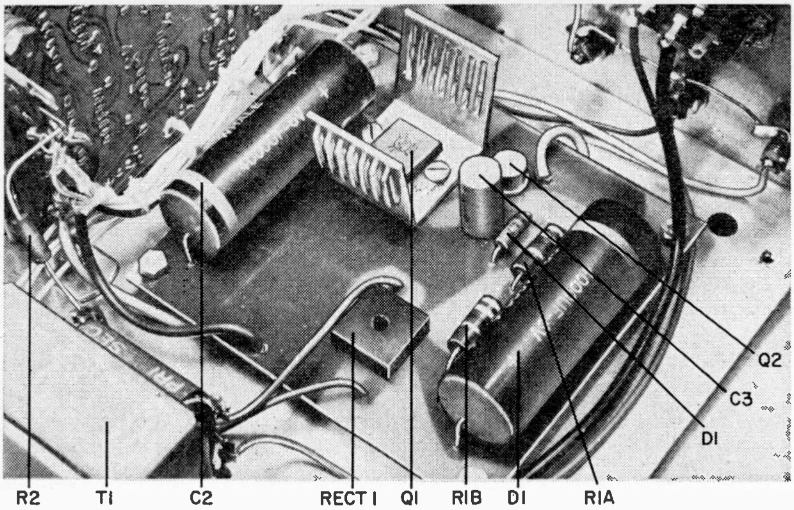
If desired, a readout-lamp display bracket can be cut and bent from a piece of 1/32″ aluminum similar to that shown in the "Counting Unit." Pop rivets can be used to secure the bracket to the board. Press the plastic lamp covers into the six holes, then press the bulbs into the plastic covers. After each bulb is wired to its correct terminals, use black "instant transfer" numerals to identify them, coating the numbers with a clear acrylic spray to prevent accidental removal.

Note that, in the finished clock, lamp mounting brackets are not used on any of the readouts, but holes are drilled in the front panel using the lamp brackets (provided with each kit) as a template. If you select this method of construction, be sure to leave *all* lamp leads as long as possible before soldering the far ends to the PC boards.

To duplicate the "Sports Timer" shown in the photos, you will need five 0-9 counting units, one 0-5 counting unit, a crystal-controlled timer, three 6.3-volt lamps and plastic covers, a power supply, and a chassis.

Power Supply. The power supply provides 3.6 volts at very low ripple for use by the IC's, 6 volts for the numerical-display incandescent lamps, and approximately 6.3-volts a.c. for the three position-indicator lamps (two making up the colon, and one for the decimal point). A suitable supply, shown in Fig. 5 consists of a transformer-powered bridge rectifier followed by a two-transistor, zener-diode-controlled regulator. The separator lamps get power from *T1* through dropping resistor *R2*.

The power supply can be assembled on the printed board shown actual size in Fig. 6. All parts, with the exception of power transformer *T1*, fuse *F1*, and dropping resistor *R1* are mounted on the board as shown in Fig. 7.



To prevent components from shorting against chassis, install spacers between the chassis and the power supply board.

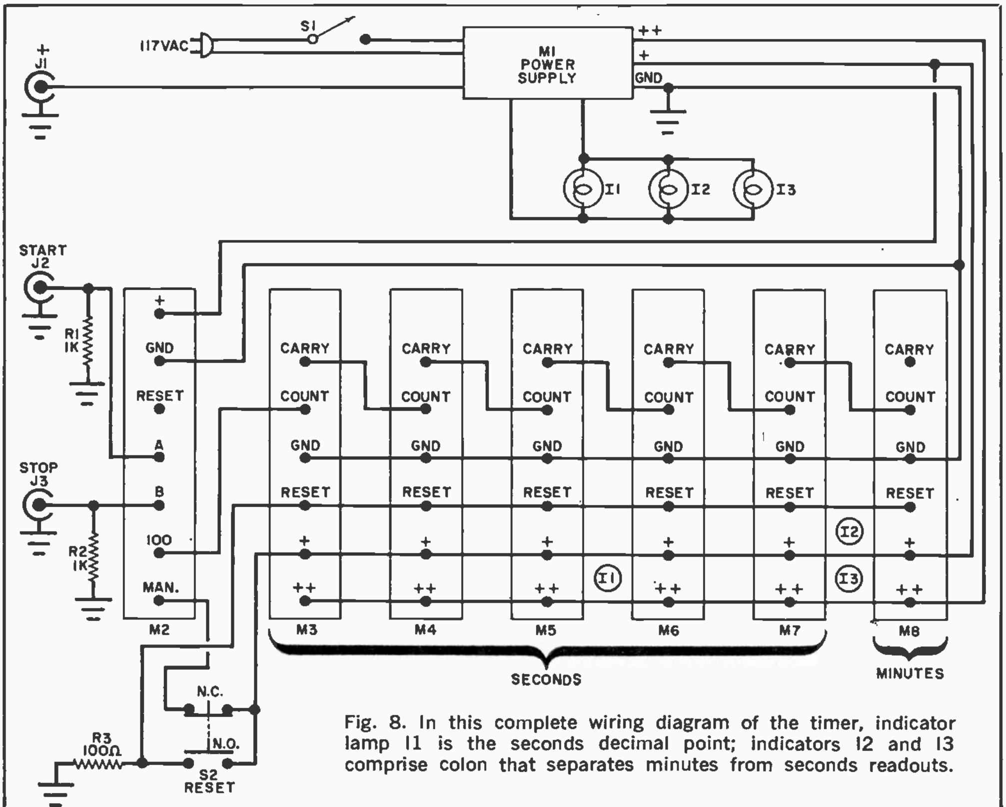


Fig. 8. In this complete wiring diagram of the timer, indicator lamp I1 is the seconds decimal point; indicators I2 and I3 comprise colon that separates minutes from seconds readouts.

PARTS LIST

I1, I2, I3—6.3-V, 50-mA pilot light and cap assembly, two green, one red (Southwest Technical Products #0-6.3, or similar)
J1, J2, J3—Phono jacks, RCA types
M1—Power supply
M2—Timing module
M3, M4, M5, M6, M8—Decade counting unit
M7—Modulo-6 counter
R1, R2—1000-ohm, ½-W resistor
R3—100-ohm, ½-W resistor
S1—S.p.s.t. switch
S2—S.p.s.t. momentary pushbutton switch
Misc.—Chassis, mounting hardware, line cord, adhesive-contact plastic (optional), wire, solder, etc.

The following parts are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216: Timing module kit with 100-kHz, 0.005% crystal, $24; decade counters, $12; chassis, punched, primer coated, and with covering material for top, $6.50.

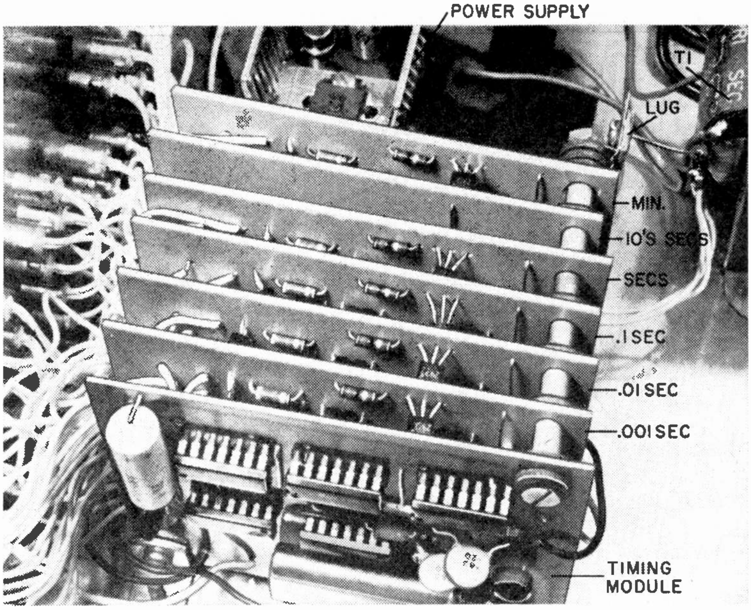


Fig. 9. Timing module and DCU circuit boards should be stacked for space conservation and neatness. Use ½"-long insulated spacers (or metal spacers and fiber washers) between each board for adequate separation. Board designations from bottom to top are M2 through M8.

Assembly. The 10" wide by 3½" high by 7" deep metal chassis, used by the author consists of two U-shaped sections. One serves as the mounting chassis for the completed circuit (Fig. 8) and the other is used as the cover.

Start the assembly by drilling the required holes in the front panel for the readouts, using the lamp bracket as a template. The plastic lamp covers are press-fit into the holes, and the lamps are press-fit into their covers. Therefore, when assembling the counters, use the full length of wire provided with each lamp. Don't forget to drill the three holes for the position identifier lamps. Drill a hole to accept the RESET pushbutton *S2*, power ON-OFF switch *S1*, and three phono jacks *J1*, *J2* and *J3*.

Before mounting any components on the front panel but after drilling the required holes, cover the entire front panel with a contact-adhesive plastic coating whose pattern or color appeals to you. Use a sharp knife to remove the material from the area where the holes are. Apply the front panel markings with any type of instant-transfer lettering. The box outline was made with thin black tape. The author used a red plastic cover for the decimal indicator (*I1*) and a green cover for the colon indicator (*I2*, *I3*).

The interior layout is shown in Fig. 9. The seven printed boards are separated from each other with ¼" spacers at the two rear mounting holes. If metal spacers are used, place a non-conducting

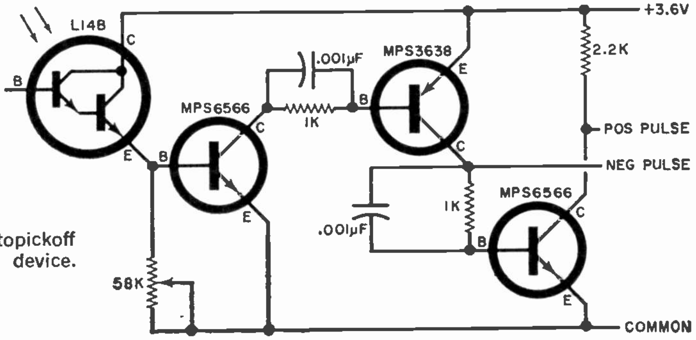


Fig. 10. Suggested photopickoff for use as a start/stop device.

washer between each spacer and the adjacent foil section to avoid any chance of short circuits. Use 3″-long thin bolts to fasten the boards together. The bolt passing through the bottom portions has a small L bracket at each end to secure the bottom edges of the boards to the base of the chassis. A similar pair of L brackets is used to secure the outer boards at the front. Mount an insulated single-lug terminal strip at the nut end of the upper mounting bolt as shown in Fig. 9 to support resistor *R2*.

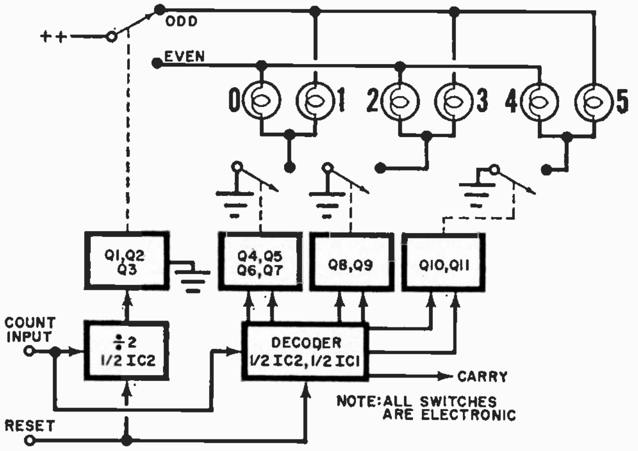
Drill suitable holes in the base to mount the fuse holder, power transformer, and power supply as shown in the photo. Mount the power supply using four small standoffs, then secure the transformer and the fuse holder.

Once all components have been mounted, insert the bulbs in the respective plastic holders and wire the components as shown in Fig. 8.

Testing. Once final assembly is complete, turn on the power (*S1*) and note that the decimal point and the colon indicator lamps come on. The various counters will be at some random numerical indication. Depressing the RESET button should cause all readouts to indicate zero.

Being very careful, use a small piece of wire to make an electrical contact between the center contact of the (+) jack *J1* and the similar contact on START jack *J2*. As soon as this is done, the counters will start to operate. The counter on the far right (thousandths of a second) will assume a dim, blurred condition, indicative of very fast counting.

(*Continued on page* 145)



NOTE: ALL SWITCHES ARE ELECTRONIC

HOW IT WORKS

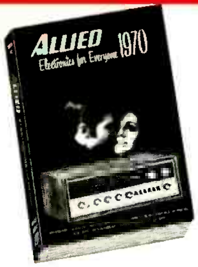
Operation of the decimal counting unit and the timing unit were described in the Winter 1969 Edition of ELECTRONIC EXPERIMENTER'S HANDBOOK; therefore, only the operation of the modulo-6 counter will be described here.

The input pulse train is fed to a divide-by-two counter (half of *IC2*), a flip-flop which changes state with each input pulse. One state of the flip-flop indicates an odd number, while the other indicates an even number. The odd-even signal is processed by transistors *Q1*, *Q2*, and *Q3* so that, on even numbers, the "even" bus is energized, and on odd numbers, the "odd" bus is energized. The five state-indicating incandescent lamps are connected in pairs to the odd and even buses, and each pair is connected to ground through a set of switching transistors. These transistors act as open switches when they are cut off and closed switches when saturated, thus determining when each bulb is lit.

After passing through the divide-by-two stage, the input signal goes to a decoder consisting of the other half of *IC2* and half of *IC1*. This counter determines whether the number being counted is 0 or 1, 2 or 3, or 4 or 5. The correct switching signals are then passed to three sets of switching transistors which connect the bulbs to ground.

As an example of how the counter works, assume that the count has reached the number 4. The divide-by-two counter has determined that this is an even number and has supplied power to the even bus. The decoder has determined that it is either a 4 or 5, and thus turns on the *Q8-Q9* combination. The other two switches are left open. Under these conditions, only bulb 5 is illuminated.

On each sixth input pulse, the counter automatically cycles back to the zero state, and supplies an output pulse to the "carry" terminal. This pulse is used as the count input for any succeeding counters.



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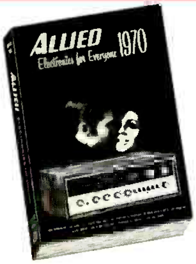

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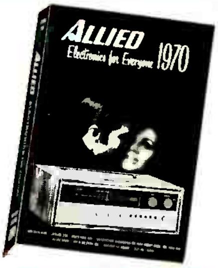

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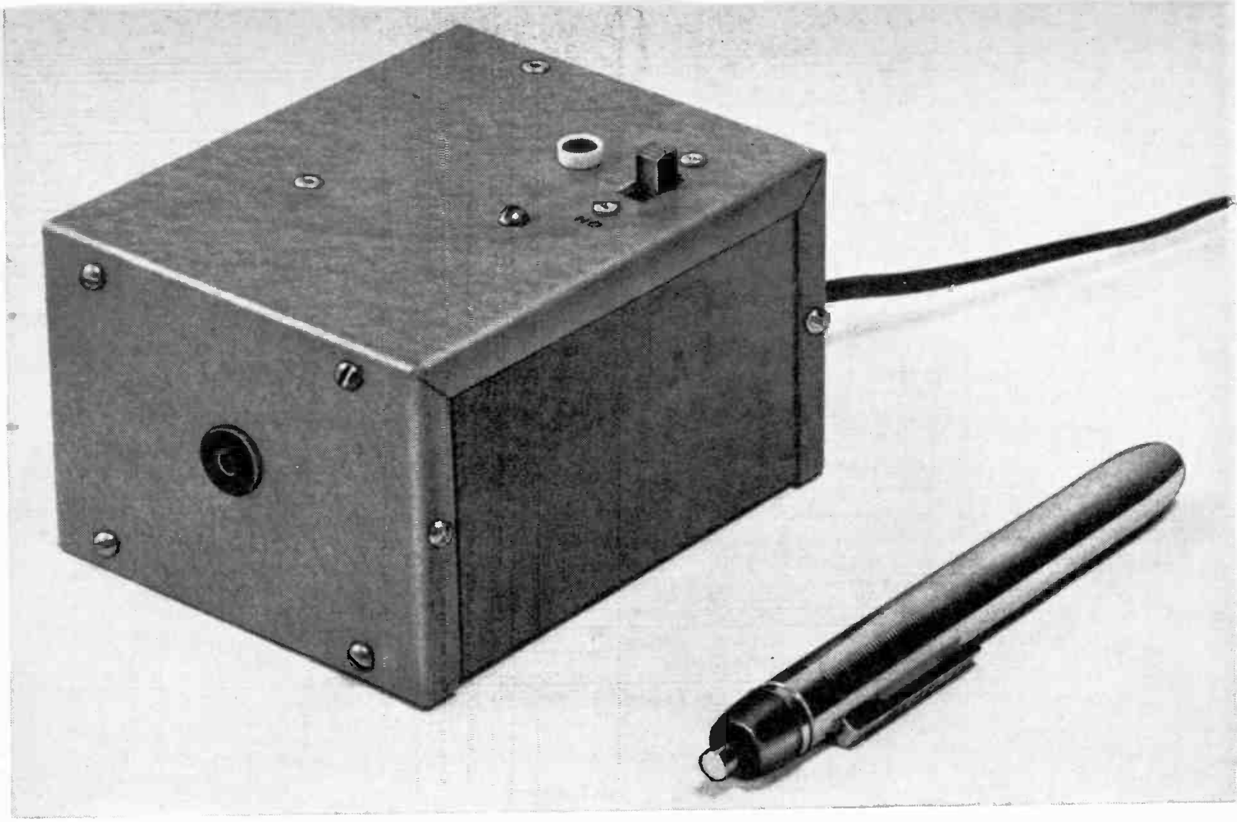


Blow Your Mind With Our FREQ-OUT ELECTRONIC LOCK

SUPER-SECRET PHOTOELECTRIC LOCK USES MODULATED LIGHT BEAM KEY

BY JOHN S. SIMONTON, JR.

THERE ARE ALL KINDS of electrical and electronic locks. None of them, however, is quite like the "Freq-Out." The "key" to this lock is a modulated beam of light which is turned on and off at a rate of about 2000 times a second. The key, using an inexpensive integrated circuit, is about the size of a pocket penlight. The Fotolock circuit can't be fooled by incandescent or fluorescent lights operating on 60-Hz power, and no amount of vigorous hand waving can break a light beam fast enough to open this lock.

While the operating range of the key described here is two or three feet, experiments with a well-focused beam from a larger flashlight indicate that the principle could be applied to longer-range operations—such as a remote control garage-door opener. Under normal lighting conditions, a much greater distance can be covered with the modulated beam than with one which is unmodulated.

The Freq-Out itself uses 117-volt a.c. line power and can be used as an intrusion alarm which cannot be bypassed

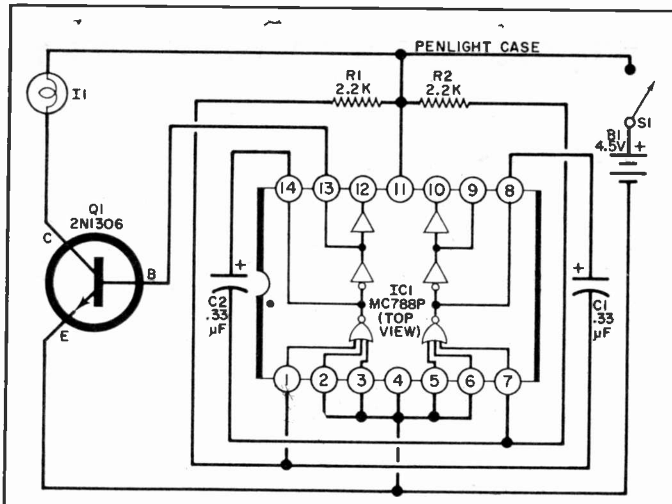


Fig. 1. The IC and associated components form a 2-kHz oscillator. This drives the transistor which in turn powers the flashlight lamp. In operation, the lamp flashes are so fast that the lamp appears to be turned on all of the time.

PARTS LIST

B1—1.5-volt hearing-aid batteries (Mallory M-76 or similar)
C1, C2—0.33 µF, 35-volt tantalum capacitor (Kemet KR33C35 or similar)
I1—#222 flashlight lamp
IC—Dual-buffer integrated circuit, MC788P (Motorola)
Q1—2N1306 transistor
R1, R2—2200-ohm, ¼-watt resistor
Misc.—Eveready #315 penlight, insulating tape, styrofoam, etc.

Note—The following parts are available from PAIA Electronics, Inc., Box 14359, Oklahoma City, Okla. 73114: penlight modulator board $1.10; PC for high-power modulator $2; kit of parts for penlight modulator with penlight less batteries $6.50; kit of parts for high-power modulator less lamp, reflector, and power supply $7.50.

with an ordinary flashlight. It is insensitive to ambient light conditions and there are no finicky sensitivity adjustments to be made.

Modulator. If you plan to build the penlight key or modulator (Fig. 1) a printed circuit board is an absolute must. You can make your own using Fig. 2 as a guide, or you can purchase a PC board (see Parts List). When soldering components to the board, use a clean iron and lots of patience. Note that the location of the notch on the integrated circuit is keyed with a small dot on the circuit board.

As shown in Fig. 2, there are only three external connections to be made to the printed circuit in the modulator. These go to the negative side of the battery, the tip contact of the lamp, and the penlight case. For simplicity, you may

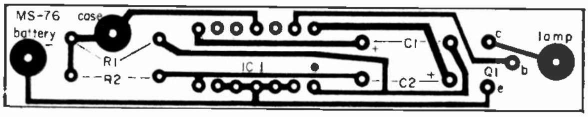


Fig. 2. Actual-size printed board for the modulator. It will fit into the penlight case with room to spare.

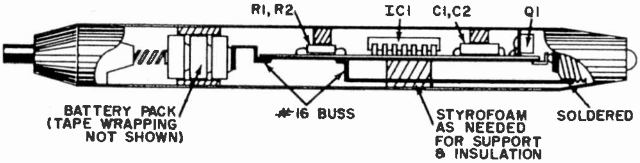
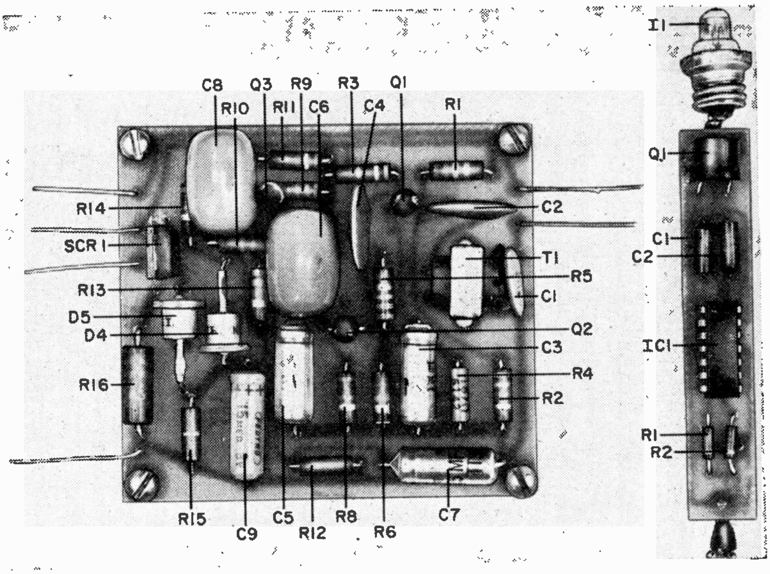


Fig. 3. The entire modulator is assembled within the penlight using styrofoam cut to make a tight fit.



The completed demodulator (left) and penlight modulator (right) before installing them in their packaging. Because some transistors have "hot" cases, it may be necessary to insulate Q1 of modulator, using plastic tape.

prefer to run a piece of #16 wire from the circle marked "case" on the printed circuit board to the rim contact of the lamp, thereby making the connection to the case through the base of the lamp. The lamp used in the modulator is the same #222 lamp supplied with most penlights.

Contacts for the battery and lamp can be formed of #16 wire and soldered directly to the large circles provided for them on the ends of the board. These contacts will be able to withstand greater stress if small tabs are formed on the ends of the wires and inserted into the holes in the board before soldering. The 2N1306 used for *Q1* is in a standard TO-5 package and can be fitted into the penlight case if care is used. Some manufacturers connect one of the elements of this transistor to the case so you may need to wrap a layer of tape around it to prevent shorting to the penlight case.

Power for the modulator is supplied by three MS-76 hearing-aid cells wired in series. Form the cells into a battery pack by stacking them and wrapping their outer edges with a piece of electrical tape. The tape not only holds the cells together, but also prevents the edges from shorting out against the penlight case.

The completed key device is assembled as shown in Fig. 3. Use as much electrical tape and styrofoam as necessary to prevent shorts between the board and the penlight case. Although the printed circuit board shown was designed for an Eveready #315 penlight, there is no reason why it shouldn't fit in any case designed to use two AA batteries. Be sure that the penlight switch disconnects both the point marked "case" on the PC board

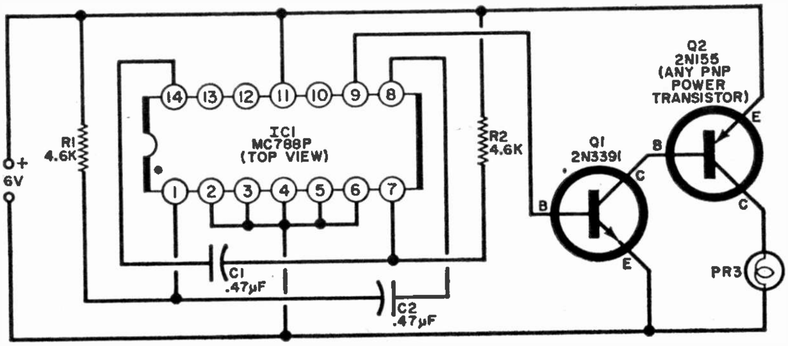


Fig. 4. This high-power modulator has a greater range than the penlight version. If the lamp is mounted within a three-inch, or larger, reflector, it can be used as an intrusion warning alarm.

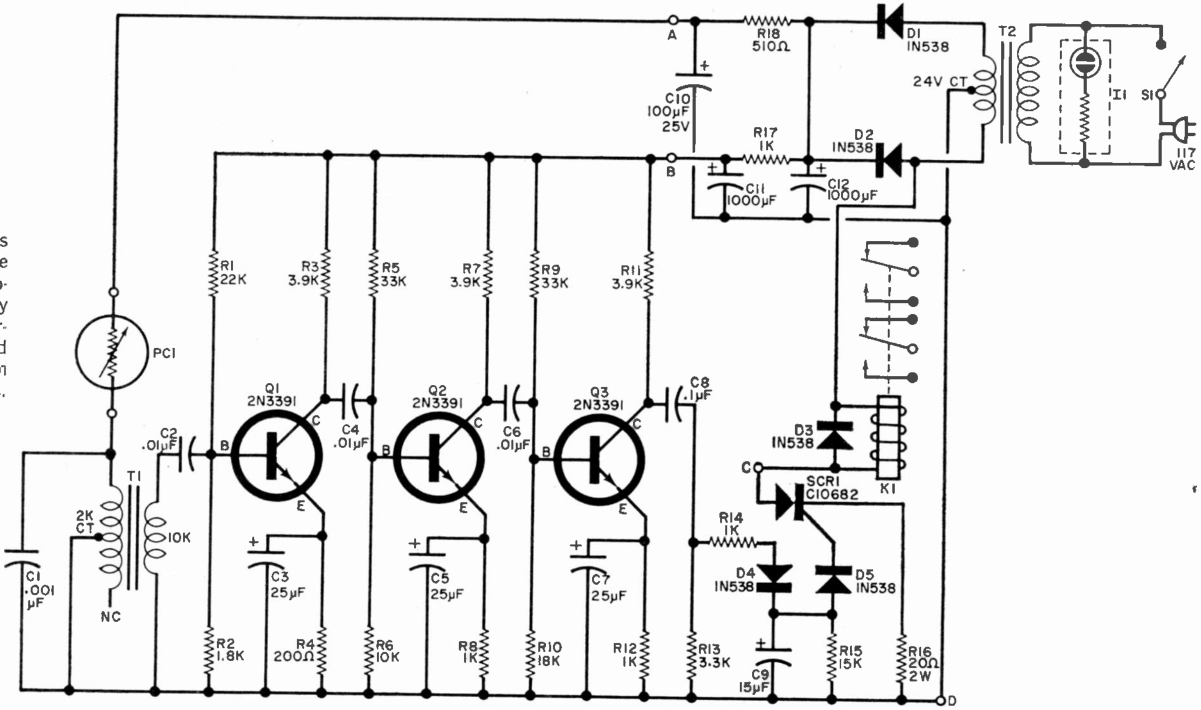


Fig. 5. Because the demodulator is a high-gain amplifier, take care that the input circuit is not located where it can pick up stray signals. This could lead to erratic operation. The lettered and open small circles on the diagram are the printed-board connections.

PARTS LIST

C1—.001-µF capacitor
C2, C4, C6—.01-µF capacitor
C3, C5, C7—25-µF, 3-volt electrolytic capacitor
C8—0.1-µF capacitor
C9—15-µF, 3-volt electrolytic capacitor
C10—100-µF, 25-volt electrolytic capacitor
C11, C12—1000-µF, 25-volt electrolytic capacitor
D1-D5—1N538 diode
I1—Neon lamp assembly (with resistor for 117 volts)
K1—D.p.d.t. relay, 6-volt d.c. coil
PC1—Photocell (Clairex CL703L or similar)
Q1, Q2, Q3—2N3391 transistor
R1—22,000-ohm
R2—1800-ohm
R3, R7, R11—3900-ohm
R4—200-ohm
R5, R9—33,000-ohm
R6—10,000-ohm
R8, R12, R14, R17—1000-ohm
R10—18,000-ohm
R13—3300-ohm
R15—15,000-ohm
R18—510-ohm

All Resistors ½ watt

R16—20-ohm, 2-watt resistor
S1—S.p.s.t. switch
SCR1—Silicon controlled rectifier (GE C106B2 or similar)
T1—Transistor driver transformer; 10,000-ohm primary, 2000-ohm C.T. secondary
T2—Filament transformer; secondary 24 volts C.T., 1 ampere
Misc.—Standoffs, rubber grommet, strain relief, line cord, utility box, wire, solder, etc.

Note—The following parts are available from PAIA Electronics, Inc., Box 14359, Oklahoma City, Okla. 73114: demodulator PC board $2.50; kit of electronic parts and circuit board for demodulator less power supply, case, and relay $16.50.

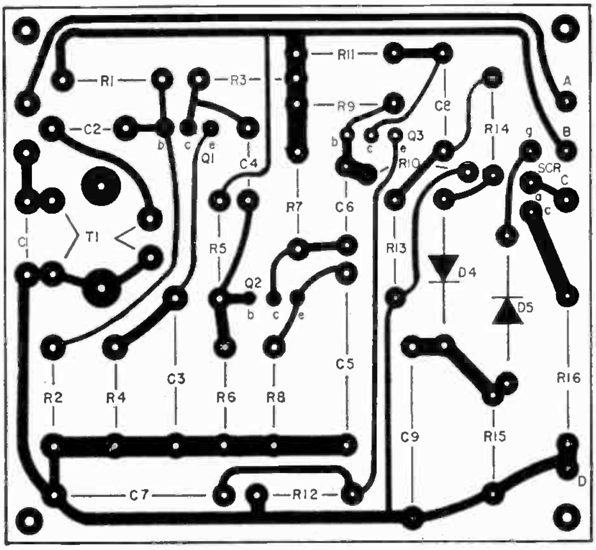


Fig. 6. Actual-size printed board for the demodulator. This also shows where the various components are to be installed on the finished circuit board.

and the outer lamp contact from the positive side of the battery pack.

For applications requiring greater range than is possible with the penlight, a larger flashlight and reflector should be used. Adapting the PC board for use in a flashlight which holds two D cells should be no problem. A PR-6 lamp should be substituted for the 222 usually used in the penlight.

If the Freq-Out is to be used as an intrusion alarm, the modulator requires a larger source of power. The schematic shown in Fig. 4 is for a unit of this type which has worked well for the author. Either a 6-volt lantern battery or a suitable power supply is used in this case. A 3½-inch reflector salvaged from an old flashlight and a PR-3 lamp are required.

Demodulator. Because the first three stages of the demodulator form a high-gain amplifier (Fig. 5), care should be taken in construction to avoid unintentional feedback and subsequent parasitic

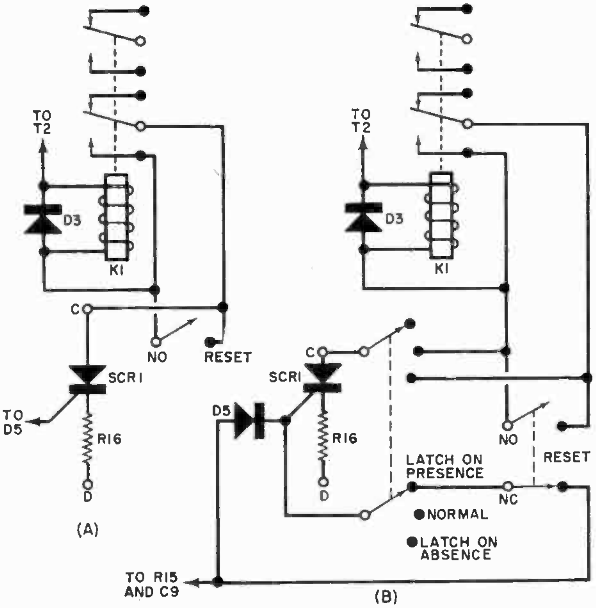


Fig. 7. Two relay configurations that may be used. In (A), the relay remains closed even after the light beam has been restored. In (B), the relay may be latched on in the presence of light, latched on in the absence of light, or operated as usual in the normal mode.

oscillation. You may make your own PC board using Fig. 6 or you can purchase one (see Parts List).

The wiring of the circuit board is straightforward, though you should use the usual precautions when soldering the semiconductors in place. Notice that transformer *T1* has been turned around so that one half of what would ordinarily be the secondary is used as the primary. It is not important which half of the secondary you use. Cut off the unused lead on the transformer so that it doesn't come in contact with some other component.

In the unit shown in the photos, the PC board is mounted on ceramic standoffs in one end of a conventional 3″ × 4″ × 5″ utility box. There should be sufficient clearance behind the board to mount the photocell in a rubber grommet.

The power-supply components in the prototype unit were soldered to a six-lug terminal strip (no grounded lugs) which was then fastened to the otherwise unused section of the utility box. Choose the location for the terminal strips carefully so that, when the two halves of the box are united, there will be no physical contact between components in the two halves. Tying all the wires going to the power supply into a cable not only gives a neat, professional appearance, but also helps prevent short circuits.

The line cord is brought into the case through an insulated strain relief. One side of the line is connected directly to *S1* and the other to *T2* through a single, ungrounded lug. Be very careful that neither side of the a. c. power line is grounded to the utility box.

When mounting *K1*, note that diode *D3* is wired directly to the coil terminals of the relay and is not on the printed circuit board. It is very easy to get the polarity of this diode wrong, so be very careful. In some applications the Freq-Out may be used to control power-line voltages, so the author mounted a multicontact plug on the back of the case for the relay contact circuits. With this arrangement, there are never any current-carrying conductors exposed.

Applications. Most applications of the Freq-Out require only that it act as a simple switch which closes in the presence of the modulated light beam and opens again when the light is interrupted. To use it as an electric door lock, connect one of the sets of normally open contacts on *K1* in series with a standard electric door-latch assembly. Locate the Freq-Out in a position where it can "look" out a window, but not too far from the key beam.

For some uses you may wish to have the electronic portion of the Freq-Out concealed in a closet or drawer and the photocell at some remote location. The

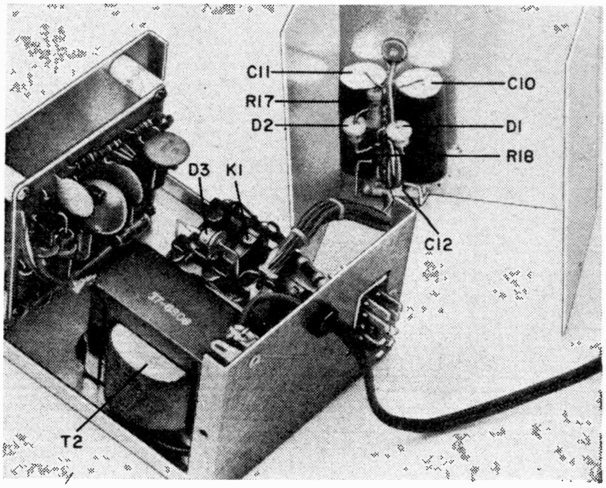
(*Continued on page* 153)

HOW IT WORKS

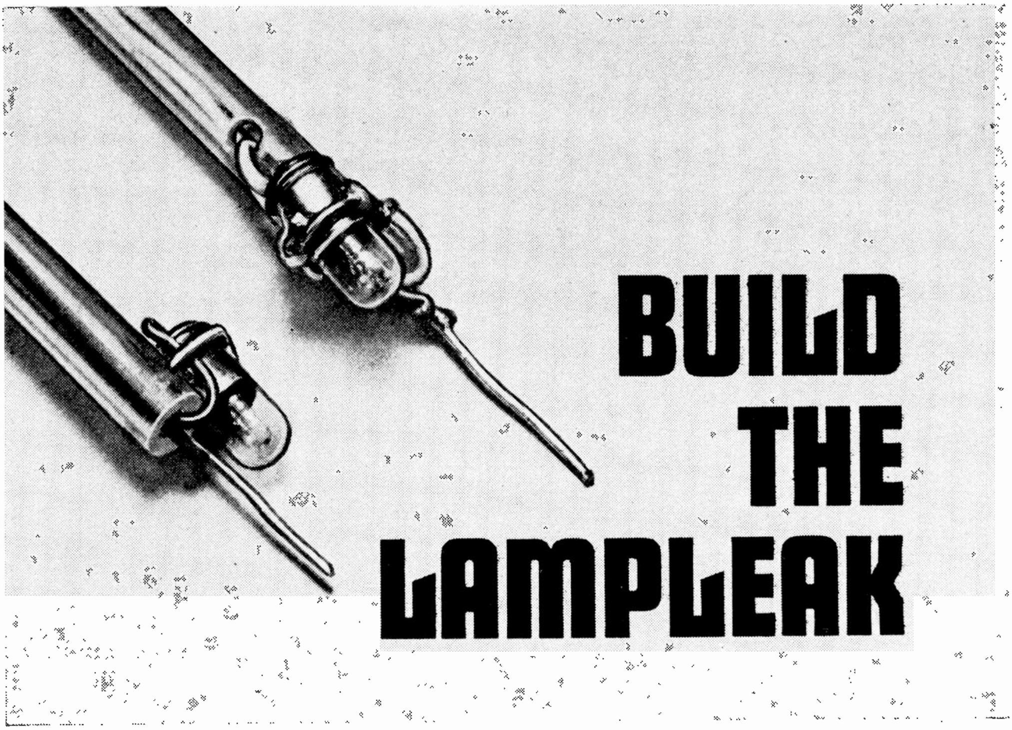
Modulator. The basis for the light-beam modulator is a dual-buffer integrated circuit (Motorola MC788P). The addition of *R1, C1, R2,* and *C2* converts the IC into an astable multivibrator having a frequency of approximately 2 kHz. One of the buffered outputs of the oscillator is used to switch transistor *Q1* and its load, *I1*.

Demodulator. The modulated light beam striking *PC1* allows a varying current to flow in the low-Q, resonant circuit composed of *C1* and the primary of *T1*. This circuit is tuned to the operating frequency of the modulator. The output of *T1* is amplified in three stages which are designed to pass only frequencies above about 800 Hz. The output of the amplifier is detected and filtered by *D4* and *C9* before being used to turn on *SCR1*. Resistor *R14* provides a slight time delay in the voltage built up across *C9* to prevent relay chatter due to sudden transients. The SCR is a half-wave rectifier used to energize relay *K1*.

Resistors *R18* and *R17* are used to filter the power supply and also to decouple the photocell from the amplifier. Resistor *R18* also limits the current flow through *PC1* under high ambient light conditions.



Assemble PC board and other components in the box as shown, with connector on one end for relay circuits.



BUILD THE LAMPLEAK

FOOLPROOF TESTER CHECKS TRANSISTORS AND DIODES

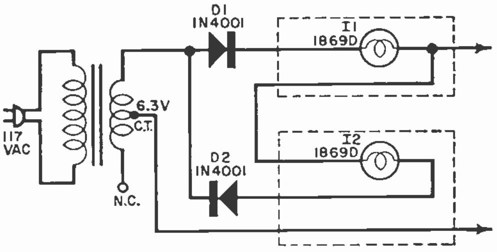
BY IMRE GORGENYI

When you want to test a semiconductor, in or out of a circuit, you usually have two options: use a semiconductor test set (which you probably don't have) or an ohmmeter. The trouble with using an ohmmeter is that you might "pop" the transistor due to excessive current flow through the junction. Besides, you can never remember which lead goes where in order to identify transistor types.

Now, at very low cost, you can build the "Lampleak", a perfectly safe semiconductor test set that can be used with any type of diode or transistor without fear of getting the polarities wrong, or destroying the device due to excessive current flow. This tester does not tell the "quality" of the semiconductor—only whether or not it works.

The circuit consists of half of the secondary of a 6.3-volt filament transformer connected in series (through the probe tips) with a parallel circuit of two low-current pilot lamps and two diodes. If the two probe tips are connected directly together, both lamps glow at a very low level, due to the low current flow through them. This current is not enough to damage any transistor or diode connected to the probes.

The circuit is arranged so that, if the probe tips are connected across a diode, regardless of which tip is connected to which end of the diode, only the lamp associated with the probe on the anode

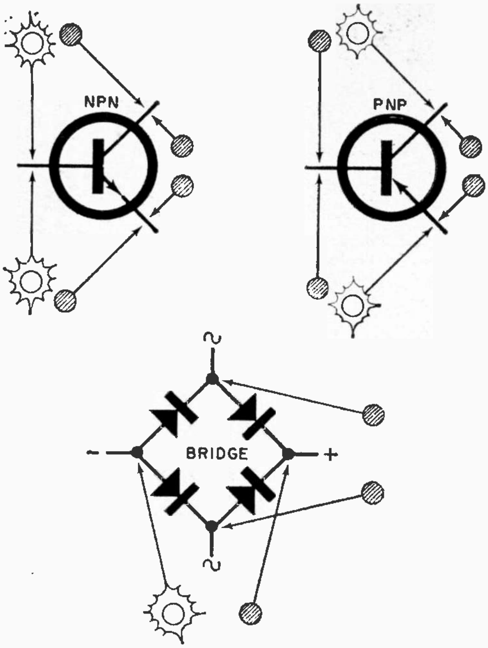


The lamps are connected so that, with equal potential on both probes, both lamps glow very dimly.

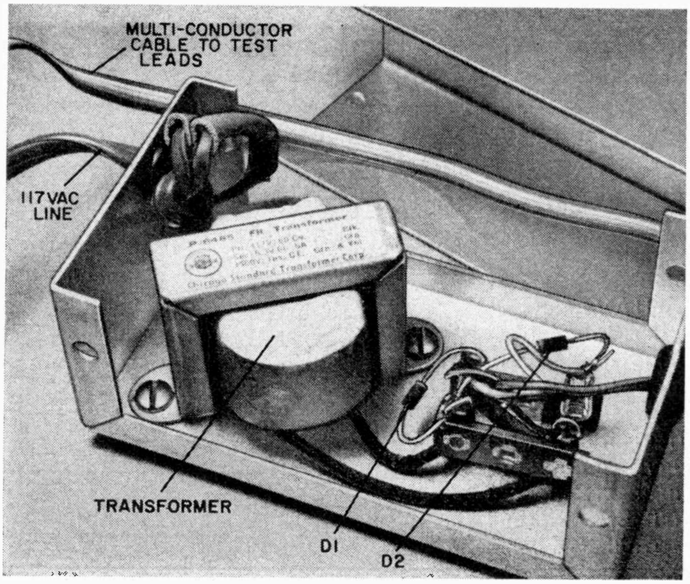
glows, indicating a good diode. If neither lamp glows or if both lamps glow, the diode is bad.

Since transistors are similar to two back-to-back diodes, the sex of the unknown transistor can be determined easily. Merely connect one probe to the base lead, the other to either the emitter or collector. If the base lamp glows, the transistor is *npn*, if the lamp connected to the emitter or collector glows, the transistor is *pnp*. In a good transistor, of either type, connecting the probes between the emitter and collector should cause neither lamp to glow. If they do, leakage of less than 500 ohms is present. These tests, along with a test for a conventional bridge rectifier, are also shown in the illustration.

The author mounted the filament transformer and the two rectifier diodes in a small enclosure. The shells from a pair of ball-point pens were used as insulated probes. A hole, sufficient to accommodate the base of the pilot lamp, was drilled near the working end of each probe. The lamp wiring was fished through the probe and soldered directly to the bulb. Although the author used General Electric 1869D lamps, any similar type of low-current, 10-to-28-volt lamp can be used. The diodes can be any silicon rectifier type. -30-

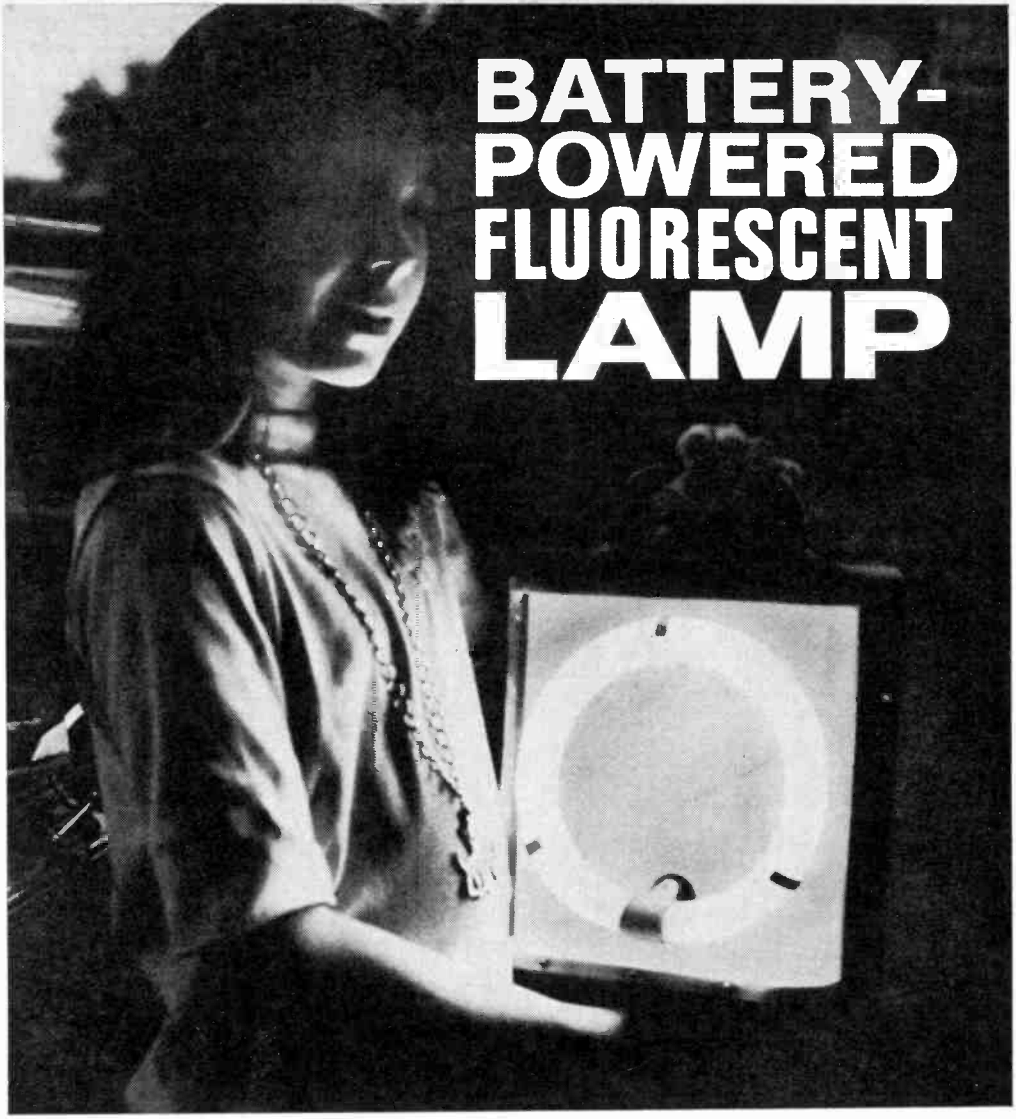


To check a transistor for type, connect probes as in two diagrams at top. If unit is npn, the lamp connected to the base will glow; if it is pnp, the lamp connected to either emitter or collector will glow. In a bridge rectifier, the lamp connected to the low side of d.c. glows.



The transformer is mounted directly on the chassis with its secondary connected to the diodes mounted on terminal strip.

BATTERY-POWERED FLUORESCENT LAMP



Extra brightness for your camping/boating trips

BY BEN RICHARDS

IT'S EASY to make an outdoor lighting system for your camping or boating trips. All you need is a 12-volt incandescent bulb and some wire to attach it to your car or boat battery. Unfortunately, there are some drawbacks to this approach: the intense point-source of light generated by a relatively small bulb can be very annoying to the eye; the amount of illumination delivered by such a bulb is limited in coverage, producing a small bright area surrounded by darkness; and the efficiency of such a lighting system is low. To get any appreciable amount of light, either a number of bulbs or a large, high-power bulb must be used. If you use either of these approaches, it won't be long before your battery gives out.

All these troubles can now be alleviated if you build the battery-powered fluorescent light described here. The light uses a 22-watt fluorescent lamp and

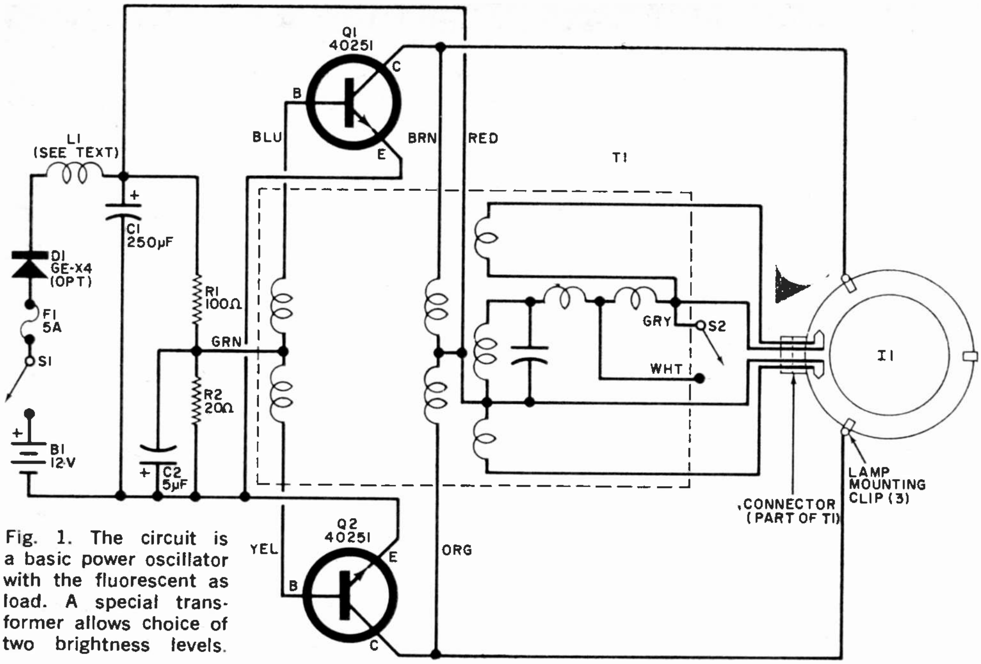


Fig. 1. The circuit is a basic power oscillator with the fluorescent as load. A special transformer allows choice of two brightness levels.

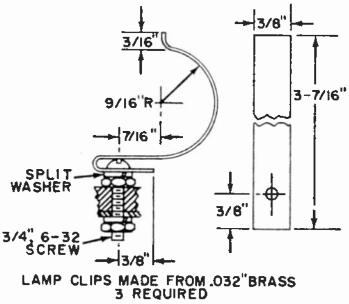


Fig. 3. Make three clips for mounting the fluorescent lamp. It is important that you get the correct curvature.

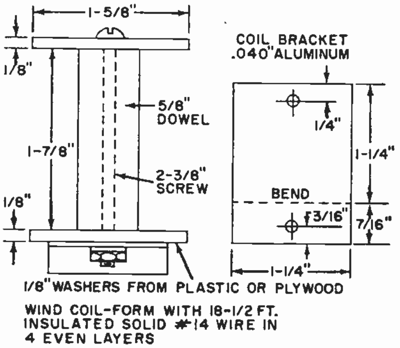
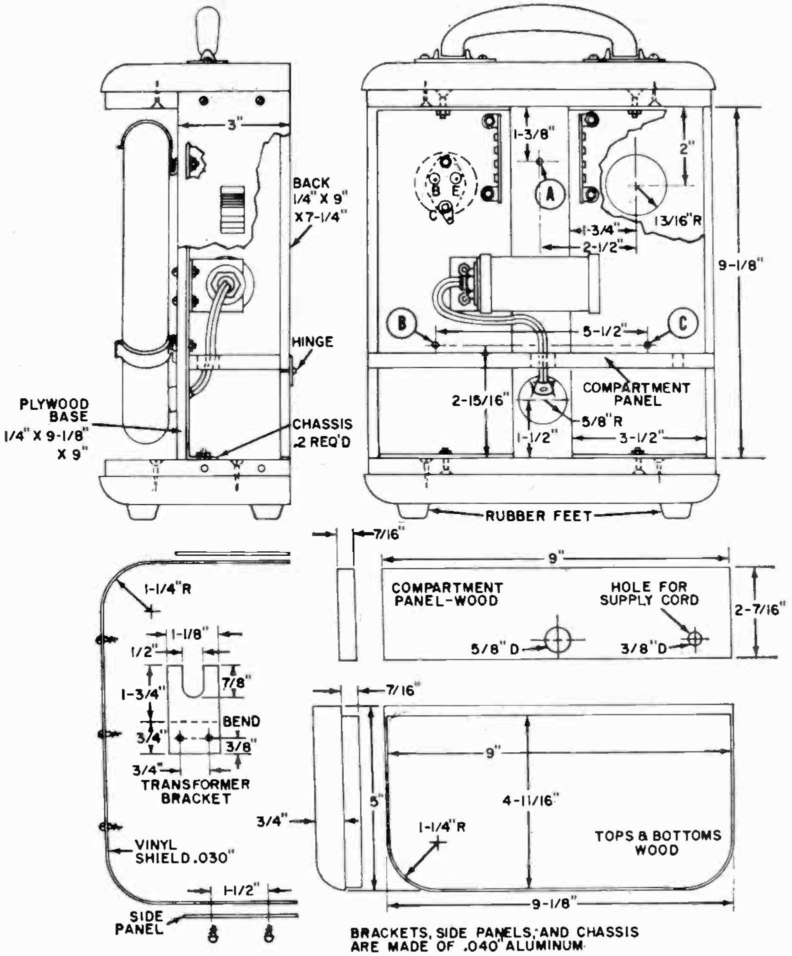


Fig. 4. Construction data for L1. Plastic tape can be wound over coil to keep it from unravelling during mounting.

works from a conventional 12-volt d.c. car, boat, or trailer battery. It produces large-area illumination without harsh glare and has two levels of illumination —bright, or subdued for extra-low battery drain. Efficiency is high, thus getting the most from the battery, and generated heat is almost non-existent. You can attach the fluorescent light to the end of a 20-ft, conventional two-conductor rubber-covered appliance cord and position it where it is needed.

Construction. A parts list is given on page 116 and a schematic in Fig. 1. Although almost any type of construction can be used, Fig. 2 and the photos illustrate the method used by the author. To duplicate this version, fabricate the wood and metal parts as shown. Note that there are two electrically isolated metal chassis, one for each power transistor. When drilling the holes for these transistors, make sure that both the base and emitter holes are large enough to prevent short circuits. Each transistor can be mounted directly on its chassis without using insulated mounting kits,



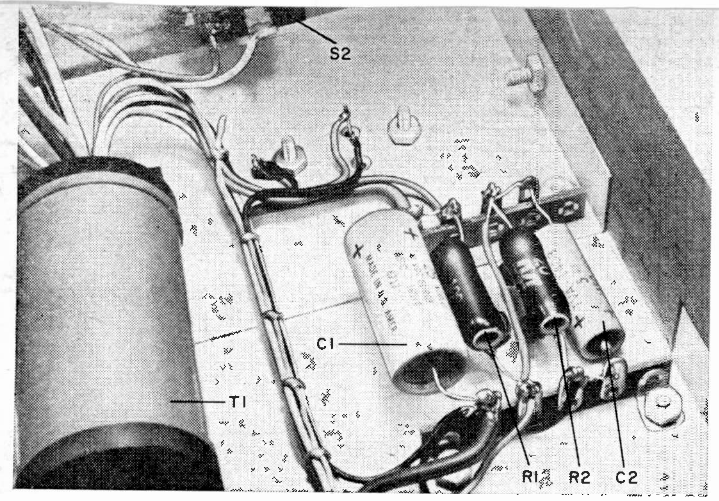
BRACKETS, SIDE PANELS, AND CHASSIS ARE MADE OF .040" ALUMINUM

HOLES A,B,C ARE LAMP CLIP MOUNTING HOLES

Fig. 2. If you want to duplicate the author's prototype, follow the construction details shown here. Note that the two transistors are mounted through the wooden front panel and the metal chassis. All wiring is done after components are mounted.

since isolation is provided by the two independent chassis. Put a solder lug under one of the collector (mounting) screws of each transistor. Fabricate three lamp-holding clips as shown in Fig. 3, making sure that the edges are smooth and that they are shaped correctly.

Assemble the two chassis, the two four-lug terminal strips (no ground lugs), and the three lamp-holding clips to the plywood front panel. Note that the two chassis are spaced so that they do not touch either each other or the metal side panels to be mounted later. The tops of the two transistors fit through holes drilled in the wooden panel. At this time, make sure that holes have been drilled to mount the fuse holder (one screw), inductor *L1* (one screw), and transformer *T1* (two screws). If optional diode *D1* is to be used, drill a hole near one end of the fuseholder to support an insulated standoff. Use countersunk machine bolts to attach the 7/16"-thick wood top and bottom to the chassis ends. Then use countersunk wood screws to secure the ¾"-thick top and bottom to the 7/16" top and bottom wood parts.



Resistors and capacitors are mounted between two terminal strips. Note how a wire harness makes for a clean, neat internal arrangement. This photo also shows the two isolated metal chassis and the method of wiring the power transistors. Both the emitter and base connections are soldered direct to the transistor leads; the collector connection is made to a solder lug under the collector (and case) mounting hardware.

A carrying handle can be secured to the top surface, but make sure that it does not cause a short circuit between the two metal chassis.

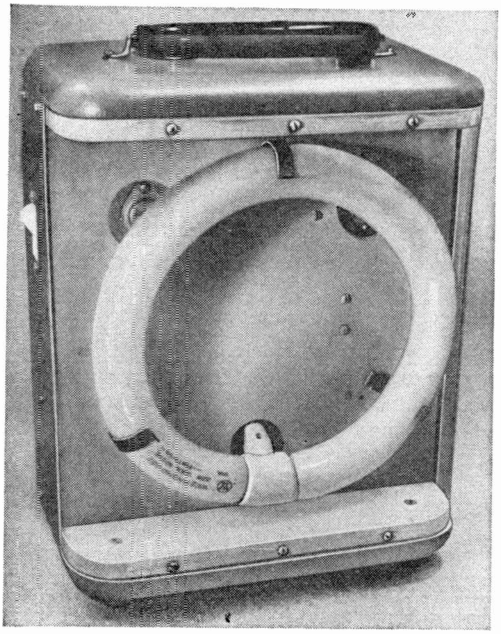
Attach the line-cord stowage compartment panel to the base-and-chassis assembly using wood screws. (A small magnetic door-latch assembly can be used to keep the stowage compartment door closed.) Assemble the entire cabinet to make sure that everything fits properly. Note that, of the three lamp clips, one is electrically connected to each chassis while the third is insulated by the wood front panel.

Construct inductor *L1* in accordance with Fig. 4. Using the photos as a guide, assemble all components in the cabinet and wire in accordance with Fig. 1. Note that the two "hot" lamp clips are connected automatically to their respective transistor collectors through the metal chassis. Be careful to observe the color coding on transformer *T1*. (The transformer is mounted to the chassis with an L bracket.) Connections to the transistor base and emitter leads are made by direct soldering. Use a long-nose pliers as a heat sink to avoid transistor damage while soldering. Do not mount resistors *R1* and *R2* too close to capacitors *C1* and *C2* to avoid heat damage to the capacitors. If the optional diode is used, it can be mounted on the chassis using a small standoff insulator at one end,

PARTS LIST

B1—Car, boat, or trailer 12-volt battery
C1—250-μF, 25-volt electrolytic capacitor
C2—5-μF, 150-volt electrolytic capacitor
D1—20 ampere, 200-PIV diode (General Electric X4 or similar) (optional)
F1—5-ampere, 3AG fuse
I1—22-watt, 7" circular fluorescent lamp (Westinghouse FC8T9/CW or similar)
L1—see text and Fig. 4
Q1, Q2—Transistor (RCA 40251)
R1—100-ohm, 5-watt, wirewound resistor
R2—20-ohm, 5-watt, wirewound resistor
S1, S2—S.p.s.t. switches (rocker-type preferred)
*T1—Ballast transformer**
Misc.—Wood, aluminum, brass strip, line cord, 4-lug terminal strips (2), fuseholder, machine screws, wood screws, transparent plastic shield, wire, solder, etc.
**An inverter-ballast transformer, Type EC-0501-LM, is available from Milwaukee Electromagnetics, P.O. Box 4476, Milwaukee, Wis. 53207, $9.60, postpaid.*

Front view of the completed cabinet. Clear vinyl shield wraps around entire front surface. Paint front panel flat white for best light reflection.



HOW IT WORKS

A.c. power to operate the fluorescent lamp from a d.c. source is generated by a pair of power transistors, operating in conjunction with a saturable transformer in a feedback-type power oscillator circuit.

Oscillation frequency is slightly above the audible range to avoid any annoying buzz from the device. A portion of the transformer winding can be shorted to provide high intensity.

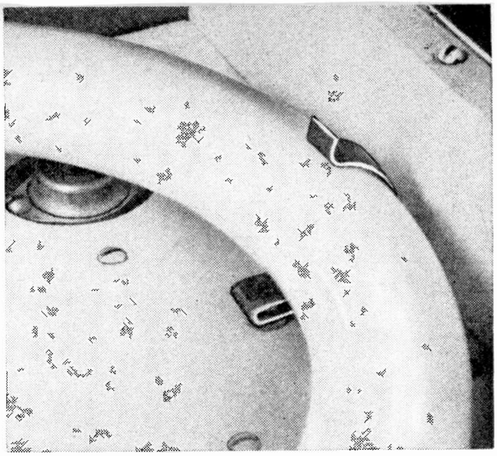
Were it not for the ballasting action of the transformer, lamp brightness would fluctuate excessively with small changes in input voltage and the lamp current could easily exceed its safe value. This happens because a fluorescent lamp acts like a voltage-regulator tube, or zener diode, and tries to maintain a constant voltage while the current through it varies. The type of lamp used has low-power filaments which are continuously heated to allow rapid self-starting and dimming.

Diode *D1* is optional and is used to prevent transistor damage if the d.c. supply leads are accidentally reversed. Inductor *L1* and capacitor *C1* minimize radio interference. Fuse *F1* is used to protect the wiring only. If the battery polarity were wrong, the transistors would fail before the fuse could blow. That is the reason for using diode *D1*.

with the other end connected directly to the fuseholder.

Once the lamp assembly has been checked electrically and mechanically, paint all exposed exterior surfaces any color desired and paint the surfaces surrounding the lamp flat white.

Attach the lamp connector (part of *T1*), then install the lamp in its three clips, making sure that it is a snug fit. Then mount the transparent plastic shield, clamp the line cord in its storage compartment, and attach the back and storage-compartment access door.

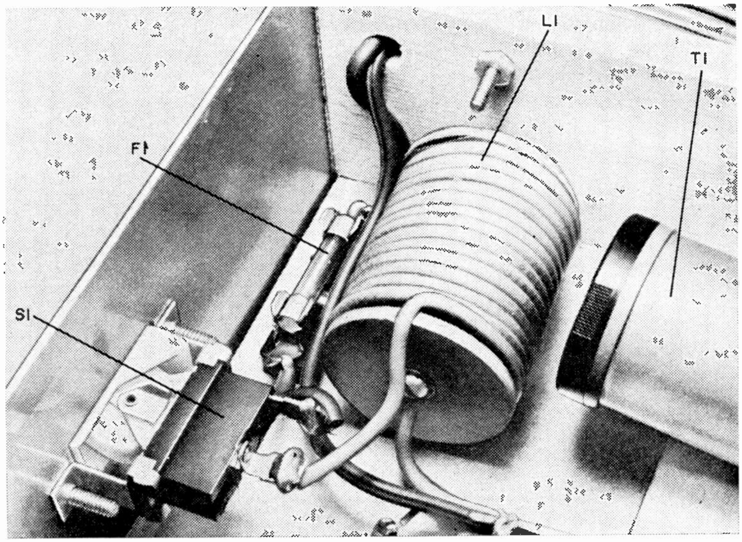


Fluorescent lamp is held by three clips (one shown here). Two of them are at same potential as the transistor collectors to aid fluorescent starting.

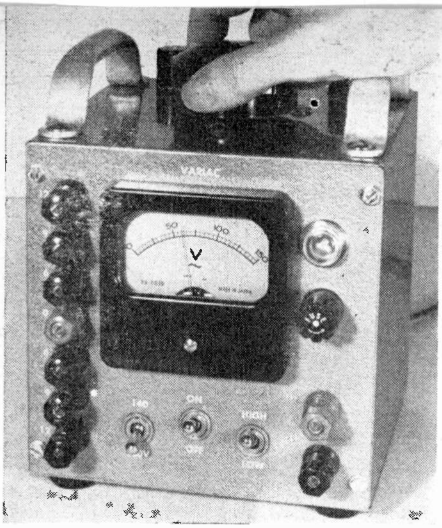
Testing and Use. Before placing the light in operation, carefully identify both the positive and negative input power leads. Connect the leads to a source of 12 volts d.c. capable of delivering at least 3½ amperes.

Turn switch *S1* on and note that the fluorescent lamp lights almost immediately. Current drain is about 3 or 3½ amperes when the lamp is started at high intensity (with switch *S2* closed). At low intensity, current drain should be about 1½ amperes when starting.

The author used a cigarette-lighter connector with a 20′ two-conductor (#16) appliance cord so that the light can be plugged into the cigarette lighter socket and positioned anywhere within 20 feet of the car. -30-



If optional diode D1 is used, mount it near the fuse and L1 (shown here).



Setting Up Your A.C. Bench Supply

THOUGHTS ON MAKING A VARIAC MORE VERSATILE

BY B. W. BLACHFORD

One of the most versatile and necessary pieces of equipment on the test bench of many an engineer, technician, experimenter, or hobbyist is the variable-voltage transformer. Although it is a relatively uncomplicated, usually dependable device, there are several points you should keep in mind when setting up your transformer to obtain a good, versatile supply.

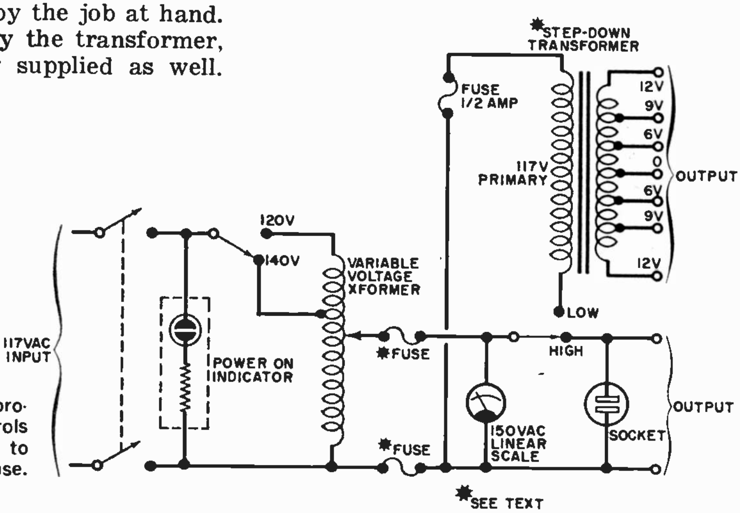
Protection. Fuses on the input (primary) side of a variable-voltage transformer do not give good protection against overloads. Fuses should be in the output (secondary) side. Also, since the device is an autotransformer, protection from burnout due to grounding can be obtained only by fusing both sides of the secondary circuit.

Use fuses with current ratings no larger than required by the job at hand. This protects not only the transformer, but the circuit being supplied as well. Under no circumstances should the fuse ratings be larger than the maximum rated output current of the transformer.

Controls and Meter. The ON-OFF switch in the line side of the transformer should be a double-pole switch with one pole in each side of the line. A single-pole switch should only be used on ordinary fixed-ratio transformers where the primary and secondary windings are insulated from each other.

Many variable-voltage transformers have a tap on the winding, usually at a point about 20 volts below the upper terminal of the full winding. To achieve versatility in your supply, it is advantageous to include a s.p.d.t. switch to permit connecting the incoming line ei-

(*Continued on page* 141)



Circuit diagram shows how protective devices and controls are connected to Variac to give ease and variety to use.

COVER STORY

BY JAMES G. SLOAT
Texas Instruments, Inc.

Build Infrared Sensor

IR "HOTBOX DETECTOR" HAS FANTASTIC SENSITIVITY

HAVING a fire alarm in a house or office is a good idea—sometimes, it's a life saver. However, most commercial alarms use sensors that only operate at some critical temperature before they actuate the alarm. Under these conditions, if a fire starts some distance from the sensor, a lot of building can burn away before an alarm is given. What is needed is a device that can detect the infrared (IR) radiation from a smoldering or unusually hot object. This radiation can be sensed from a distance.

In the realm of burglar alarms, most low-cost units use either a frangible trip wire or a light beam to detect intruders. Trip wires, in many cases, can be seen and light beams can either be seen directly or can be detected by the dust motes in the air. This, of course, nullifies the alarm. What is needed here is an invisible beam of IR and a detector

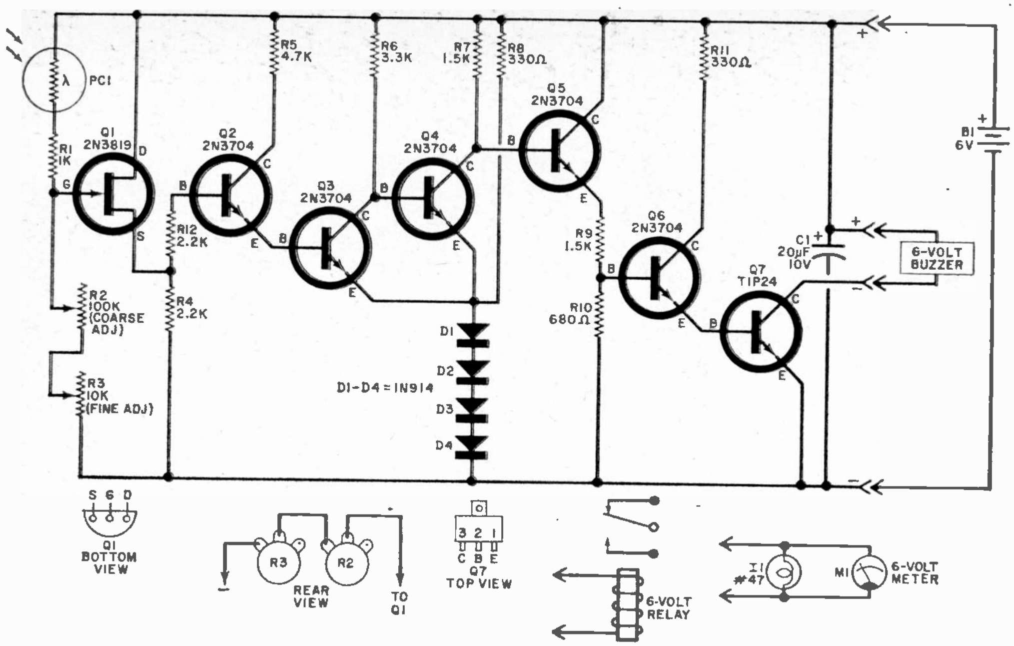


Fig. 1. No power is applied to output indicator until PC1 "sees" a predetermined level of infrared.

PARTS LIST

B1—6-volt lantern battery
C1—20-μF, 10-volt electrolytic capacitor
D1-D4—1N914 diode
PC1—Infrared detector kit, including reflector and filter (Radio Shack #276-035 or similar)
Q1—2N3819 field-effect transistor (see text)
Q2-Q6—2N3704 transistor (see text)
Q7—Power transistor (Texas Instruments TIP24 or similar, see text)
R1—1000-ohm
R4, R12—2200-ohm
R5—4700-ohm
R6—3300-ohm
R7—1500-ohm
R8, R11—330-ohm
R9—1500-ohm
R10—680-ohm
All resistors ½-watt
R2—100,000-ohm potentiometer
R3—10,000-ohm potentiometer
I1—#47 indicator lamp and holder
M1—6-volt meter movement
Misc.—Plastic case and cover (Harry Davis type 260 or similar), 6-volt d.c. buzzer (optional), 6-volt d.c. relay (optional), miniature jack and plug with earphone-type lead, perf or PC board, camera pistol grip (optional), knobs (2), cement or epoxy, mounting hardware wire, etc.
Note—An etched and drilled PC board may be purchased from Excello Circuits Co., 847 W. 23 St., Houston, Texas 77008, for $3.95.

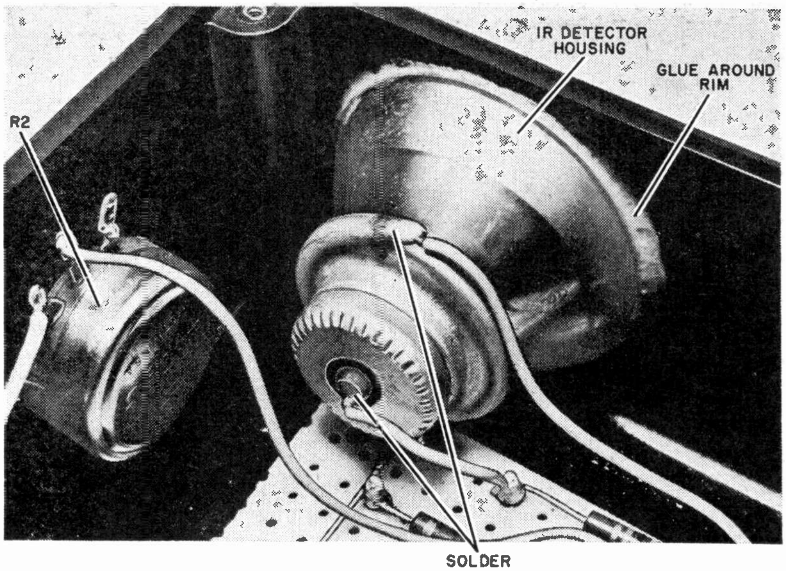
that responds only to IR and not to visible light.

Incidentally, the infrared portion of the electromagnetic spectrum lies between the highest radio frequencies and visible light. Because all material emits IR radiation if its temperature is above absolute zero, the amount of IR radiated is a measure of heat (not necessarily actual flames).

The "Hotbox" IR detector described here not only makes an ideal fire or burglar alarm, but has many other uses. For example, it can check for over-heating conditions in electrical and mechanical equipment or detect the difference between a cloudy and a clear sky. When not serving some truly practical purpose, it can tell you when your soldering iron is up to temperature, turn on your hi-fi or TV when you light a cigarette, or provide a low-cost test instrument for studying the IR properties of various materials.

Because the Hotbox is, by necessity, a low-cost device, its IR range is limited. It responds only to objects that are at least 75°C hotter than the ambient temperature of the detector. Therefore it does not respond to the warmth of a human body. Commercial IR detectors are submerged in cryogenic (extremely low temperature) chambers making the detector sensitive not only to humans, but also to very low levels of IR.

Similar to visible light, IR can be reflected around corners by shiny sheets of metal or conventional mirrors, thus enabling the device to "see" around cor-



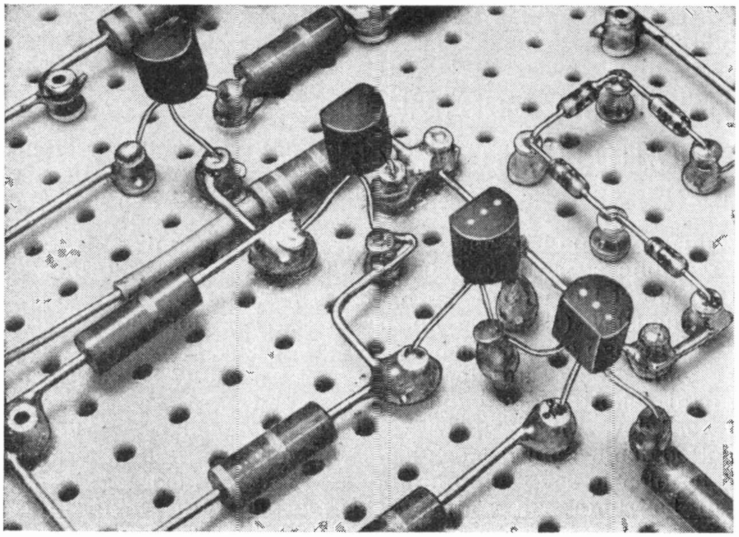
When soldering the lead to the IR detector housing, work fast so that you do not overheat the IR element within the reflector. Other connection is made to bulb tip.

ners if desired. The reflector unit specified in the Parts List for Fig. 1 is as directional as a flashlight, so that the device can be pointed very precisely at the IR source.

Construction. Putting the Hotbox together is simple and straightforward. Lead dress is not critical and the circuit (shown in Fig. 1) is very flexible with regard to resistor values and transistor parameters. In fact, almost any silicon *npn* transistors can be used for *Q2* through *Q6*. Most *n*-channel FET's will work for *Q1*, while almost any *npn* power transistor can be used for *Q7*.

The author used perf-board construction (see photos), although a printed-

This is what good perf-board construction looks like. Note the clean, almost polished look of the solder connections and the neat arrangement of parts.



HOW IT WORKS

The heart of the circuit is a threshold detector composed of transistors *Q2*, *Q3*, and *Q4* and their associated components. Each of silicon diodes *D1* through *D4* has a constant 0.6-volt drop when forward biased with a few milliamperes. Under all conditions, current flows through *R8* and forward biases the four series-connected diodes so that the voltage at the emitters of *Q3* and *Q4* is fixed at 2.4 volts. This fixed voltage establishes the operating point for the circuit.

If the detector, *PC1*, is shielded from IR radiation, *Q2* and *Q3* are turned off, and current flows through *R6* into the base of *Q4*. Thus *Q4* is turned on and appears as a short circuit between its collector and emitter. The collector voltage of *Q4* is therefore close to 2.4 volts.

Emitter follower *Q5* acts as a buffer between the threshold detector and the output stage. Because its base-emitter junction behaves like a forward-biased diode, the emitter of *Q5*, under all circuit conditions, is about 0.6 volt below the collector of *Q4*. When *Q4* is conducting, the emitter of *Q5* is at about 1.8 volts. Voltage divider *R9* and *R10* presents slightly less than one third of *Q5*'s emitter voltage to the base of *Q6*. With 1.8 volts on the emitter of *Q5*, the voltage at the base of *Q6* is about 0.55 volt, which is not enough to turn on *Q6*. Since no current flows through *Q6*, *Q7* does not receive base drive and is turned off. If an indicator is connected in series with the collector of *Q7*, it is not energized as long as *Q7* is in the off state.

Assume now that the voltage at the base of *Q2* increases. This transistor must be conducting in order for *Q3* to conduct. However, this requires a bias of at least 3.6 volts on the base of *Q2* to overcome the emitter bias on *Q3*. When this condition is satisfied, *Q2* and *Q3* both turn on, and the base-emitter junction of *Q4* is bypassed. This turns *Q4* off and its collector voltage jumps from 2.4 volts to about 5.5 volts. The emitter voltage of *Q5* jumps correspondingly from 1.8 to about 4.9 volts. Under this condition, voltage divider *R9* and *R10* provides a forward bias for *Q6*, causing it to conduct. This turns *Q7* on and the output indicator is energized.

Field-effect transistor *Q1* is connected as a source follower with the detector *PC1* and a pair of trimming potentiometers, *R2* and *R3*, determining its gate voltage. The sensitive area of the detector is lead sulphide whose resistance decreases when exposed to infrared radiation. If the detector is shielded from IR and the trimmer potentiometers are adjusted for a *Q1* gate level of 3 volts, then, when *PC1* is exposed to IR, the voltage at the gate of *Q1* goes above 3.6 volts. The remainder of the circuit is then triggered on. Adjustment of the coarse and fine potentiometers determines at what IR level the Hotbox produces an output signal.

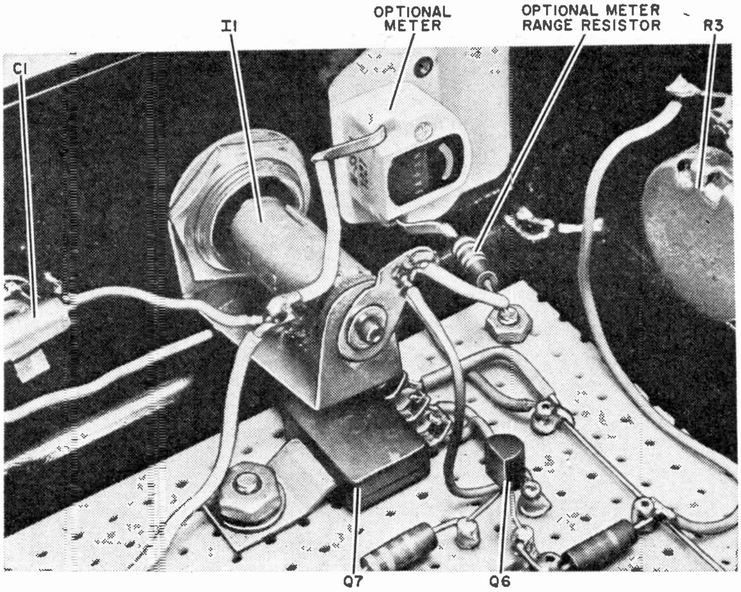
circuit board is available. The components layout for the perf board is shown in Fig. 2.

To prepare the case, use a circle cutter or fine saw to cut a hole in one end of the case slightly smaller than the rim diameter of the IR detector reflector. Secure the reflector to the case using high-quality cement or epoxy. The filter provided with the IR detector must be cut to size, with the protective paper left on it during the cutting process. Cut the filter slightly larger than the diameter of the reflector hole. When you are ready to affix the filter, remove the paper from both sides and glue the filter into place, covering the reflector.

At the top of the case, drill holes for the two potentiometers, *R2* and *R3*. In the end opposite the IR reflector, drill appropriate holes for indicator lamp *I1* and a miniature phone jack for the battery power leads. The author used the type of phone jack and earphone cable and plug usually furnished with imported transistor radios. The battery is carried on the waist belt. If desired, a hole can be cut out for an optional 6-volt meter. This meter is used for daylight indications when the glow of the lamp may be obscured by bright light.

Once the case has been prepared, mount the perf board (or PC board) in the case, using a standoff at each corner. Connect the circuit board to the other components according to Fig. 1. The schematic also shows the correct way to wire potentiometers *R2* and *R3*. One of the connections to the IR detector must be made to the reflector. Use a small file to clean away the protective coating. Tin this area soon after filing, avoiding excessive heating of the detector. If you want to use the Hotbox to trigger an external relay, mount a pair of binding posts near the power input jack. Connect the binding posts in parallel with the indicator lamp.

Checkout. Check all wiring for circuit errors, wrong component installation, and faulty soldering. Assuming that all is well, connect the 6-volt battery to the circuit being careful to get the polarity correct. Aim the IR detector end of the Hotbox so that it does not "see" any incandescent lamp, hot soldering iron, or other source of IR energy. With both *R2* and *R3* completely counterclockwise, the indicator light should be off (and the optional meter should indicate zero). Slowly rotate *R2* clockwise. At some point, the indicator light will come on. Once it is on, back off on *R2* until the light

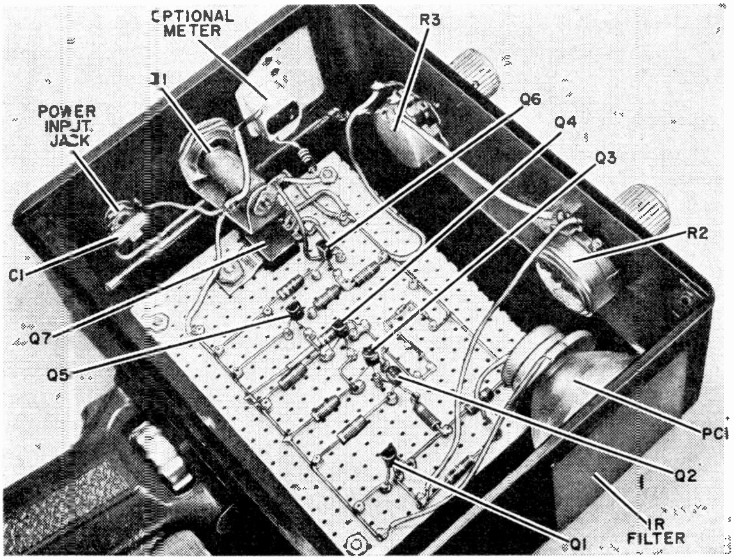


The optional meter range resistor converts the low-current meter into a 6-volt full-scale indicator. The resistor value depends on the type of meter. The meter reads the voltage drop across I1.

goes off. Now turn *R3* clockwise until the light comes on again. Then rotate *R3* slowly counterclockwise until the light just goes off. The detector is now set for maximum sensitivity. Potentiometer *R2* is used as the coarse control while *R3* is the fine adjustment. The settings of these controls determine at what level the Hotbox responds. If a particular device normally runs hot, set the controls

(*Continued on page* 152)

Fig. 2. Internal arrangement of the detector. The optional camera pistol grip is secured with its own screw and makes portable use very convenient. With it, you can aim the detector where desired.



VR with IC

PRECISE REGULATION IN A TO-5 PACKAGE

BY TOM THORKELSON

THE WIDESPREAD popularity of the integrated circuit has brought to light the urgent need for an inexpensive regulated d.c. power supply that can be safely used for IC experimentation. Working on the assumption that most experimenters already have an unregulated power supply on their benches, the problem was to design an inexpensive accessory that could upgrade the common power supply to provide lab features.

Now, for less than $5, such an accessory is obtainable in the form of the NJS300 voltage regulator available from New Jersey Semiconductor Products, Inc., Blue Star Shopping Center, U.S. Highway 22, Watchung, N.J. 07060.

This National Semiconductor IC contains 12 transistors, eight resistors, and three diodes—two of which are zeners—all contained in a compact TO-5 eight-lead package. The NJS300 accepts unregulated d.c. inputs ranging from +8 to +30 volts, and delivers any regulated d.c. output voltage between +2 and +20 volts.

When connected to the output of an unregulated power supply, voltage regulation is 0.5% for load changes and 0.1% for a 1-volt change in input. The input-output voltage differential ranges from 3 volts minimum to 20 volts maximum. Additionally, the voltage regulator gives short-circuit protection, fast action regulation, choice of output voltages, and low idle drain.

With the addition of external components, you can build a power supply to deliver almost any regulated current. The short circuit protection simply shuts down the power supply when the output terminals are shorted together; removing the short restores the voltage to its former value.

How to Use. The voltage regulator's pin designations are shown in Fig. 1. You can leave pin 1 unconnected for standard regulator operation, or connect a resistor between pins 1 and 8 to provide current limiting. The resistor value can be determined from the relationship $R = 0.350/I$, where I is the desired current limit in amperes. For example, if you want to limit the current to 10 mA

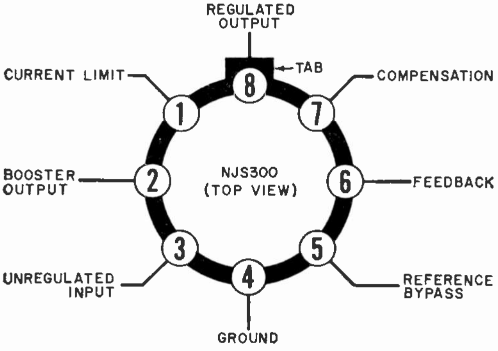


Fig. 1. Voltage-regulator pin arrangement. Components are added to provide for various load types.

(0.01 ampere) the resistance needed is 0.350/0.01 or 35 ohms.

If you want to use the regulator for output currents not in excess of 12 mA, connect pin 2 to pin 3. For output currents exceeding 12 mA, other external components (to be given later) are needed.

The unregulated input voltage is applied to pin 3 and must never exceed 30 volts. An input below 8 volts cannot be properly regulated, though it is possible to get a regulated 2-volt output with the unregulated 8-volt input. In any case, the unregulated input must be at least 3 volts greater than the desired output.

Pin 4 is normally connected to the circuit ground. Do not make any connection to pin 5.

A portion of the regulated output is applied to pin 6 as feedback. The amount of feedback used depends on the output desired. Two resistors are used as a voltage divider to obtain a portion of the output for the feedback. The ohmic values of these two resistors are determined from the curves in Fig. 2. For example, assume that a 4-volt regulated output is desired. The values of *R1* and *R2* (see How It Works) are found to be 5000 and 4000 ohms respectively.

A 47-pF capacitor should be connected between pins 6 and 7 for all applications to improve compensation response time.

Applications. Three different current-limiting circuits, suitable for a variety of

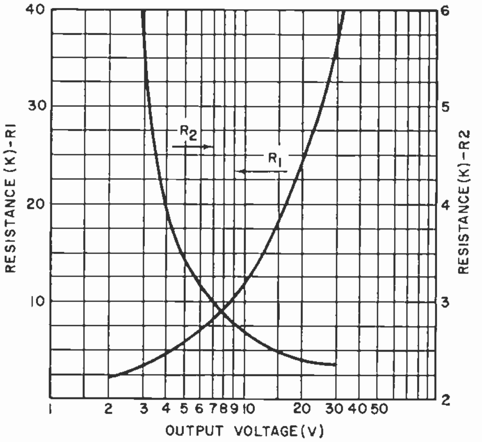
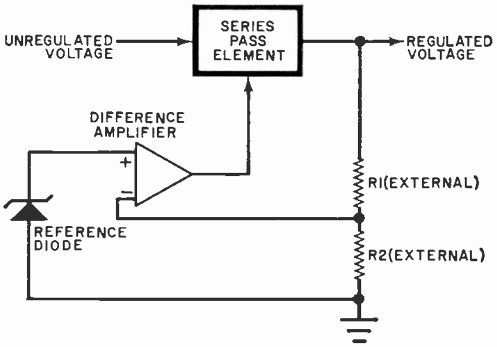


Fig. 2. Resistance values (in kilohms) for R1 and R2 in feedback circuit versus desired output volts.

HOW IT WORKS

The NJS300 voltage regulator consists of 12 transistors, 8 resistors, and 3 diodes, all deposited and interconnected on a single silicon chip $\frac{1}{16}$" square. These 23 elements make up a feedback control system as shown in the diagram.

The unregulated d.c. input is applied to a series-pass element that is controlled by an error voltage from a difference amplifier. The error is determined in the amplifier by comparing a portion of the regulated output voltage with the voltage across a precise voltage reference diode. (The sample of regulated output is taken from an external voltage divider consisting of resistors R1 and R2.) If the regulated output voltage is not correct, the error voltage developed by the difference amplifier causes the series-pass element to adjust the output until it returns to the predetermined value.



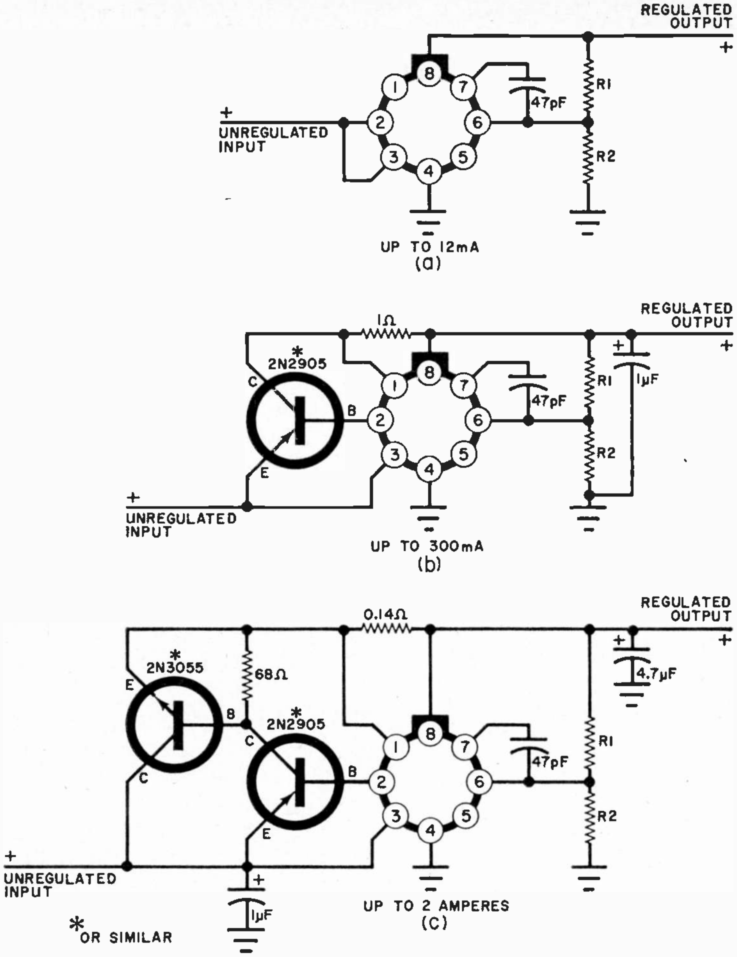


Fig. 3. Circuit at (a) provides a regulated output under 12 mA. Booster transistor is added in circuit (b) for output to 300 mA with smoothing capacitor. Second transistor (c) provides up to 2 A.

experimenters' power supplies are shown in Fig. 3. In Fig. 3(a), the current-limiting resistor between pins 1 and 8 is omitted because the current output demand should not exceed 12 mA. (A resistor could be added, of course, if a lower current limit is desired.) A transistor and resistor have been added in Fig. 3(b) to provide output current up to 300 mA. In Fig. 3(c), a pair of transistors is used to provide an output up to 2 amperes. In the second and third circuits, solid-tantalum filter capacitors have been added to improve smoothing. Also, in these two cases, the current-limiting resistors have been determined for the approximate maximum current value. If a lower current limit is required, the resistor value should be changed accordingly. -30-

Advanced Ham Frequency Calibrator

COMPLY WITH NEW RULES—CHECK YOUR OPERATING FREQUENCY TO 25 KHZ

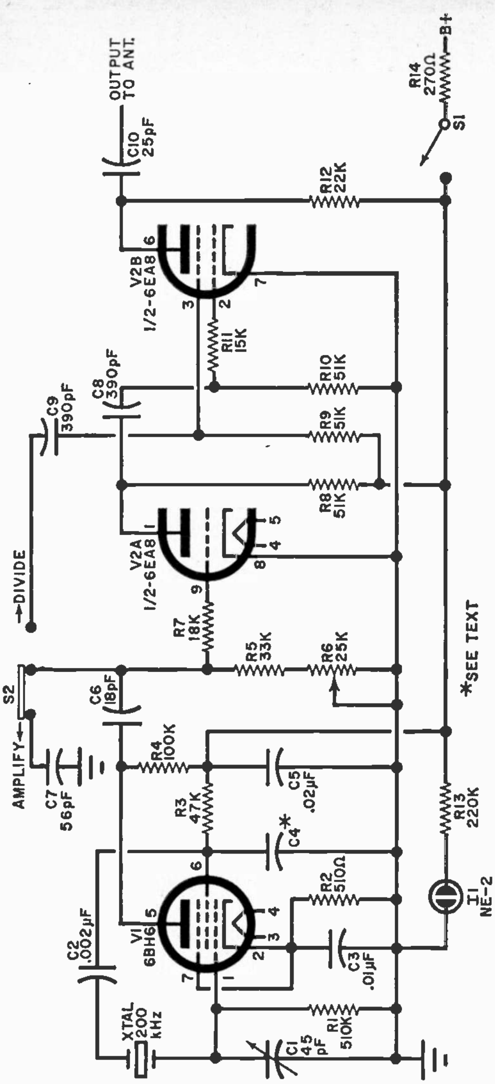
BY NEIL JOHNSON, W2OLU

THE MAJORITY of American hams has been content to comply with FCC rules for checking operating frequency by using a 100-kHz crystal-controlled frequency standard. Under the latest FCC regulation, however, Advanced and Extra class licensees are required to check their operating frequencies to make certain that they fall within certain 25-kHz sub-bands in the conventional ham bands. At present, there is no low-cost commercial unit available for this purpose. The crystal-controlled calibrator described here fills the need.

It would be natural to assume that such a device would incorporate the latest in semiconductor devices. However, a casual survey of hams in the N.Y. metropolitan area showed that over 95% of them are still using vacuum-tube receivers. This being the case, the frequency calibrator was designed to work in conjunction with this type of receiver.

Because power can be obtained from the receiver, the frequency calibrator can be built directly into the receiver cabinet, with only a couple of front-panel switches to control operation. Power requirements are low for a vacuum-tube unit: 600 mA for filaments and 10 mA or less for the plates. One switch determines whether the frequency output is at 200-kHz or 25-kHz intervals and the other turns the calibrator on and off.

Construction. The author elected to construct his calibrator on perf board, although point-to-point or printed-circuit board construction can be used. The use of good-quality components, especially in the crystal oscillator stage, is recommended. Silver mica, or zero-temperature-coefficient ceramic capacitors should be used. By-pass capacitors should be ceramic or Mylar, while tube sockets should be either ceramic or mica-filled. Do not use tube shields as they tend to attenuate the higher harmonics of the circuit. Use as short a lead as possible from the r.f. output of the calibrator to the receiver antenna terminals. Avoid the use of lengthy coaxial cable as this reduces the signals above 30 MHz. Neon lamp *I1* and its associated dropping resistor *R13* are optional. Between 150 and 200 volts d.c. is required by the plate circuits, and this can be obtained from the receiver power supply. If the available B+ is higher than 200 volts, a 2-watt dropping resistor can be inserted between *R14* and the B+, allowing 100 ohms for each volt to be dropped. For example, if the B+ is 250 volts, the resistor should be approximately 5000 ohms.



No tuned circuits are used, giving the crystal oscillator a harmonic-rich output. The second stage (V2) acts as a frequency divider controlled by R6.

Avoid the use of World War II surplus crystals. The best type is the HC6U, a source for which is given in the Parts List.

Note that no value is given for *C4*, the screen bypass capacitor for *V1*. Values will vary from 150 pF maximum to 50 pF minimum, depending on the crystal used. With the crystal specified in the Parts List and a 51-pF screen bypass capacitor, the crystal resonated with 15 MHz from WWV.

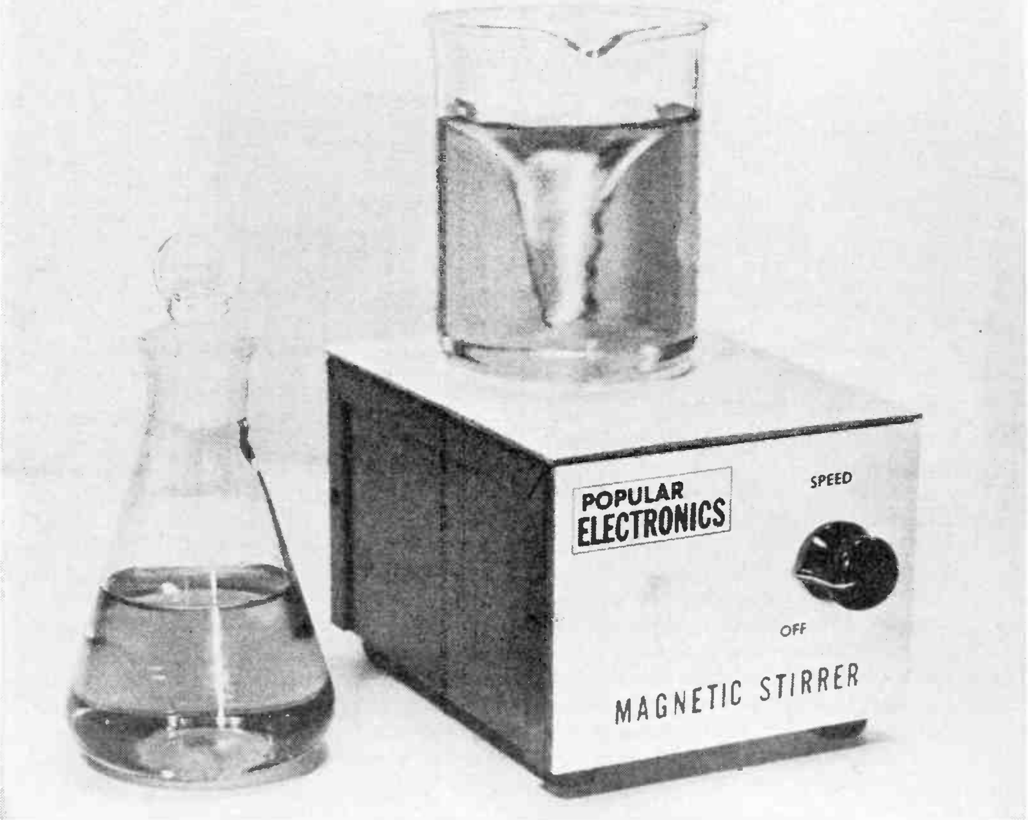
PARTS LIST

C1—3.2- to 50-pF trimmer capacitor (E.F. Johnson type S or similar)
C2—0.002-µF capacitor
C3—0.01-µF capacitor
C4—See text
C5—0.02-µF capacitor
C6—18-pF capacitor
C7—56-pF capacitor
C8, C9—390-pF capacitor
C10—25-pF capacitor
I1—NE-2 neon lamp (optional)
R1—510,000-ohm
R2—510-ohm
R3—47,000-ohm
R4—100,000-ohm
R5—33,000-ohm
R7—18,000-ohm
R8-R10—51,000-ohm
R11—15,000-ohm
R12—22,000-ohm
R13—220,000-ohm
R14—270-ohm
All resistors ½-watt
R6—25,000-ohm potentiometer
S1—S.p.s.t. switch
S2—S.p.d.t. switch
V1—6BH6 tube
V2—6EA8 tube
*XTAL—200.000-kHz HC6U**
Misc.—Perf board, ceramic tube sockets (one 7-pin, one 9-pin), ceramic crystal socket, mounting hardware, terminal strips, wire, etc.
**A 200.000-kHz HC6U crystal is available from JAN Crystals, 2400 Crystal Drive, Fort Myers, Florida 33901, for $2.30 ($2.50 with socket) postpaid.*

Operation. With power applied to the calibrator and the r.f. output connected to the antenna terminal of the receiver, turn on switch *S1*. The optional neon indicator lamp should come on. Place *S2* in the AMPLIFY position and, with the receiver BFO turned on, note that, as the receiver tuning is operated, a signal is heard at each 200-kHz interval along the dial. Turn off the calibrator and tune the receiver to any of the WWV standard frequency stations. Once you have accurately set a zero beat (using the receiver BFO) with WWV, turn the calibrator back on, turn off the receiver BFO, and adjust *C1* until the calibrator and WWV zero beat with each other.

Place *S2* in the DIVIDE position. Adjust frequency division potentiometer R6 until seven calibrator signals are heard between the 200-kHz intervals on the dial. In the author's prototype, this occurred with *R6* set at about 11,000 ohms. Flip *S2* back and forth between its two positions, making sure that the 25-kHz "birdies" return whenever *S2* is on DIVIDE. If not, a slight readjustment of *R6* is required. -30-

BUILD VARIABLE-SPEED MAGNETIC STIRRER



BY R. C. DENNISON

electronics IN THE chemistry LAB

UNIFORM MIXING AND STIRRING WITH ELECTRONICS

A MAGNETIC STIRRER that mixes chemical solutions smoothly, thoroughly, and without splashing is here. A photographer can use it to mix developers or hypo, and chemists, pharmacists, biologists, and other lab workers will find many uses for it.

Laboratory procedures are speeded up, or made more exact, by uniform stirring action while reagents are being added or while various ingredients are being blended. For example, during a titration, an acid or base is added to a solution until the proper pH is obtained. (See article on page 21.) Without constant stirring, it is easy to overshoot the balance point and thus waste time and materials. Other applications involve mixing or stirring toxic, volatile, or flammable solutions which must be kept stoppered and mixing dyes or colored solutions before they are analyzed in a

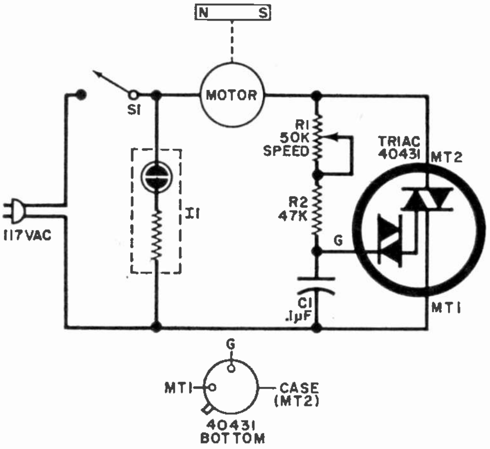


Fig. 1. Use of a triac with built-in trigger simplifies circuit design and provides smooth control of motor speed from creep to maximum.

PARTS LIST

C1—0.1-µF, 200-volt capacitor
I1—Neon indicator lamp with resistor assembly (117-volt)
Motor—Shaded-pole a.c. motor (R.M.S. M4RK or similar)
R1—50,000-ohm linear potentiometer (with attached switch)
R2—47,000-ohm, ½-watt resistor
S1—S.p.s.t. switch, part of R1
Triac—RCA type 40431 (do not substitute)
Misc.—Triac heat sink (Wakefield 254-S1 or similar), aluminum posts ¼" diameter by 1½" long internally threaded for 6-32 screws (H. H. Smith 8349 or similar) two required, 6-32 binding-head screws (four required), 4-lug terminal strip, aluminum box 5" x 4" x 3", sheet of thin (1/16"-thick) cork to cover top of box, self-adhesive plastic (white), epoxy glue, grommet, rectangular driving magnet 1" x ½" x ¼", stirring magnet, wire, rubber feet (4), knob.
Note: Plastic-coated stirring magnets and retrievers are available from Arthur H. Thomas Co., Box 779, Philadelphia, Penna. The driving magnet is available from Maryland Magnet Co., 5412 Gist Ave., Baltimore, Md. 21215.

colorimeter. One non-chemical use has been suggested—mixing alcoholic drinks without a shaker!

The magnetic stirrer consists of two magnets, a low-power a.c. motor, and an electronic motor-speed control. One of the magnets (called the driver) is attached to the shaft of the motor so that it rotates in a horizontal plane as the motor revolves. The other magnet (called the stirrer) is placed within the beaker, flask, bottle, or other non-magnetic container which is placed atop the magnetic stirrer, directly over the driver magnet.

As the motor and the driver magnet rotate, the stirrer magnet attempts to keep in magnetic alignment, and in the process, constantly stirs the liquid in the container.

There are many ways to control the speed of the motor. The simplest would be to use a power rheostat in series with the motor. While this is low in cost, it generates heat which might be undesirable in some applications. A Variac could be used, but this is a bulky, relatively expensive component. By making use of a triac, however, a simple low-cost elec-

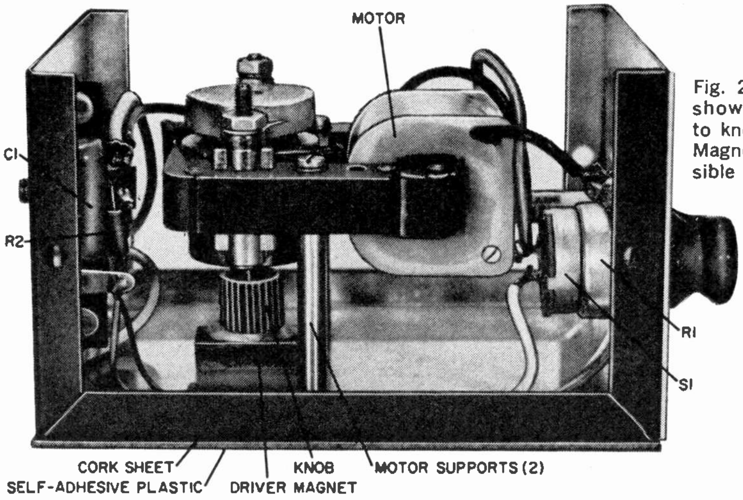


Fig. 2. View of inverted chassis shows driver magnet fixed to knob secured to motor shaft. Magnet must be as close as possible to non-magnetic frame top.

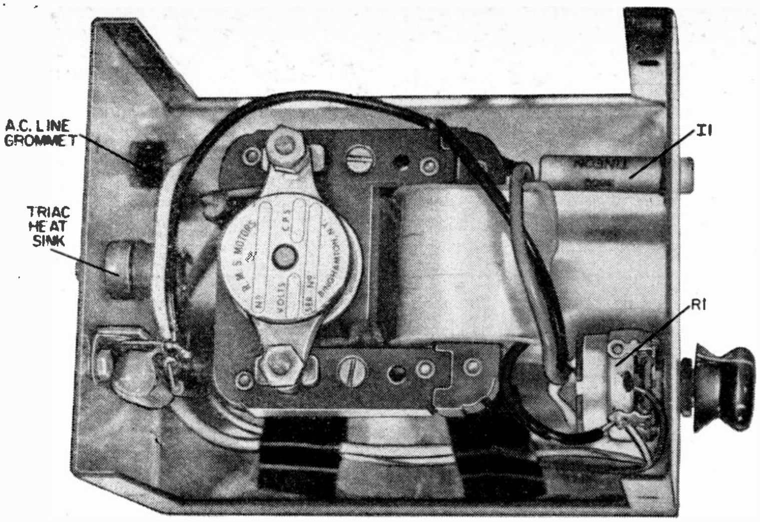


Fig. 3. When testing the magnetic stirrer with the top off, be sure not to touch any of the wiring since all of the circuit is connected to the a.c. power line. Do not use the metal chassis as a common tie point for any of the circuit.

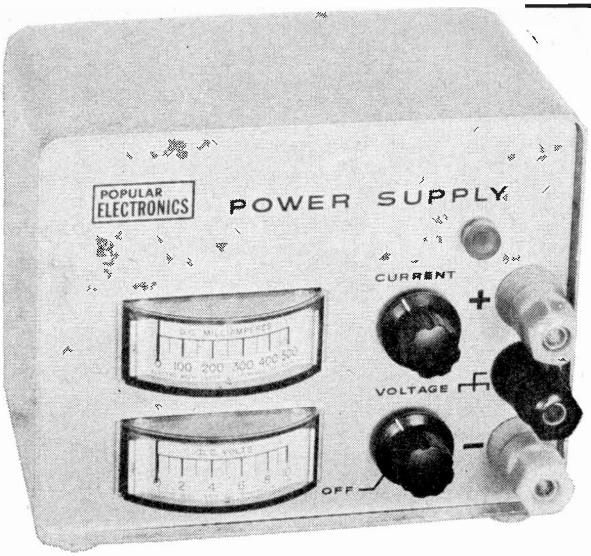
tronic circuit such as that shown in Fig. 1 can be constructed. This circuit does not generate heat and provides for infinite variation of motor (therefore, stirring) speed. Remember that a triac is similar to an SCR, but has the advantage of being bidirectional so that only one triac is required for full-wave control. Gating of the triac and actual speed are controlled by the phase-shifting network consisting of *R1*, *R2*, and *C1*.

Construction. The motor and speed-control circuit are assembled in a 5″ × 4″ × 3″ aluminum box as shown in Figs. 2 and 3. To get a good fit within the close confines of the box, shorten the motor shaft by approximately ⅜″. A small knob from an old radio is used to attach the driver magnet to the motor shaft. To do this, first enlarge the hole in the knob until it is a snug fit on the motor shaft. Slide the knob on the shaft, and hold the ¼-inch thick driver magnet to the top of the knob. The distance from the top of the magnet to the laminations of the motor should be slightly less than 1½″. Using a good quality cement, preferably epoxy, secure the knob on the shaft. Then cement the driver magnet to the upper surface of the knob taking care to center it for good balance. Place the finished motor assembly to one side and allow the cement to dry.

Drill a hole in the side of the chassis to accept the triac heat-sink mounting bolt, then secure the heat sink to the chassis (see Fig. 3). Mount the four-lug terminal strip near the heat sink. Slide the triac into the heat sink and secure it in place using a flat spring. The heat sink has a built-in insulator so that no external insulating washers are needed. Mount capacitor *C2* and resistor *R2* on the terminal strip. On the other side of the chassis, drill holes to mount potentiometer *R1* and power-on indicator *I1*.

Using the two mounting holes on the motor as a guide, drill two holes in the upper surface of the chassis. Making sure that the driver magnet is secure to the knob and that the knob is firm on the motor shaft, mount the motor to the chassis using 6-32 binding-head screws and two internally threaded aluminum mounting posts ¼″ in diameter by 1½″ long. The driver magnet should be free to rotate as close to the top of the chassis as possible. Wire the circuit as shown in Fig. 1. Triac MT2 terminal is the case of the triac which is plated to accept a soldered connection. Use a low-wattage soldering iron to make this connection, so as not to damage the triac by overheating it. Pass the a.c. line through the chassis using a rubber grommet as an insulator.

(*Continued on page* 151)



Experimenter's "Professional" Power Supply

- ADJUSTABLE 0-10 VOLTS
- ADJUSTABLE 0-500 mA
- SHORT-CIRCUIT-PROOF
- ALL FOR ABOUT $20

BY DON LANCASTER

LOOKING FOR a professional-quality low-voltage power supply? Here's one that puts out 0-10 volts at half an ampere or less, is fully regulated, and automatically protects both itself and your circuits from any possible damage. An adjustable current limiter sets the absolute maximum current that can possibly be delivered to the circuits—no high damaging currents are possible should an accidental short circuit or polarity reversal occur. The power supply can even run short-circuited overnight with no harm!

This power supply circuit (Fig. 1) is ideal for IC experiments, where you can easily set the 3.6 or 4.5 volts at the high-current levels you will need in multiple circuits. You'll also find it handy as a battery eliminator for transistor radio servicing, and a general replacement for "D" cells or similar batteries in bench experiments, and anywhere else you're working with transistor or IC circuitry.

The performance specs are very impressive: less than 1 millivolt of r.m.s. output ripple; regulation better than 300 millivolts, no load to full load. There are dual meters, one for voltage and one for current, with no confusion over what scale you are reading. Two controls are provided—one for adjusting voltage, the other to set the short-circuit current limit. And the split output terminal design gives you either a positive or negative case ground. All this in a three-pound 3″ x 4″ x 5″ package you can easily put together in several evenings for $15 to $30, depending upon how fancy you care to get.

Construction. The power supply will just fit in a 3″ x 4″ x 5″ metal box. Holes for the meters are cut with a nibbling tool. Color-coded five-way binding posts are used at the output, red for +, yellow for −, and black for the case. If you use *exactly* ¾″ mounting centers between the binding posts, you can use a standard double banana plug connector to your experimental projects. Line switch *S1* mounts on the rear of voltage-adjust potentiometer *R6*.

Although not essential, a small printed circuit board greatly simplifies the wiring and makes all the small parts easy to mount. The board should be laid out and drilled as shown in Fig. 2. Component layout and interconnections are shown in Fig. 3. Be very careful of all circuit and component polarities. The PC board mounts on the chassis spacers with four #6 screws.

To bleed the heat from *Q3*, use a Wakefield NC623K heat sink drilled to suit the 2N3766 unit specified, and an insulated mounting kit. (As this heat sink is a $1.50 item, you might prefer to build your own with 1/8" aluminum or some other low-priced material.) Use silicone grease on *Q3*, and check to be certain the transistor is insulated from the heat sink proper. The heat sink mounts on the rear of the case with pop rivets or #6 hardware.

Assembly. The various elements are assembled in the case in accordance with the layout selected. Figure 4 shows the author's unit before wiring. The printed board is mounted at the top, directly above the two meters, and the fuse holder is at the rear. The two potentiometers and three binding posts are also visible. The transformer (*T1*) and filter capaci-

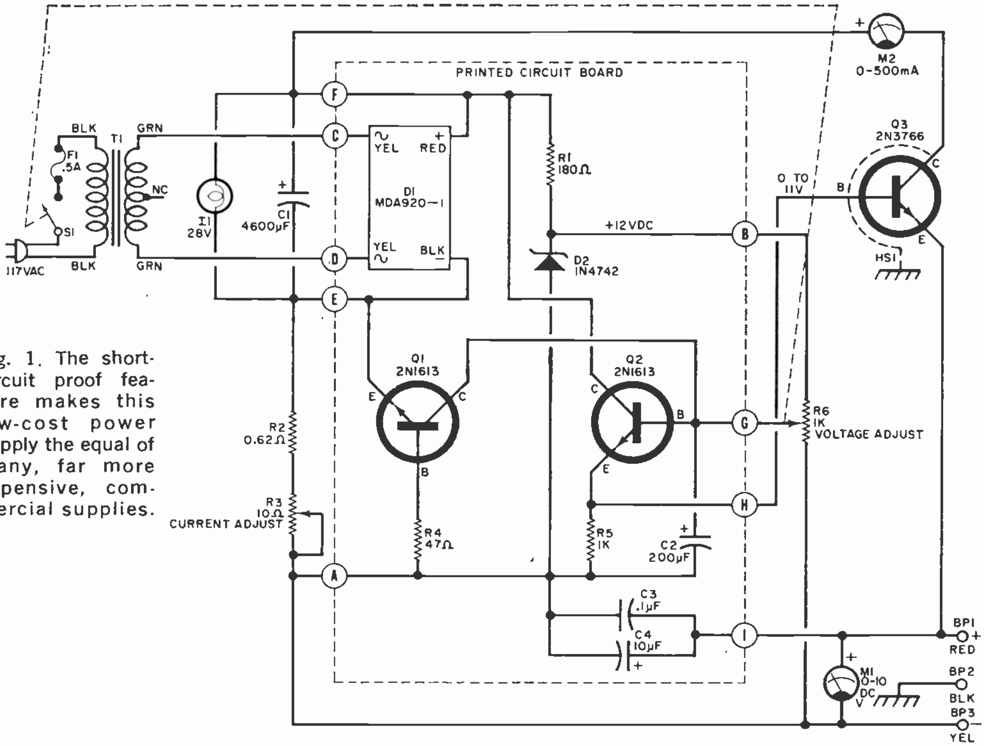
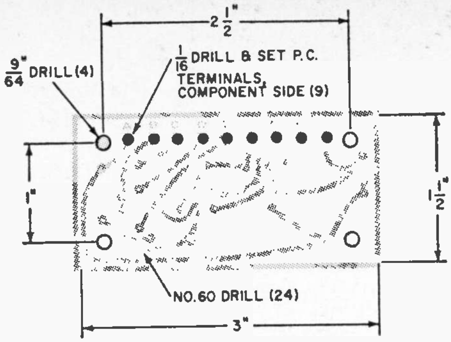


Fig. 1. The short-circuit proof feature makes this low-cost power supply the equal of many, far more expensive, commercial supplies.

PARTS LIST

BP1, BP2, BP3—5-way binding post, one red, one black, one yellow
C1—4600-µF, 15-volt computer-grade electrolytic capacitor (Sprague 462G015AA, or similar)
C2—200-µF, 15-volt electrolytic capacitor
C3—0.1-µF, 50-volt miniature disc ceramic capacitor
C4—10-µF, 15-volt electrolytic capacitor
D1—1.5-ampere, 50-volt, full-wave bridge rectifier (Motorola MDA930-1, or similar)
D2—12-volt, 1-watt zener diode (Motorola 1N4742, or similar)
F1—0.5-ampere fuse with holder
HS1—3" x 4 7/16" flat-finned heat sink (made from Wakefield NC623K—see text)
I1—28-volt, miniature pilot light assembly
M1—0-10 d.c. voltmeter, edgewise-type (Emico Model 13, or similar)
M2—0-500 d.c. milliammeter, edgewise-type (Emico Model 13 or similar)
PC1—1½" x 3" printed circuit board
Q1, Q2—2N1613 transistor
Q3—2N3766 transistor with mounting kit for TO-66 case
R1—180-ohm, ½-watt carbon resistor
R2—0.62-ohm, 1-watt carbon resistor
R3—10-ohm, 5-watt miniature wire-wound potentiometer (Mallory VW-10, or similar)
R4—47-ohm, ½-watt carbon resistor
R5—1000-ohm, ½-watt carbon resistor
R6—1000-ohm, ½-watt potentiometer (with s.p.s.t. switch S1)
S1—S.p.s.t. switch (on R6)
T1—12.6-volt, 2-ampere filament transformer (Allied Radio 54 D 1420 or similar)
1—3" x 4" x 5" enclosure (Bud CU-2105-A, or similar)
1—Hard anodized-aluminum dialplate, available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Arizona 85014; in silver color for $2.75, red or copper for $3.25, postpaid in USA; stock #PSY-1 (optional)
Misc.—Insulated mounting kit and #6 hardware for Q3, line cord and strain relief, ¾" knobs (2), mounting clip for C1, ground strap for BP2, #10 nylon cup washers (4), TO-5 transistor pads (2), printed circuit terminals (9), solderless terminals (9), wire nut, #6 hardware, wire, solder, etc.



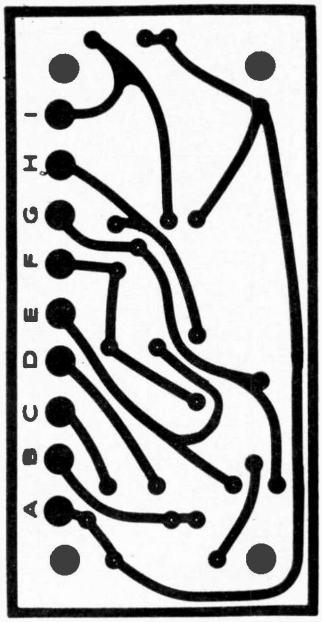


Fig. 2. Foil side of full-size PC board (right) is drilled as shown above and components mounted as shown in Fig. 3.

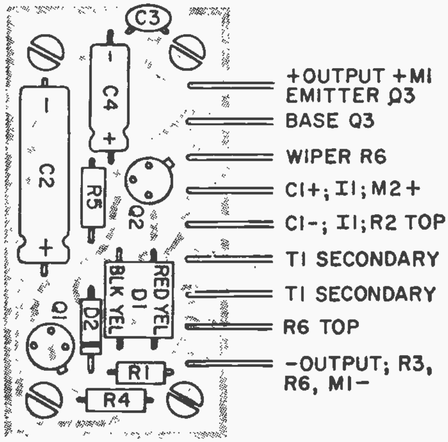


Fig. 3. Parts arrangement on component side of the printed board. Observe polarity of the capacitors.

HOW IT WORKS

The power supply circuit uses full-wave, capacitor-filtered, 16-volt, unregulated d.c. generated by 12.6-volt, 2-ampere filament transformer *T1*, rectifier bridge module *D1*, and filter capacitor *C1*. Transistors *Q2* and *Q3*, and 12-volt zener diode *D2* make up a voltage regulator. Together *Q1* and *Q2* have a gain of around 10,000, effectively "amplifying" the filtering effect of capacitor *C2*. Voltage-adjust potentiometer *R6* across *D2* permits setting the output voltage smoothly from zero to 10 volts. A heat sink is required for *Q3* as it will dissipate about 16 watts in the short-circuit mode.

A silicon transistor needs 0.6 volt between base and emitter before it will conduct current. To get short-circuit protection, a 0.62-ohm current sensing resistor (*R2*) is placed in series with the output, and transistor *Q1* is connected across this resistor. As long as the current is less than 1 ampere, the voltage drop across *R2* is less than 0.6 volt, and *Q1* stays *off*. If too much current flows, *Q1* immediately turns *on*, and robs the zener diode of its supply voltage; the output voltage, drops immediately, thus preventing any fault currents. A wire-wound control potentiometer (*R3*) connected in series with the 0.62-ohm resistor permits setting the maximum short-circuit current to be delivered to a load.

tor *C1* are mounted on the rear wall of the case. Long leads are used to interconnect these two components, and to wire *Q3* to the PC board.

Wiring should present no major problems. Use #18 wire on the high-current portions of the instrument—between the collector of *Q3* and meter *M2*, from *M2* to terminal F of the PC board, from the emitter of *Q3* to the red (+) binding post, and between the yellow (—) binding post and *R3*, *R3* to *R2* (*R3* can be soldered directly to *R2*), and *R2* to ter-

(*Continued on page* 145)

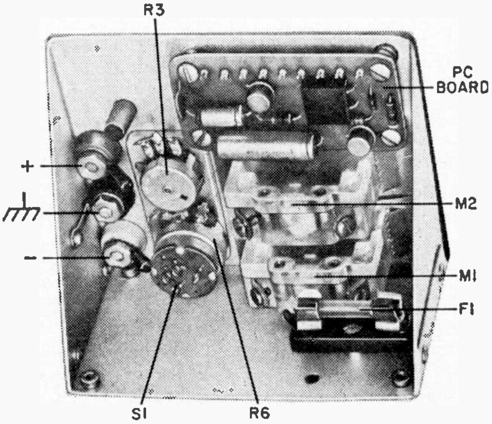
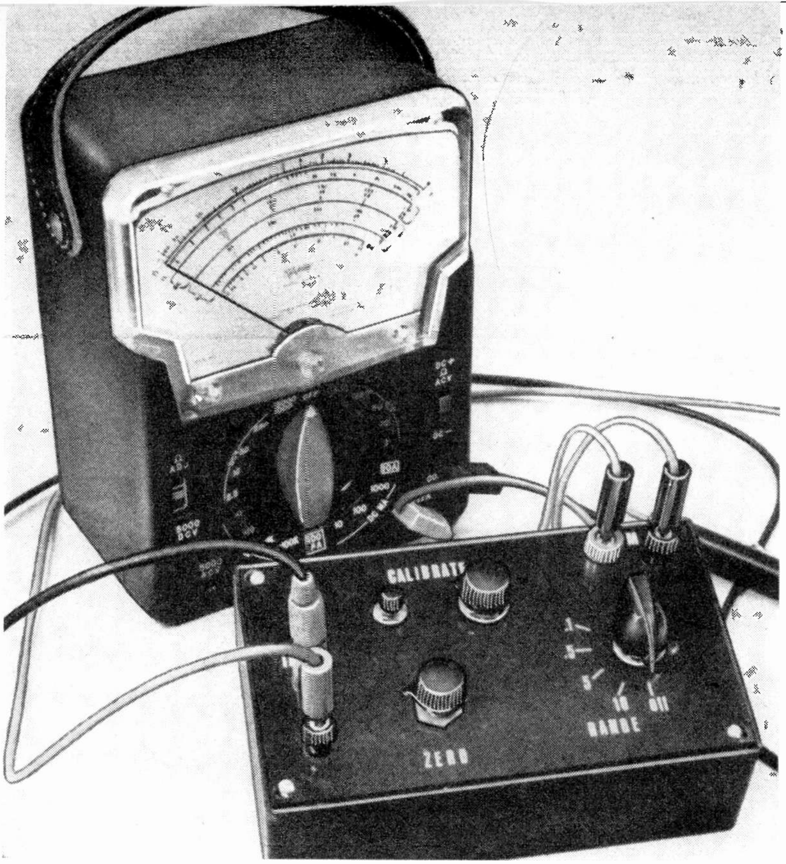


Fig. 4. Author's unit before wiring. Capacitor C1, transformer T1, and transistor Q1 are on rear cover.



FET REJUVENATES VOM

ADAPTERS IMPROVE SENSITIVITY OF ORDINARY VOLT-OHMMETER

BY SOL D. PRENSKY

THE OVER-WORKED VOM has been the best friend of the electronics experimenter for many years. While usable for most measurements, there comes a time when the faithful VOM must be shunted aside for the VTVM, especially when it comes to measuring the low-level voltages in semiconductor circuits, or when probing around in high-impedance circuits.

The reason for dropping the VOM by the wayside? Low input resistance—typically 20,000 ohms per volt—which puts an excessive load on critical circuits under test and produces false voltage indications. Also the VOM lacks sufficiently low full-scale voltage ranges. Most VOM's cannot measure below 1.0 or 1.5 volts at best. Since voltages in some semiconductor circuits do not exceed 0.1 volt, it is impossible to read them on a VOM, even if it has a suitably high input resistance to avoid circuit loading. Even VTVM's have their faults—the older ones do not have low enough full-scale voltage ranges.

Now the field-effect transistor (FET) has come along to allow the VOM to retrieve its rightful place on the workbench. A pair of FET's can be added to your VOM to convert it into a very high-input-resistance (10 megohms) voltmeter and also give it two more low-voltage ranges—0.5 and 0.1 volt full scale. Because both the FET adapter (powered by internal batteries) and the VOM require no power, you are not dependent on the a.c. power line.

PARTS LIST

BP1-BP4—5-way binding post, two black, two red
B1—6.75-volt mercury battery (2), (Mallory TR235R or similar; see text)
D1—5.6-volt zener diode 1N5232 (Motorola) or 1N1520 (International Rectifier)
Q1, Q2—N-channel FET TIS58 (Texas Instruments) or MPF103 (Motorola)
R1—8-megohm
R2—1.8-megohm
R3, R4—100,000-ohm
R5—50,000-ohm
R6, R8—15,000-ohm
R7—2000-ohm
R9—10-megohm
R10—220-ohm
R11—2700-ohm
R12—47-ohm
} *all resistors ½-watt, 5%*
R13—10,000-ohm linear potentiometer
R14—50,000-ohm linear potentiometer
S1—D.p.d.t. momentary pushbutton switch (Lafayette 99H6183 or similar)
S2—5-position, 2-pole rotary switch (Lafayette 30H4234 or similar)
Misc.—Plastic case, transistor sockets (2), perf board, knobs, mounting hardware, etc.

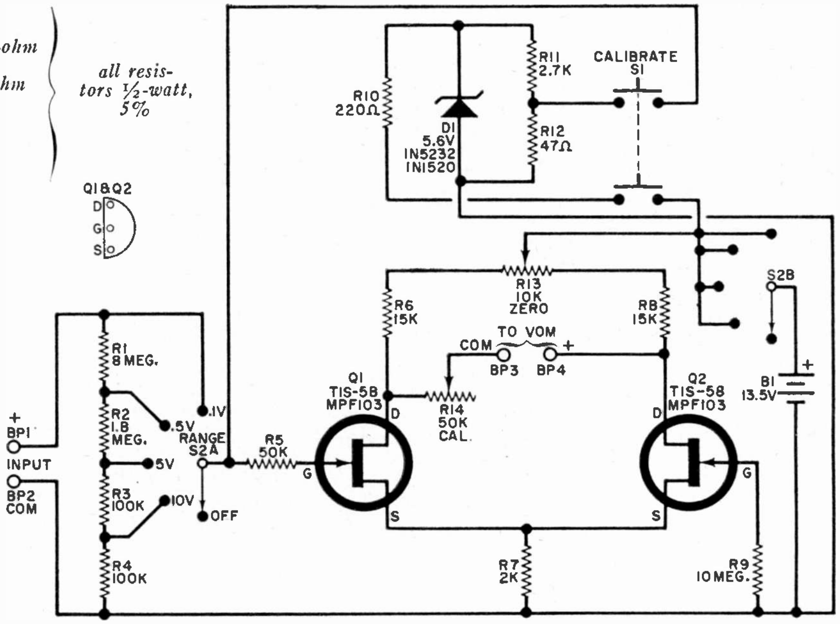


Fig. 1. Designed for use with 20,000 ohms/volt VOM's equipped with a 0-1-volt d.c. range, this circuit provides the VOM with effective input resistance of 10 megohms.

PARTS LIST

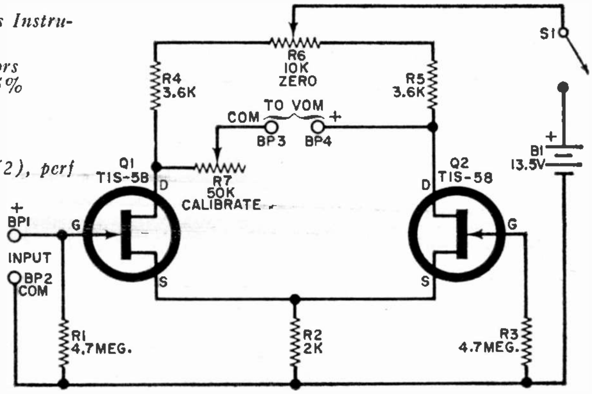
BP1-BP4—5-way binding post, two black, two red
B1—6.75-volt mercury battery (2), (Mallory TR235R or similar; see text)
Q1, Q2—N-channel FET TIS-58 (Texas Instruments)
R1, R3—4.7-megohm
R2—2000-ohm
R4, R5—3600-ohm
} *all resistors ½-watt, 5%*
R6—10,000-ohm linear potentiometer
R7—50,000-ohm linear potentiometer
S1—S.p.s.t. switch
Misc.—Plastic case, transistor sockets (2), perf board, knobs, mounting hardware, etc.

Fig. 2. For VOM's with only 1000 ohms/volt sensitivity, this simple circuit is used to provide d.c. input resistances on the order of five megohms.

Construction. If your VOM is of the popular 20,000-ohms-per-volt type, use the circuit shown in Fig. 1. If you have a 1000-ohms-per-volt VOM, use the circuit in Fig. 2. Note that the Fig. 2 circuit provides only 1-volt full-scale range at five megohms input resistance.

The circuit may be assembled on a perf board which is then mounted in a plastic case. The case also contains the

(*Continued on page* 140)



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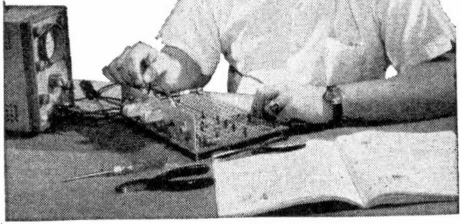

Transistor experiments on programmed breadboard — using oscilloscope.

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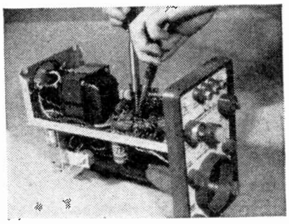
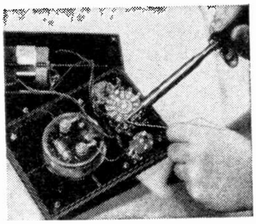


Construction of Oscilloscope.



Construction of Multimeter.

RCA

(*Continued from page* 136)

batteries used for power. Although the author used a pair of 6.75-volt mercury cells, you can use any combination of batteries to produce between 9 and 13 volts for satisfactory operation. The two FET's draw only 0.5 mA during a measurement, while the seldom-used calibration circuit takes 15 mA. Batteries should last a long time.

Operation. Place the VOM range switch in the 1-volt d.c. position, then connect the VOM to the FET adapter output binding posts, making sure that proper polarity is observed. Connect a pair of test leads to the adapter input binding posts and short these two leads together. Then place the FET adapter RANGE switch (*S2*) in any position other than OFF. Rotate the ZERO potentiometer (*R13*) until the VOM needle is on zero.

Separate the two test leads on the input of the adapter and place the RANGE switch in the 0.1-V position. Depress the CALIBRATE pushbutton (*S1*) and adjust the CALIBRATE potentiometer (*R14*) until the VOM indicates exactly 1-volt d.c. Release the pushbutton.

If your VOM has a full-scale range of 1.2 or 1.5 volts, adjust *R14* for an exact 1-volt reading. In either case, the scale markings of the VOM must be multiplied by 100 to give you a reading in millivolts. Once calibration has been performed for the 0.1-V position of *S2*, the calibration will hold true for the other three ranges. In the case of the 0.5-V position, multiply the VOM reading by 500 to obtain the value in millivolts (or divide by two to get the value in volts); in the 5-V position, multiply the VOM scale by 5 to get the value in volts; and in the 10-V position, multiply the VOM scale by 10 for the value in volts.

Because of the very high input resistance and the 0.1-volt full-scale lowest range, the FET adapter can be used to measure very small current flow through a circuit. This is done by measuring the voltage drop across a resistor with a low ohmic value in series with the current flow. Apply Ohm's Law (E=IR) to find the current. -30-

---

Broadband Dipole For 75/80 Meters

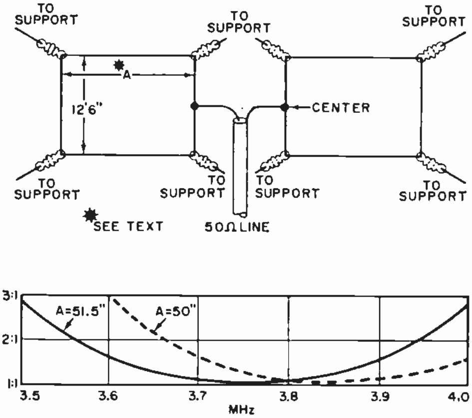
BY BOB DAHLQUIST, WB6KGF

THIS ANTENNA WILL ALLOW you to load your transmitter across the entire 500 kHz of the 75-80-meter band without using an antenna tuner, and with a SWR less than 3:1.

Construction is shown in the diagram. About 260 feet of antenna wire is required, as well as eight insulators, a conventional Hy-Gain center insulator (or substitute), and a length of 50-ohm transmission line long enough to go from the antenna to the transmitter. You will also need three antenna supports, masts or trees, between 30 and 40 feet high. Although these supports should be in a reasonably straight line, the antenna will work if it is folded up to 90°, making a horizontal Vee.

For coverage of the entire band, side A should be 51 feet, 6 inches. To cover just the phone portion of the band, side A is made 50 feet long. The resultant SWR is also shown in the diagram.

Because the SWR is affected by the height of the antenna and whether or not it is folded, you may have to shorten or lengthen side A to obtain the lowest SWR. -30-



Length of side A depends on coverage desired and determines the standing wave ratio for the dipole.

BENCH SUPPLY

(*Continued from page* 118)

ther to the full winding or to the tap. With the switch in the latter position, you can get an output approaching 140 volts.

It is also a good idea to have a means of obtaining very low voltages without depending on the setting of the variable transformer. For this purpose, use a HIGH-LOW switch which, in the LOW position, puts a step-down transformer across the output of the variable transformer. The author uses a multi-tap transformer here, but any step-down transformer with a 12-volt center-tapped secondary which is capable of carrying at least 1 ampere would be suitable.

Having a meter in the output of the supply is extremely convenient and timesaving. A meter with a 0-150 volt linear scale is best. Unfortunately, a number of inexpensive a.c. voltmeters have nonlinear scales. Although they serve perfectly well in other applications, such meters do not have a scale range that is sufficiently detailed to be of value when used with a variable-voltage transformer.

You can use the meter for the low-voltage output if you determine the voltage (turns) ratio of the step-down transformer accurately and apply this ratio to the meter reading.

Packaging the Supply. The assembly shown in the photo uses a 2.4-ampere Variac mounted in a 6″ × 6″ × 6″ aluminum cabinet, with the knob for the Variac on the top. Two large handles also on the top can be used to carry the supply; they also protect the Variac knob so that it can't be accidentally moved and they provide a place to rest the palm of your hand while making a setting of the knob.

Although the schematic diagram shows only one 120-volt output receptacle, the author's setup has two wired in parallel for added convenience. They are located on the rear of the cabinet so that cords plugged into them are out of the way of the work area and the controls.

-30-

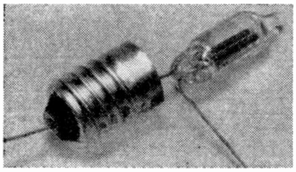
METHODS

THE BEST OF TIPS & TECHNIQUES

GADGETS

ADD SCREW BASE TO NE-2 NEON LAMP

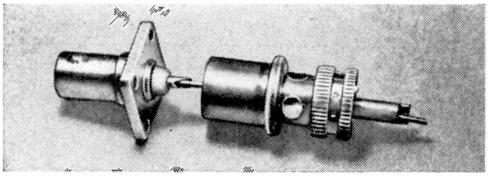
At one time or another you have probably had (or will have) a need for an NE-2 neon lamp with a screw base for one of your projects. Unfortunately, NE-2 lamps come with wire leads not designed for screwing into pilot lamp sockets. However, you can solve the problem quickly enough if you have an incandescent pilot lamp you're willing to sacrifice — or one that has burned out and you never threw away. Carefully break the glass envelope of the incandescent lamp, and remove the elements and whatever glass remains in the screw base. Insert one of the wire leads on the NE-2 through the bottom contact of the lamp as shown in the photo; the other lead goes to the metal case. Insulate the leads from each other, solder both in place and, you'll have a screw-base NE-2 lamp.



—*Hubert Melin*

EMERGENCY COAX CONNECTOR

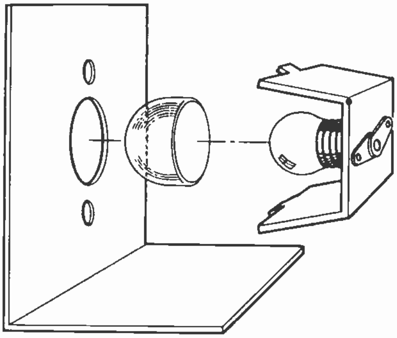
What do you do when you have to connect a PL259 plug to a UG 261/U BNC-type jack? Well, you could change the connector on either the cable or the piece of equipment the cable must be connected to. However, this means you'll just have to change the connector again when you're finished. A quick way out of this problem is to make an adapter. A type UG 261/U single-hole mounting BNC connector makes a good slip fit into the stem of a PL259 plug for the adapter assembly. First, solder a length of bare, solid hookup wire into the BNC connector, and slide the wire through the stem of the PL259 plug as shown in the photo. Now, bend the end of the wire over the center contact of the PL259, bringing the flange of the BNC into contact with the PL259 plug. Solder the wire in place and also solder together the outer conductors of both connectors. For this application you can discard the shell of the PL259. Shrink some heat-shrinkable tubing over the assembly, and you have a good emergency adapter.



—*Robert Runnels,* WA8UGT

COLORED LAMPS AID LOGGING DX

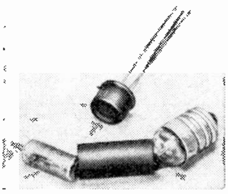
Add color to the tuning dial of your shortwave receiver and you can make logging stations easier. The colored glow lets you distinguish between main tuning and bandspread at a glance. This works especially well with the Knight-Kit Model R-100A receiver. Remove the #47 lamps, and replace them with #51 lamps. Then place colored dome-type lenses (for example, red for main tuning and green for bandspread) over the lamps, and replace the lamp holder on its bracket.



—*Gary Hummell*

HEAT-SHRINKABLE TUBING COUPLES PHOTOCELL TO LIGHT SOURCE

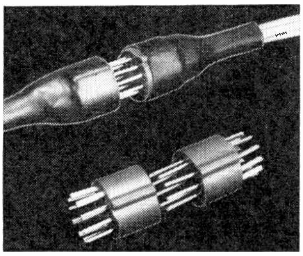
The next time you build a project that uses a photocell control circuit, use heat-shrinkable tubing to join the lamp and photocell mechanically end-to-end to produce a light-tight coupling. After butting the lamp and photocell together, slip a length of the heat-shrinkable tubing over the two. The length of tubing used should be adequate enough to allow ¼" overhang at the ends of the lamp and photocell. Shrink the tubing, making sure the overlap makes a good seal.



—*Royland Pettersen*

SUBMINIATURE CONNECTORS FOR PROJECTS AND EQUIPMENT

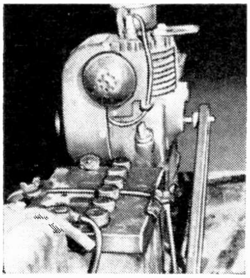
You can make inexpensive subminiature connectors from 6-, 8-, or 10-pin TO-5 integrated circuit sockets. A socket with the wires from the circuit soldered to the pins serves as the female connector. The male connector must be prepared by carefully melting a small amount of solder into each of the IC socket's holes. Then cut the required number of lengths of wire (transistor or IC leads make a perfect fit) to ¼" or ⅜". Heat the pins of the IC socket, and drop in the lengths of wire. Then solder the wires to the appropriate pins on the male connector. Finally, slip a 1" length of heat-shrinkable tubing over each connector, and shrink it in place.



—*C. A. Schieszer*

MOWER ENGINE SAVES GAS WHEN CHARGING BATTERY

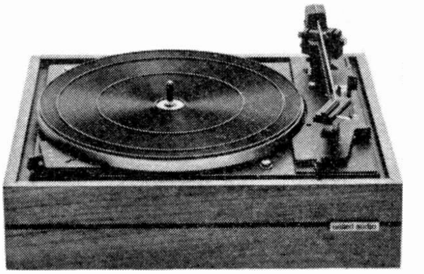
The camper usually has to rely on his car's electrical system for power to operate lights and radios, and this generally means that his car's engine must be kept running to keep the battery fully charged. However, with the aid of an old lawn mower engine, and some hardware, the battery can be kept fully charged with a very small outlay for gas. First, use four heavy bolts to mount a metal plate semipermanently inside the car's engine near the generator or alternator. Then mount the mower engine on the metal plate. In use, you simply remove and save the fan belt, and run another belt from mower engine to generator. The generator's mounting bracket provides belt adjustment. Overcharging is prevented by the car's voltage regulator. When not in use, the fan belt goes back in place and the mower engine stores neatly away in your car's trunk.

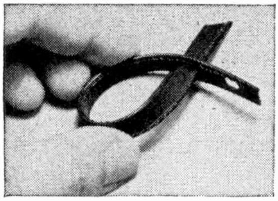


—*Harry I. Miller*

TV LEAD-IN DOUBLES AS CABLE TIES

One of the most unsightly—and possibly most dangerous—things in ham shacks and workshops is dangling wires and cables. If you have some extra 300-ohm twin-lead TV lead-in cable handy, however, you can fabricate





your own cable tie/hangers and eliminate the problems. Cut the lead-in to the approximate lengths needed, square at one end, and at an angle at the other end. Then punch a hole at the squared end to facilitate hanging, and a slot (slightly shorter than the twin-lead is wide) directly below the hole. (See photo for details.) Wrap the fabricated cable tie/hanger around the cables to be bundled together and pass the angled end of the tie through the slot. Pull tight and anchor the tie with a nail or screw where desired. For low voltage, use the twin-lead as is; for high voltage, tear or cut out the conductors.

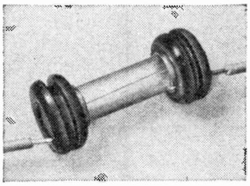
—*Stan Mosher*

ADD POWER LAMP/STROBE ACCESSORY TO YOUR TURNTABLE

You can add a power indicator light and strobe light accessory to your turntable for making quick and frequent checks of turntable speed. If your turntable doesn't already have a power indicator, mount a bayonet socket (with built-in resistor for operating neon lamps at 117 volts) on the front skirt of the turntable's base. At one end of the length of coaxial cable, solder a plain bayonet socket; at the other end a spare bayonet-type lamp base. In both cases, the center conductor of the coax goes to the "hot" contact, while the coax braid goes to the shell or "common" contact. Insulate any exposed metal with heat-shrinkable tubing. Plug the coax into the turntable-mounted lamp socket, and insert an NE51 or NE51H (if you want a brighter light, choose sockets to accept the brighter NE51H lamp). Then read turntable speed with a conventional strobe disc.

—*Henry R. Rosenblatt*

PIGTAILS FOR 3AG FUSES



It is often difficult to obtain pigtail-type fuses from local electronics parts dealers—they just aren't as common as they used to be. So, what do you do if you need to replace this type of fuse in a hurry? You *can* solder wires to the caps of conventional fuses, taking the chance that this will not "blow" the fuse as a result of the applied heat. A second and safer alternative is to secure pigtails to the fuse caps with snug-fitting rubber grommets. You simply force 3/16" rubber grommets over the fuse caps, wedging the wire pigtails between the grommets and caps. This home-brew technique will suffice temporarily until you can stock up on regular pigtail-type fuses.

—*Tod Wagner*

POWER SUPPLY

(*Continued from page* 134)

minal E of the PC board. Four #10 nylon cup washers serve as feet.

Current Limiting. The current limit can be preset from 50 to 500 mA. Up to about three-quarters of the current limit, the power supply produces a constant-voltage output. When the predetermined critical current value is reached, the regulator automatically switches over from constant voltage to constant current. For instance, suppose your circuit takes 60 mA of current under normal conditions. You would simply set your current limit about double, say 120 mA.

As long as the circuit is working properly, you get constant voltage out of the supply. Should a polarity reversal or a fault occur, the supply will provide no more than 120 mA. —30—

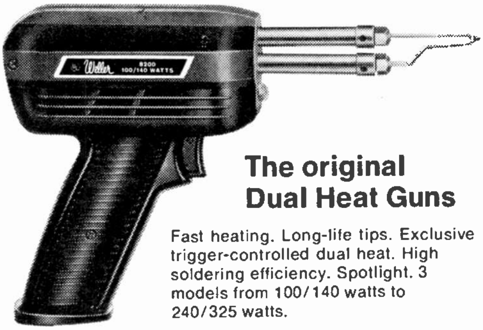
SPORTS TIMER

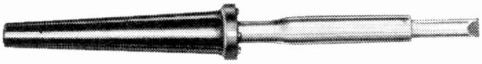
(*Continued from page* 102)

The counters to the left of it will operate much slower. The second to the left indicates hundredths of a second and the third indicates tenths of a second. The counter to the left of the decimal point indicates unit seconds, while the next counter to the left is tens of seconds. The latter is the modulo-6 counter that only goes to 5. At the 60th second, all counters to the right of the colon drop to zero with the minutes counter advancing to the next count. The counters will not stop, and you will see them proceed to 9 minutes, 59.999 seconds and repeat.

To stop the counter at any time, insert the wire jumper between the center contact of *J1* and the similar contact on the STOP jack *J3*. The various counters will stop and the real time can be read on the front-panel indicator lamps. Depressing the RESET button will zero the count. If the RESET button is depressed while

(*Continued on page* 149)





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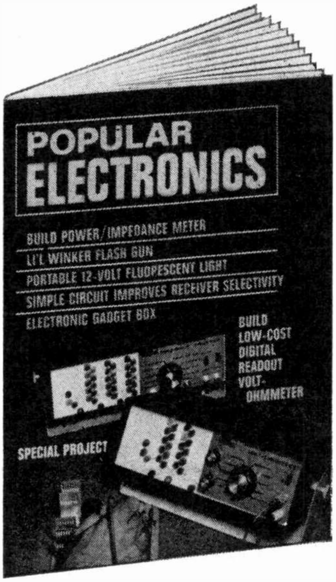

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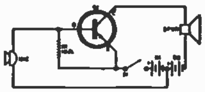

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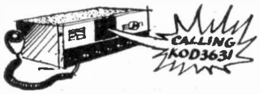

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(*Continued from page* 145)

the counting is taking place, the indicated time value will drop to zero, but immediately start up again as soon as the RESET button is released. This pushbutton has no effect on the three fixed indicator lamps. To shut the system down, turn *S1* to OFF.

Before assembling the cover on the chassis, use contact-adhesive plastic to give it a finished look.

Starting and Stopping. There are many ways to start the clock, and all depend on providing the START input jack with a positive-going pulse. For races of all types, you can use the photopickoff shown in Fig. 10 at either the start or finish line. Place a light source on one side of the track, focused either by a lens or a length of tubing in front of the lamp so that the light beam strikes the photo-Darlington transistor. A similar lens system, or length of tubing can be placed over the photo transistor to prevent triggering by ambient light. The switch shown in Fig. 10 is used to select either the presence or absence of light as the trigger.

The (+) jack is used to provide 3.6 volts to power any external trigger circuit.

Modifications. The timing unit kit is supplied with a 100-kHz, 0.005% tolerance crystal. With this crystal, the last digit on the right will not be accurate, although it can be used as a relative time indicator. Replacing the 0.005% crystal with one with an accuracy of 0.001% will produce the correct timing in the thousandths column.

If you want to read times up to one hour, add another modulo-6 counter at the left, driven by the "carry" of the minutes counter M8. The clock will now read to 59 minutes, 59.999 seconds. If you want to read up to 10 hours, add both the tens-of-minutes counter and another decade counter driven by the last "carry" output. The clock will now read to 9 hours, 59 minutes, and 59.999 seconds. This should be enough for almost any race. To convert the clock to read only hours, minutes, and seconds, as does a conventional clock, requires a little more logic and may be the subject of another article. -30-

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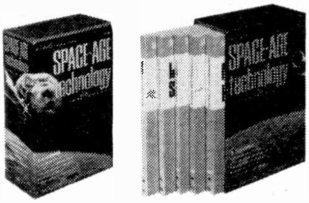

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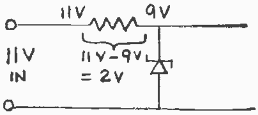
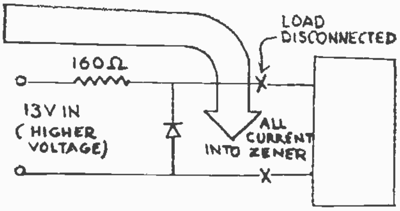
ZENER DIODE

(*Continued from page 88*)

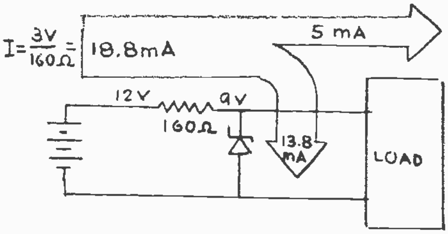
We also know there is only two volts driving the current through the resistor.



Ohm's law tells us that R = E/I = 2/0.0125 = 160 ohms. To handle our "worse case" conditions, the resistor value must be halved. Such a large change requires us to determine what would happen if someone disconnects the receiver and the voltage is up to 13 volts.



Fortunately, Ohm's law shows that a ¼-watt resistor will adequately handle the current, and multiplying 9 volts by 13.8 mA tells us that our 250-milliwatt zener is dissipating only 124.2 milliwatts. Now we have a regulator circuit we can build with confidence.



We have paid a price for our regulator, however, in the form of 13.8 mA wastage current through the zener diode. The advantage is that the receiver will operate reliably no matter what happens.

Now you know what a zener diode is and, more important, how it is used effectively. Our hypothetical example revolved around a radio-receiver load. But the load could just as easily have been a hi-fi amplifier or test instrument. -30-

MAGNETIC STIRRER

(Continued from page 131)

Clean the top outside surface of the chassis, and glue on a sheet of $1/16$″-thick cork that just covers the top. The appearance of the stirrer will be enhanced by covering the cork surface with white self-adhesive plastic sheet. White is used so that the true color of the liquid being stirred is visible. Allow the cork cement to dry thoroughly before applying the plastic or wrinkles will appear.

Testing and Use. Apply power to the circuit by rotating the speed-control potentiometer (*R1*) until switch *S1* closes and power-on indicator *I1* lights. As *R1* is rotated, the motor (and driving magnet) should spin faster and faster. Make sure when you wire the potentiometer, that the slowest motor speed occurs just after *S1* turns on. Turn off the power before the next step.

Fill a small beaker with water and place it on the white upper surface of the magnetic stirrer, directly above the driver magnet. Drop in a steel paper clip or small bar magnet. It will instantly align itself with the driver magnet. Position the beaker until the paper clip or bar magnet is centered within the beaker. As *R1* is rotated and power comes on, the stirring magnet will start to rotate (with the motor), and as *R1* is rotated up its range, the stirrer will rotate faster and produce a vortex in the water.

To avoid chemical interactions with the liquid being stirred, especially with corrosive or very active solutions, it is best to use a stirring magnet having a protective plastic coating. A magnet with a teflon coating is available (see Parts List).

A very handy gadget to have is a stirring-magnet retriever. This enables you to extract the stirring magnet without putting your fingers in the solution (with possible disastrous results if the solution happens to be corrosive or toxic). You can make a retriever by sealing a small magnet within a long plastic tube, or you can purchase one at low cost (see Parts List). -30-

IR DETECTOR

(Continued from page 123)

so that the Hotbox does not respond to this normal temperature but will respond to any higher temperature. Also remember that, although the Hotbox does not respond very readily to visible light, it does respond quite rapidly to the source of such light if it is hot—such as the filaments of incandescent or fluorescent bulbs, sunlight, etc. Keep this in mind when installing the Hotbox as a fire alarm.

Once the device is working properly, aim it at a source of IR energy—incandescent or fluorescent lamp filaments, lighted cigarette, hot soldering iron, etc. The indicator lamp should come on as the "beam" of the IR detector crosses the hot spot. You can determine the size of the detector's beam by placing the detector on one side of a pane of glass and moving a lit cigarette around the other side of the glass, marking the glass with a grease pencil where the detector goes on and off. You can make the calibration or measurement at various distances between the Hotbox and the glass pane.

For many applications, an external signal indication is desirable or necessary. In this case, a 6-volt d.c. relay coil can be substituted for the indicator lamp, with its contacts used to actuate a remote signalling system. A 6-volt d.c. buzzer can also be substituted for the relay for a local audible signal.

To use the detector as a burglar alarm, get a conventional IR lamp (heat lamp) from a drug or department store and position it so that the Hotbox can see it either directly or through a series of mirrors. Arrange the relay output so that, as long as the Hotbox sees the IR source the external signalling device will not be actuated. If an intruder breaks the IR beam, the alarm should go off. This is a fail-safe system since, if the intruder sees the IR source and turns it off, the alarm will sound anyway.

If a high-power alarm system is to be used, a power relay whose contacts can carry the required current can be activated by contacts on the relatively low-current relay that is driven directly by the Hotbox. -30-

FREQ-OUT

(*Continued from page* 110)

photocell is small enough to be hidden easily in decorative woodwork and may be separated from the modulator by a considerable distance as long as co-axial line is used to connect the two.

Some applications may require a set of contacts which close when the demodulator is actuated and remain closed until some specific action is taken to reset the relay. This can be done using external circuits, of course, but it is easier to do it by replacing *D5* with a wire jumper. Then the relay will automatically latch in once it has been actuated. A single-pole, normally closed switch placed in the lead between *K1* and point C on the PC board will serve as a reset switch.

There are some applications, such as garage door openers, which require contacts that alternate states on successive activations. This can be accomplished in the Freq-Out by substituting an impulse relay (such as Potter and Brumfield type PC11D) for *K1*. For applications where a stepping relay is required, a Guardian type IR-705-12P-6D is small and relatively inexpensive.

Most intrusion-alarm applications require that the relay be closed under normal conditions because of the light beam falling on the photocell. When the beam is interrupted, the relay opens and an alarm is sounded. It is also desirable to have the relay remain open after the light beam has been restored. The Freq-Out may be made to operate in this way by breaking the connection from point C on the PC board to *K1* and wiring the free ends to one of the normally open contacts on the relay. In addition, a normally open single-pole pushbutton switch should be wired across these contacts to serve as a reset [see Fig. 7(A)].

A more versatile system is shown in Fig. 7(B). With this arrangement, using a three-position switch, the relay may be latched on in the presence of a light signal, latched on in the absence of light, or operated in the normal mode. A common reset for both latching modes is also provided.

Operation. Once you have selected the

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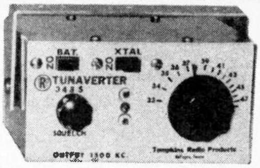

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type of Freq-Out you want and have built the modulator and demodulator, setting up the system is easy. Simply plug in the demodulator, turn it on and shine the light on the photocell. If you wish, you can use mirrors to bend the light beam and lenses to focus the beam. The Freq-Out is designed to operate in the near-infrared portion of the spectrum so you can make the beam almost invisible by filtering it through several layers of red cellophane. The operation of the unit will not be affected.

Although the circuits in the Freq-Out are insensitive to normal variations in ambient lighting, bright sunlight should not be allowed to fall directly on the photocell. If necessary, a shield of cardboard or plastic should be used to protect the photocell. —30—

PC BOARDS

(*Continued from page* 40)

the panel, copper side up, in the tray and occasionally tip the tray back and forth so that the etchant keeps moving. Use a plastic rod to tilt the tray, as most etchants will discolor skin or clothes they contact. Once etched (all the copper has been removed from the unwanted areas), wash the panel in running cold water for a few minutes.

There are two ways to remove the dyed resist. You can dip the board in the developer then wipe it clean using a towel or other cloth; or, you can use some fine steel wool to remove the dyed resist. If you use the former method, make sure that you go over the copper pattern with fine steel wool to prepare the surface for soldering (after the holes are drilled). If you use the latter process, you can, if desired, use steel wool to remove the black dyed resist from a small area immediately surrounding the soldering holes. In this way, when the board is finished, the pattern will stand out in a distinctive black.

After some use, the developer will develop a "skin". This means that it should be disposed of and a new batch of developer used. —30—

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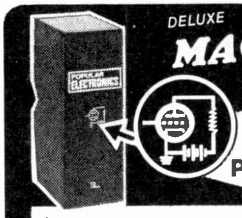

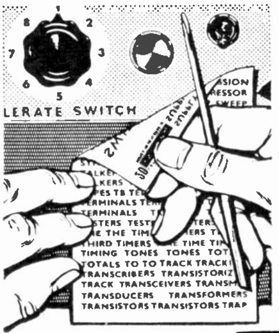

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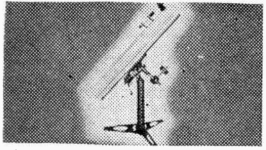

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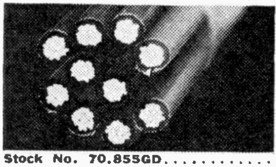

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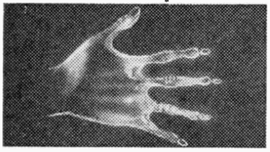

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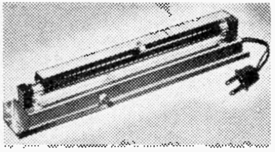

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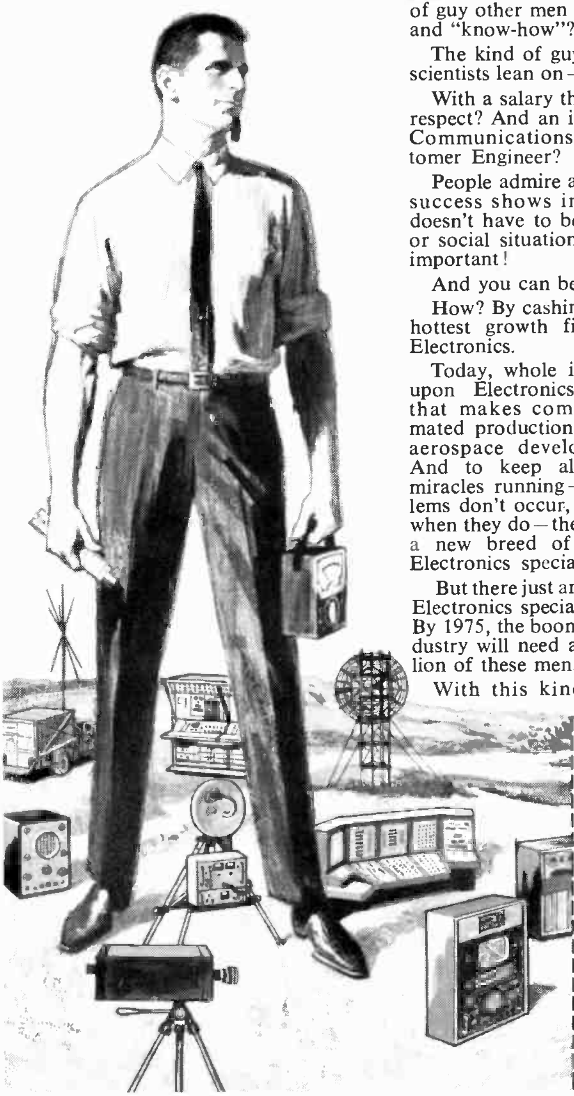

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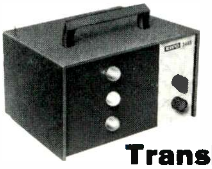

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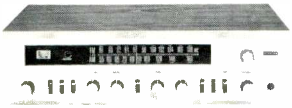

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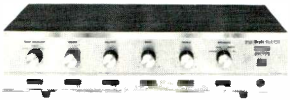

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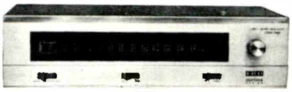

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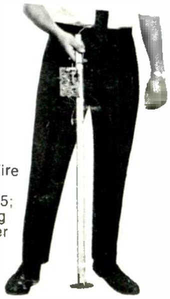

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