1970 POPULAR ELECTRONICS

ELECTRONIC EXPERIMENTER'S HANDBOOK

SPRING EDITION

$1.50

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DIGITAL-SETUP DARKROOM TIMER
(page 11)

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1970 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

SOMETHING FOR EVERYONE

As you go through the "Contents" of this issue of the ELECTRONIC EXPERIMENTER'S HANDBOOK, I think you will be impressed by the variety of do-it-yourself construction projects. They range from the ultra-complex to some of surprising simplicity. I also think that the selection includes at least 3 or 4 projects of interest to every experimenter—regardless of his "specialty."

As in previous issues, each construction project has been thoroughly tested and carefully reviewed by the author and editorial staff. Parts lists have been brought up to date and where necessary circuit corrections (and additions) made to any projects that have previously appeared in POPULAR ELECTRONICS. In the rare instances where disagreements exist between the POPULAR ELECTRONICS version and the EXPERIMENTER'S HANDBOOK version, the latter is always correct.

OLIVER P. FERRELL
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Cover photo by Justin Kerr

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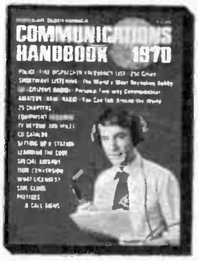

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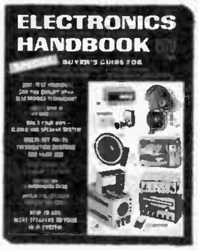

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PARTS/METHODS/IDEAS/GADGETS/DEVICES

tips & techniques

HOMEBREW BATTERY TERMINALS

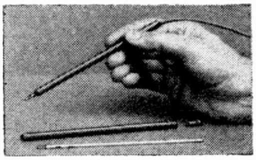
Where space isn't at a premium, AA battery terminals such as those shown in the photo can be fabricated with the aid of a spring, some stranded wire, and a couple of rubber splice caps. The small compression spring (taken from an old record player or from motor brushes) should be clean and free of rust. Solder a length of the hookup wire to one end of each ¼"-⅜" long spring, and crimp down the other end of each spring to make sure of good electrical contact with the battery's terminals.

The splice caps are made by Ideal (#415). To save space, cut off the thumb tabs. Then punch a small hole through the splice caps, and feed the hookup wires through, pulling on them so that the springs fit snugly into the narrow portions of the caps. (To identify the cap polarities, use a red wire for the positive and a black or blue wire for the negative terminals.) Now, fix the AA cell in place.

—Wendell H. Arthur

HOMEBREW TEST PRODS FROM OLD BALL-POINT PENS

Have you ever wondered what you can do with those old, dried-out ball-point pens you have been throwing away? If you think hard, you will see one possibility: they make handy test prods. Single-piece body pens with brass ink cartridges are ideal for the job (see photo). Using a pointed tool, lift off the top plug and push out the ink cartridge. Then cut off and discard the part of the cartridge just above the dimples in the cartridge tube.

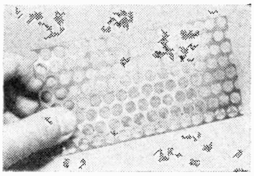


Thoroughly clean the remaining piece, and tin the interior of the tube. Now, string the test cable through the pen body, insert the bared end of the cable in the cartridge, and solder in place. Press fit the point back into the pen body, leaving about ½" protruding. Finally, gently squeeze out the steel ball in the pen tip with side cutters, and round off the tip. A bead of epoxy cement at the other end of the pen body serves as a strain relief for the test cable.

—A. A. Mangieri

AUTOMOBILE AIR FILTER IS SOURCE OF CHASSIS VENTING MATERIAL

There are still some circuits and equipment in electronics that must be housed inside an enclosed chassis to prevent electrical shock hazard but require conventional ventilation to guard against heat damage. Unfortunately, perforated metal sheets—ideal for fulfilling both needs—are sometimes not readily available in electronic parts stores. However, if you have an old dry-type automobile air filter handy, you have a ready source of this difficult-to-find perforated aluminum stock.

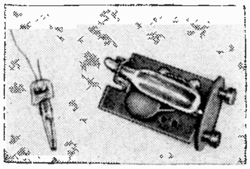


This material, which forms the outer wall of the filter, can be cut to size with tin snips or heavy-duty scissors. Then all you have to do is place the cut piece over the chassis cutout, bolt it in place with machine hardware, and you have a functional cooling grille that will provide ventilation while keeping the hands of the user out of danger.

—James D. Brenner, Jr.

FLUORESCENT LAMP STARTERS MAKE THERMAL SWITCHES

Need an inexpensive thermal switch in a hurry? Well, if you have a spare fluorescent lamp starter handy, you're in business. These lamp starters contain ideal miniature thermal switches that can be used as they are or modified to suit your needs. First, remove and discard the metal shell of the starter. Then, carefully clip the leads of the glass-enclosed thermal switch (see photo).



The switch is normally set for closure at about 150°F. If you want it to close at a higher or lower temperature, you'll have to break the glass envelope carefully, leaving the base intact. Then, for higher temperature action, bend the bimetallic elements farther apart; for lower temperature actuation, bend them closer together. To find the correct distance between the two elements for a given application, you'll have to use a trial-and-error procedure.

—John Rowe

BEWARE OF SNAP CONCLUSIONS

Most people—even some professional electricians—assume that the small holes at the ends of the prongs on the common electric plug are for temporary cable splicing. Not so! They were put there for a purpose in the days when we didn't have springy metals for the prongs to hold them in position. The holes engaged dimples in the contacts in the receptacle. The holes are obsolete, but traditional.

—Henry R. Rosenblatt

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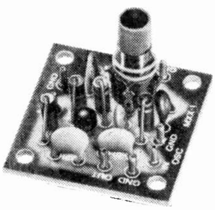

MXX-1 Transistor RF Mixer $3.50

A single tuned circuit intended for signal conversion in the 3 to 170 MHz range. Harmonics of the OX oscillator are used for injection in the 60 to 170 MHz range.

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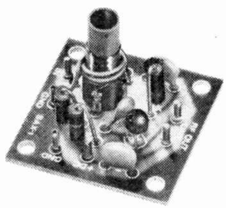
Hi Kit 20 to 170 MHz
(Specify when ordering)



SAX-1 Transistor RF Amplifier $3.50

A small signal amplifier to drive MXX-1 mixer. Single tuned input and link output.

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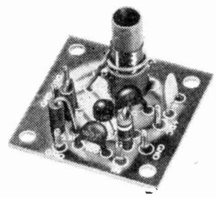
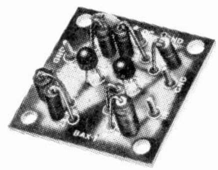


PAX-1 Transistor RF Power Amplifier $3.75

A single tuned output amplifier designed to follow the OX oscillator. Outputs up to 200 mw, depending on the frequency and voltage. Amplifier can be amplitude modulated. Frequency 3,000 to 30,000 KHz.



BAX-1 Broadband Amplifier $3.75

General purpose unit which may be used as a tuned or untuned amplifier in RF and audio applications 20 Hz to 150 MHz. Provides 6 to 30 db gain. Ideal for SWL, Experimenter or Amateur.

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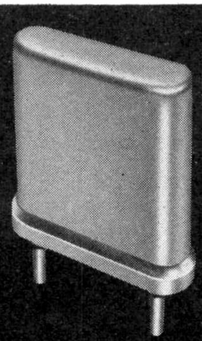

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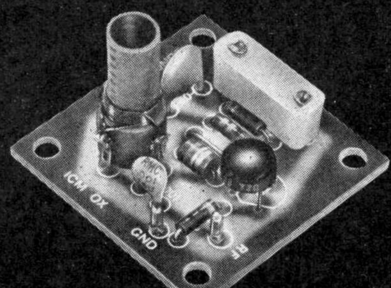

OX Oscillator

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COVER STORY

BY A. A. MANGIERI

Digital Darkroom Timer

ACCURATE AND REPEATABLE BETWEEN 0.1 AND 130 SECONDS

IS YOUR DARKROOM really complete? You might have the best in developing and enlarging equipment; but if you don't have an accurate, versatile timer, your photographic efforts will be difficult and probably unrewarding. The digital electronic timer described here is the ultimate in timing equipment and will simplify much of your darkroom work—as well as improve your printing.

This timer provides various combinations of timing ranges: 0.1 to 1.3 sec in 0.01-sec steps; 1 to 13 sec in 0.1-sec steps; and 10 to 130 sec in 1-sec steps. It has excellent repeatability, long-term stability, and high accuracy; and it is not affected by noise or voltage changes (between 105 and 135 volts) in the power line.

Six output modes include instant off, instant on, delayed off, delayed on, enlarger control and safelight operation. The use of a new semiconductor device, the programmable unijunction transistor (PUT), permits a design employing economically sized capacitors and affords a simple means of calibrating each timing range individually.

Optionally, the timer can be built as a single-range timer with a range of 2 to 60 seconds; or any of the ranges can be omitted without affecting the timing parameters.

Construction. The schematic of the timer is shown in Fig. 1. If you want to build a single-range 2-to-60-sec timer, replace the dashed rectangle marked X with the one marked Y. In this case, you can omit *S4* and use the *C3-C4* and *R9, R12, R16* combinations for timing. (The other components connected to *S4* can be eliminated.)

As shown in Fig. 2, a metal chassis

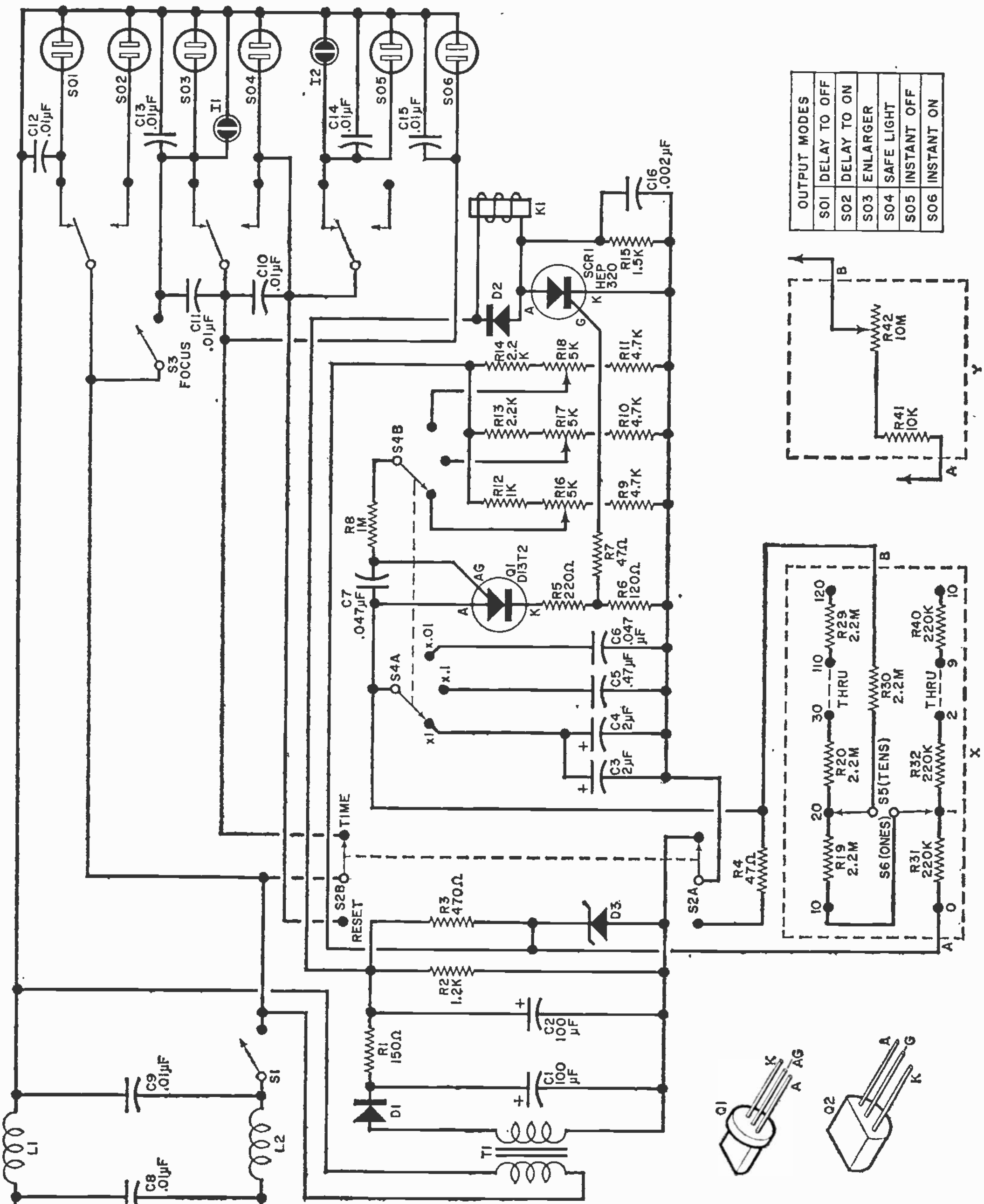


Fig. 1. If you don't need the switched discrete time intervals, then replace switching circuit of box X with the variable control of box Y. In this case, the timing depends on the accurate calibration of potentiometer R42.

divided into two compartments is used to avoid stray a.c. pickup in the timer circuit. In the prototype, a 6″ × 8″ × 3½″ metal chassis with a U-shaped rear cover was used.

Make up an L-shaped metal panel to support the power supply and relay. The lip of this panel will be clamped to the front panel by switch *S2* and its mounting hardware. Assemble the components on the metal panel using the layout shown in Fig. 3. Insulate the case of dual capacitor *C1-C2* from its mounting clip using electrical tape or a small piece of plastic sheet. Install a small grommet between the dual capacitor and *S2* so that a pair of leads can be passed through the chassis. Make another small grommetted hole close to *K1* and near *D3* for two other leads.

The timer module, shown in Fig. 4, is constructed on a piece of high-quality perforated board. Transistor sockets are used for both *Q1* and *SCR1*. Mount components as shown in the photograph, taking care to get the correct polarities. Timing capacitors must have very low leakage, therefore low-dielectric-absorption Mylar capacitors are recommended. Electrolytics and most paper types are not suitable. Also, be sure to use the screwdriver-adjusted potentiometers called for.

The power input circuit with the two filter coils and fuse is assembled on a piece of perforated board as shown in Fig. 5.

Once the three subassemblies have been built, they are installed within the chassis as shown in Fig. 2. Prior to mounting them, however, hold them in place and mark the front (top) panel for the switches and pilot lights as shown in the overall view. Drill the required holes in the top panel. Then (at the end remote from the timing module) measure for and drill mounting holes for the six power outlets and for the line cord.

Note the locations of the three screwdriver-adjusted timing potentiometers on the timer module and drill holes in the adjacent metal panel for making the adjustments.

Mount the resistors on switches *S5* and *S6* and mount them in their respective holes. Mount the other front (top) panel controls as required. Then permanently mount the timing module, making sure that the potentiometer adjustments are aligned with their respective holes in the chassis. Wire the circuit as shown in Fig. 1.

Label all controls, switches, etc., as shown in the photograph. Almost any type of dry transfer lettering may be

PARTS LIST

C1,C2—Dual 100-µF, 100-volt electrolytic capacitor (Sprague TVL-2326 or similar)
*C3,C4—2-µF, 100-volt Mylar capacitor (CDE WMF-1W2 or similar)**
*C5—0.47-µF, 100-volt Mylar capacitor (CDE WMF-1P47)**
*C6,C7—0.047-µF, 100-volt Mylar capacitor (CDE WMF-1S47)**
C8-C15—0.01-µF, 1000-volt disc capacitor
C16—0.002-µF, 100-volt disc capacitor
D1,D2—1-ampere, 600-PIV silicon rectifier (Motorola HEP-158 or similar)
D3—15-volt, 1-watt zener diode (Motorola HEP-607 or similar)
F1—5-ampere fuse
I1, I2—117-volt neon indicators with resistors, one amber, one red (Leecraft "Timeon")
K1—3p.d.t., 24-volt d.c. relay, 600-ohm coil (Knight KN105-3C-24D, Allied 41F4662 or similar)
L1,L2—Inductor, 21 turns #16, ½" diam, close-wound, self-supporting.
Q1—Programmable UJT (General Electric D13T2. do not substitute)
R1—150-ohm, 5-watt resistor
R2—1200-ohm, 5-watt resistor
R3—470-ohm, 1-watt resistor
R4,R7—47-ohm
R5—220-ohm
R6—120-ohm
R8—1-megohm
R9-R11—4700-ohm
R12—1000-ohm
R13,R14—2200-ohm
R15—1500-ohm
(R4 through R15: All resistors ½-watt)
R16-R18—5000-ohm trimmer potentiometer (Clarostat U39)
R19-R30—2.2-megohm, ½-watt 5% resistor
R31-R40-220,000-ohm, ½-watt 5% resistor
R41—10,000-ohm, ½-watt resistor (optional)
R42—10-megohm potentiometer, linear taper (optional)
S1,S3—S.p.s.t. 6-ampere toggle switch (Cutler-Hammer 8381K21C or similar)
S2—D.p.d.t. 6-ampere toggle switch (Cutler-Hammer 8373K21C or similar)
S4—2-pole, 3-position, rotary switch (Mallory 3226J or similar)
S5, S6—1-pole, 12-position rotary switch (Mallory 32112J or similar)
SCR1—0.8-ampere, 30-volt silicon controlled rectifier (Motorola HEP-320 or similar)
SO1-SO6—117-volt a.c. chassis socket
T1—25-volt, 1-ampere, filament transformer (Knight, Allied 54A1421 or similar)
Misc.—Metal chassis 6" x 8" x 3½"; perforated board; push-in terminal (Vector T9.4); sheet aluminum; fuse clip; terminal strip; line cord; knobs; #16 bare enameled wire: hardware, etc.
**The following parts are available from Allied Radio Corporation, 100 N. Western Ave., Chicago, Ill. 60680: C3,C4—43F6996 ($1.50); C5—43F6991 ($0.47); C6,C7—43F6985 ($0.27). Q1 is available from Newark Electronics Corp., 500 N. Pulaski Rd., Chicago, Ill. 60624.*

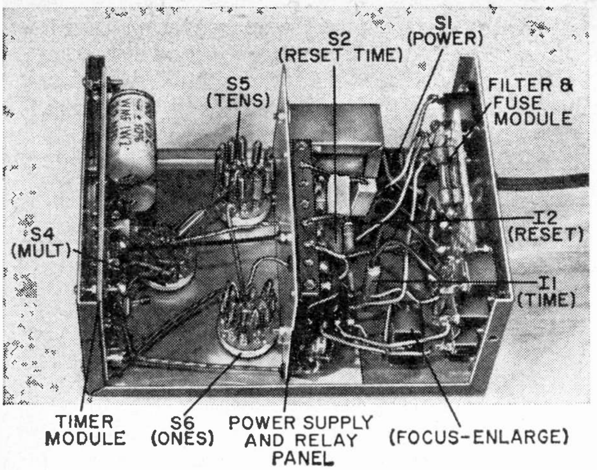


Fig. 2. A metal chassis is suggested for the timer to avoid picking up stray electrical noise which may cause erratic timing. The power supply and relay panel is secured to the main chassis by mounting hardware for switch S2. Other two boards are mounted on four stand-off terminals.

used. Coat it with a protective plastic spray to prevent damage during use.

Calibration. Plug an electric clock, having a sweep second hand, into ENLARGER outlet *SO3*. Place *S2* in the RESET position, *S3* to ENLARGE, MULTIPLIER switch *S4* to 1, tens-of-seconds switch *S5* to 60, and single-seconds switch *S6* to 0. Note the second-hand indication of the clock, and then place *S2* to TIME and turn on power switch *S1*. The red timing lamp should come on and the clock should start to operate. About one minute later, the TIME lamp will go off and the clock will stop. Run this test again and adjust *R16* until the interval is exactly 60 seconds. Recheck the timing with *S5* set to 120 sec.

To calibrate the 0.1-second multiplier range, set *S5* to 120 and the MULTIPLIER switch to 0.1. Note the second-hand indication on the clock. Place *S2* on TIME and turn *S1* to ON. Adjust potentiometer *R17* until the clock indicates 12 seconds. To adjust the 0.01 MULTIPLIER range, set *S5* to 100 and check that the clock goes for one second. Adjust *R18* until it does.

If you want to improve the accuracy and repeatability of the timer, select and match 5% resistors for the timing circuits associated with *S5* and *S6*.

POWER AT OUTLETS

OUTLET	WHEN POWERED
SO1 (DELAYED OFF)	During reset and timing
SO2 (DELAYED ON)	After timing is complete
SO3 (ENLARGER)	During timing; S3 on FOCUS
SO4 (SAFE LIGHT)	During reset and after timing
SO5 (INSTANT OFF)	During reset
SO6 (INSTANT ON)	During focus, during and after timing

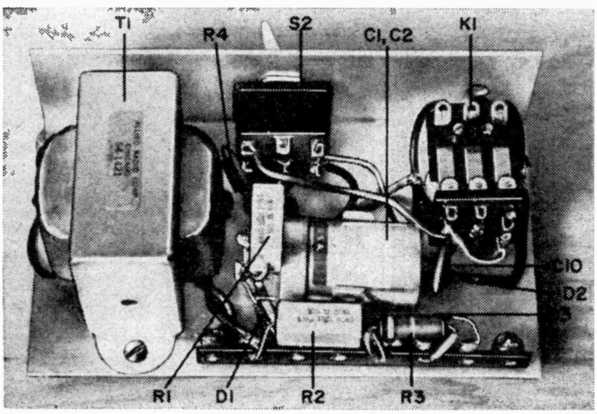
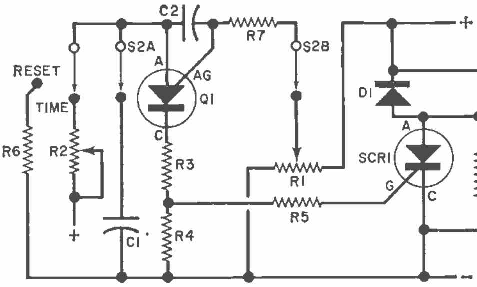


Fig. 3. Component mounting of the power supply and relay panel. Insulate metal case of dual capacitor C1-C2 by wrapping it in plastic tape before inserting the capacitor in its mounting clip. A terminal strip supports small components.



HOW IT WORKS

In the simplified diagram shown here, transistor *Q1* is a special SCR type of device called a programmable unijunction transistor (PUT) and differs from a conventional SCR in that it has an anode gate. Potentiometer *R1* is adjusted to set the d.c. voltage at the anode gate of *Q1*. In the actual circuit, *R1* is selected by a switch from three independent timing potentiometers. When *S1* is set to TIME, charging current flows through switch-selected charging resistors (in this case *R2*), into switch-selected charging capacitor *C1*. The upper end of *C1* is connected to the anode of *Q1*. When the anode voltage of *Q1* builds up slightly higher than the voltage present on the anode gate, *Q1* turns on producing a voltage spike across *R3* and *R4*, and simultaneously discharging *C1*.

The voltage spike at the junction of *R3* and *R4* is applied to the gate of *SCR1* and causes it to turn on. As the SCR fires, it energizes relay *K1*. The contacts on the relay are used for the various external functions.

When *S1* is placed in the RESET position, capacitor *C1* discharges through *R6* and the relay circuit is de-energized.

Programmability is provided by the potentiometer selected by *S2B* to set the stand-off ratio of *Q1*. Resistor *R7* sets the current needed to fire *Q1* to a very low value, thus permitting the use of large timing resistors and small timing capacitors. This is not possible if a conventional UJT is used for *Q1*.

Capacitor *C2* prevents premature turn-on of *Q1* by a.c. line noise. The a.c. line is also filtered. Resistor *R8* slows down the anode voltage build-up of *Q2* to prevent premature turn-on when *S1* is placed in the TIME position. Diode *D1* suppresses voltage spikes at the coil of *K1* when it is de-energized.

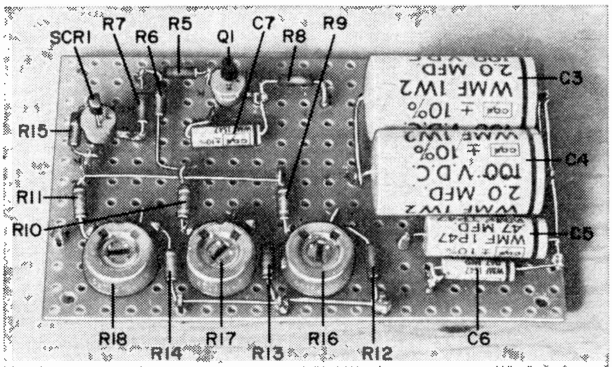


Fig. 4. Timing module may be fabricated on perforated board. The use of sockets for semiconductors removes the chance of heat damage when installing.

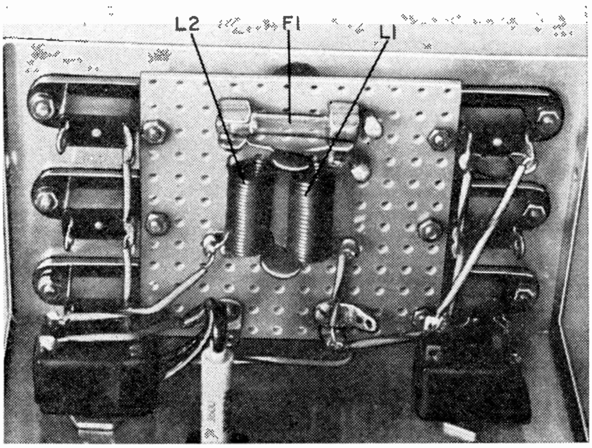
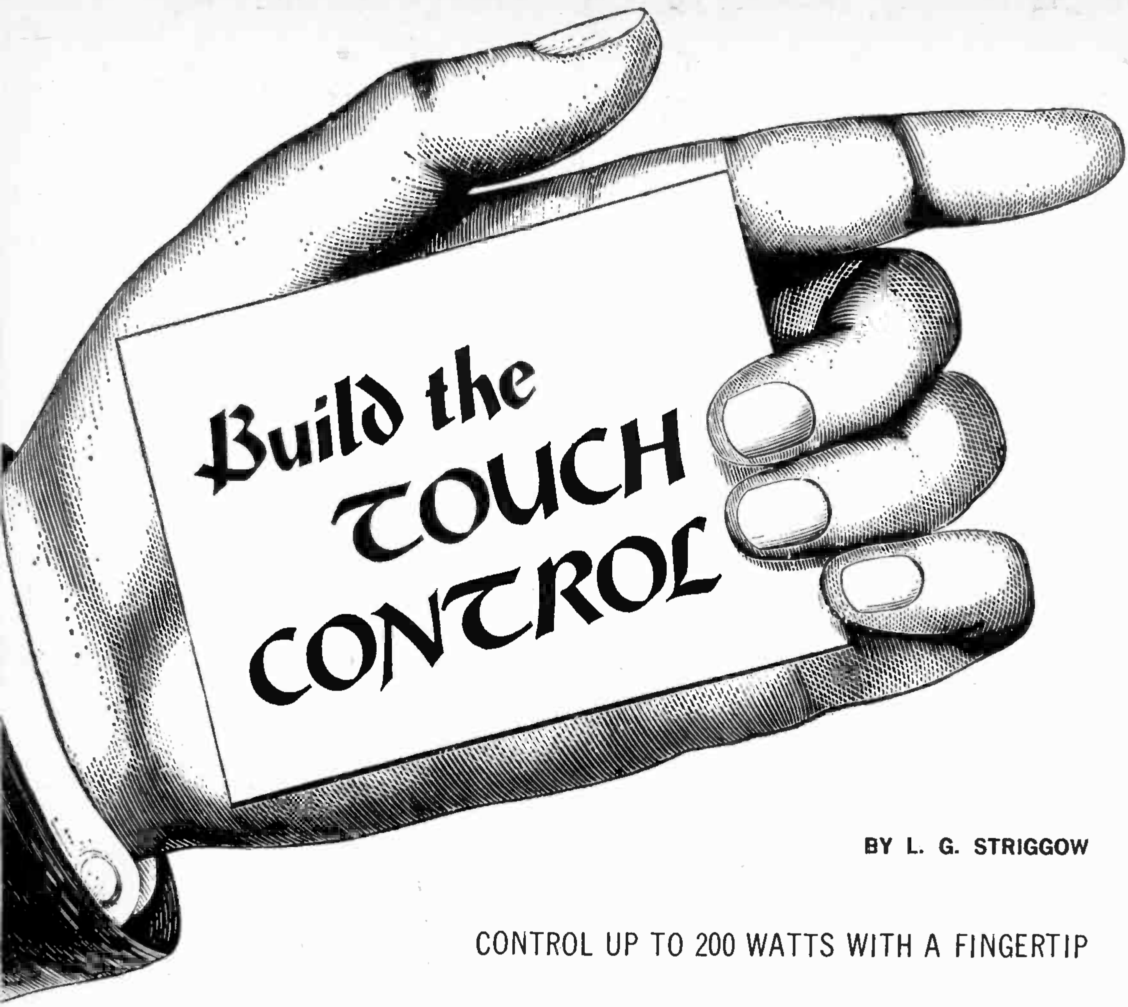


Fig. 5. The filter and fuse module (power input) is also fabricated on piece of perforated board.

If you have built the single-range 2-to-60-second timer, a special scale for *R42* must be prepared. Using a pointer knob, set *R42* at about 85 to 90% of full resistance and adjust *R16* for 60 seconds. Mark the position for *R42*. Then by trial and error, locate and mark the settings of *R42* for 50, 40, 30, 20 and 10 seconds. These major divisions can then be subdivided into discrete second steps and marked on the front panel.

Although it should not be required for

(*Continued on page* 64)



Build the TOUCH CONTROL

BY L. G. STRIGGOW

CONTROL UP TO 200 WATTS WITH A FINGERTIP

ELECTRONICS experimenters are always looking for new ways to control the light fixtures in their homes. Here's the latest wrinkle—a light switch that turns on and off with just a touch. You may have seen this type of switch in the call buttons on some new elevator controls. It doesn't provide any dimming control, but the convenience of being able to turn the lights on or off with the touch of a finger, or elbow if your hands are full, is a real plus.

Construction. The circuit for the touch control is shown in Fig. 1. Although any type of construction can be used, the author built his on a small PC board whose foil pattern is shown actual-size in Fig. 2. Note that, instead of etching away copper to produce a network of interconnecting leads, in this case you only etch away relatively thin isolation lines between the copper segments. Once the board is made, assemble the components as shown in Fig. 3.

In this assembly, the SCR's and capacitors are inserted conventionally while the resistors and diodes are mounted vertically. To install the two transistors and the silicon unilateral switch, bend the leads over and mount the units upside down on the board. Use fine solder and a low-wattage soldering iron. Make sure that there are no solder bridges across the isolation lines on the board.

Caution. Because full line voltage is present at various points in the circuit, once the PC board has been built and checked and connections have been made to it, it is suggested that the entire assembly be encapsulated using any com-

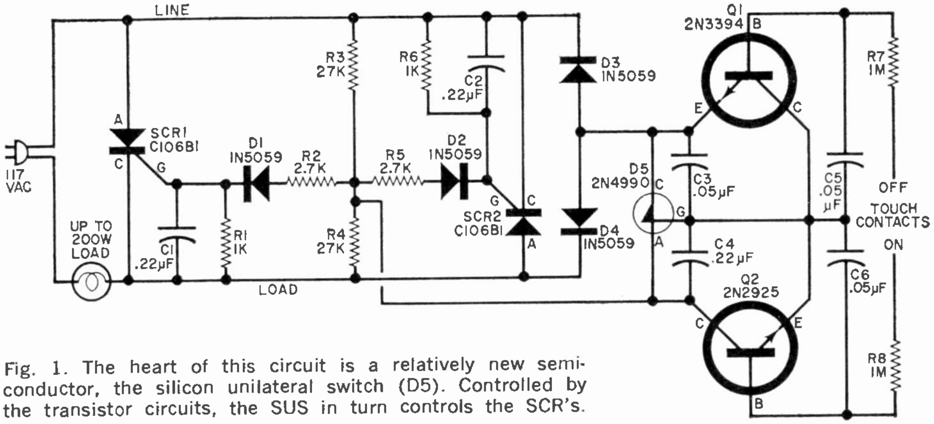


Fig. 1. The heart of this circuit is a relatively new semiconductor, the silicon unilateral switch (D5). Controlled by the transistor circuits, the SUS in turn controls the SCR's.

PARTS LIST

C1, C2, C4—0.22-μF, low-voltage capacitor
C3, C5, C6—0.05-μF, low-voltage capacitor
D1-D4—1N5059 diode
D5—Silicon unilateral switch (GE 2N4990)
R1, R6—1000-ohm, ¼-watt resistor
R2, R5—2700-ohm, ¼-watt resistor
R3, R4—27,000-ohm, ¼-watt resistor
R7, R8—1-megohm resistor
SCR1, SCR2—Silicon controlled rectifier (GE C106-B1)
Q1—2N3394 transistor
Q2—2N2925 transistor
Misc.—One-megohm resistor (optional, see text), line cord, metal for touch contacts, insulated wire.

mercial potting compound. An alternate is to give the complete board several coats of nail polish, preferably transparent, allowing each coat to dry thoroughly before applying the next. To avoid shock, take care not to damage this insulation when handling the board.

Operation. Connect a lamp of 200 watts or less to the load terminal of the board, then connect the other side of the lamp and the line terminal of the board to a source of commercial 117-volt a.c. power. Placing a finger tip on the "touch on" area should make the lamp go on; contacting the "touch off" area should make it go out. A pair of small metal plates can be connected to these terminals, using insulated wire as the connectors, to act as the actual touch plates. If the lamp should only flicker when the "touch on" terminal is contacted, reverse the power-line plug.

If you want to extend the touch plates for some distance, connect a one-megohm resistor to the line terminal and locate the other end of the resistor (by way of an insulated connecting lead) between the two touch plates. Simultaneously touching both the end of the one-megohm resistor and either of the touch plates

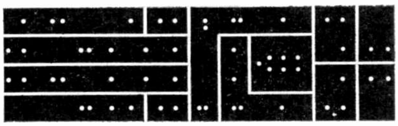
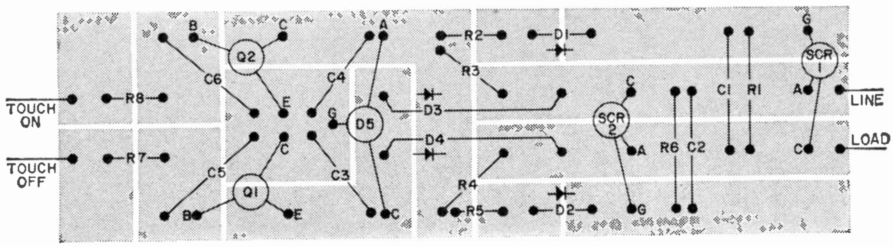
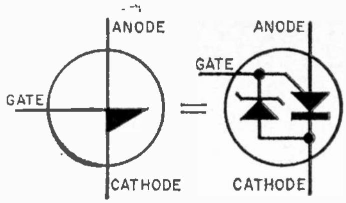


Fig. 2. Actual-size PC board is very small so use care when making it. Unlike conventional boards, this board uses area contact rather than a pattern.

Fig. 3. The components will be tightly packed (see photo on p. 18), so mounting is rather unorthodox. Note that transistors and D5 are "upside down."





HOW IT WORKS

Operation of the touch control circuit depends on *D5*, a silicon unilateral switch (SUS). This semiconductor is essentially a miniature SCR with an anode gate (instead of the usual cathode gate) and a built-in low-voltage avalanche diode between the gate and the cathode. The SUS switches on when its gate is raised to a voltage level in excess of that required to cause the avalanche diode to saturate. When the avalanche diode is forced out of conduction, the SUS cuts off.

When power is applied, transistor *Q1*, across the gate and cathode of *D5*, automatically brings *D5* into conduction. This applies a negative voltage to the gates of the SCR's cutting them off and removing power from the load. When contact is made to the "turn on" terminal, *Q2* conducts to turn *D5* off. This automatically allows both SCR's to turn on, on the next positive-going a.c. alternation, thus providing power to the load. Contacting the "turn off" terminal causes the circuit to revert to its original condition, thus removing power from the load the next time that the a.c. line alternation goes to zero. The gating voltage for both transistors comes from the a.c. field present in the human body when the person is in the presence of commercial a.c. power lines.

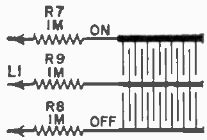
The gates of the SCR's are connected to the power supply (at the junction of *D3* and *D4*) through *D5*. Since the SUS can only turn off at the zero point of the a.c. waveform, the SCR's are turned on only at that point. This characteristic provides minimum distortion to the line current (such as that caused by the opening and closing of mechanical contacts).

Resistors *R7* and *R8* prevent shock when either of the touch terminals is contacted.

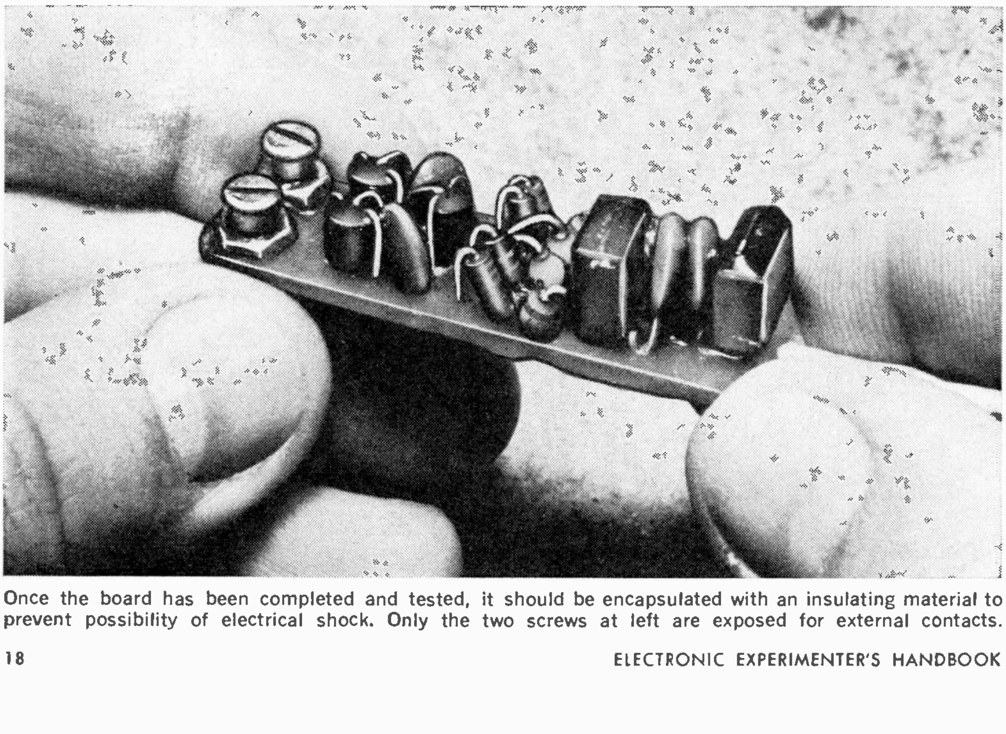
will operate the circuits. One way of doing this is to make two isolated metal contact areas for the on-off operation, with a narrow metal strip for the resistor contact between them. In this way, contact can be made to turn the light either on or off.

Remember at all times that many portions of the circuit board are "hot" to ground and avoid getting a shock.

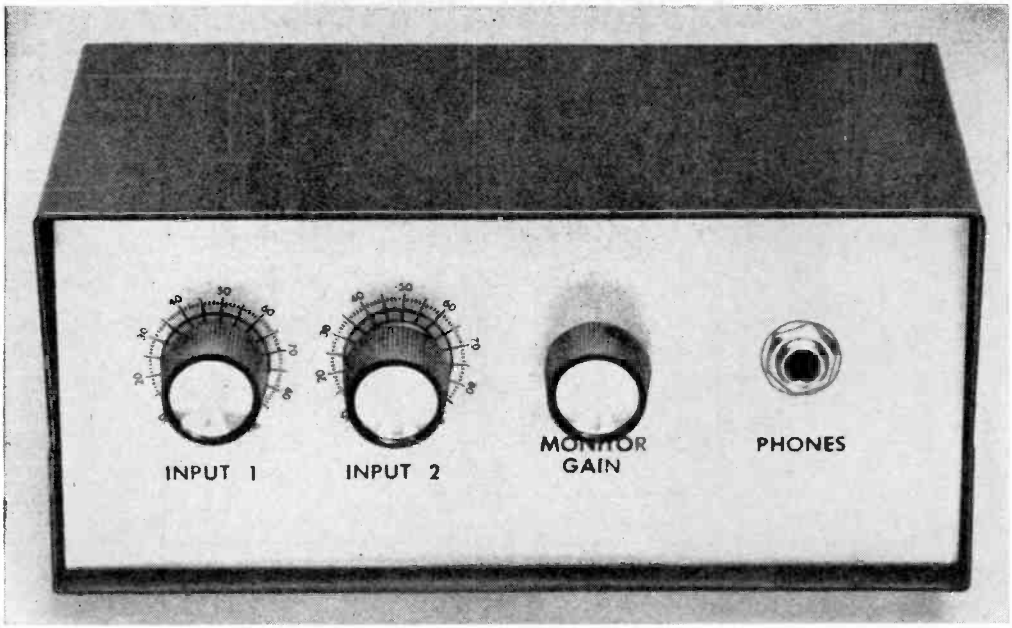
Besides a lamp, the touch control can be used to turn on any 117-volt a.c. resistive or inductive load whose power requirements are less than 200 watts. —30—



Prepare an etched board similar to above for use as a moisture detector or touch panel wall plate. For moisture detection, L1 gives a positive source.



Once the board has been completed and tested, it should be encapsulated with an insulating material to prevent possibility of electrical shock. Only the two screws at left are exposed for external contacts.



SOUND-WITH-SOUND MIXER

With Pre-Record Monitoring

BY DOUG DeMAW, W1CER

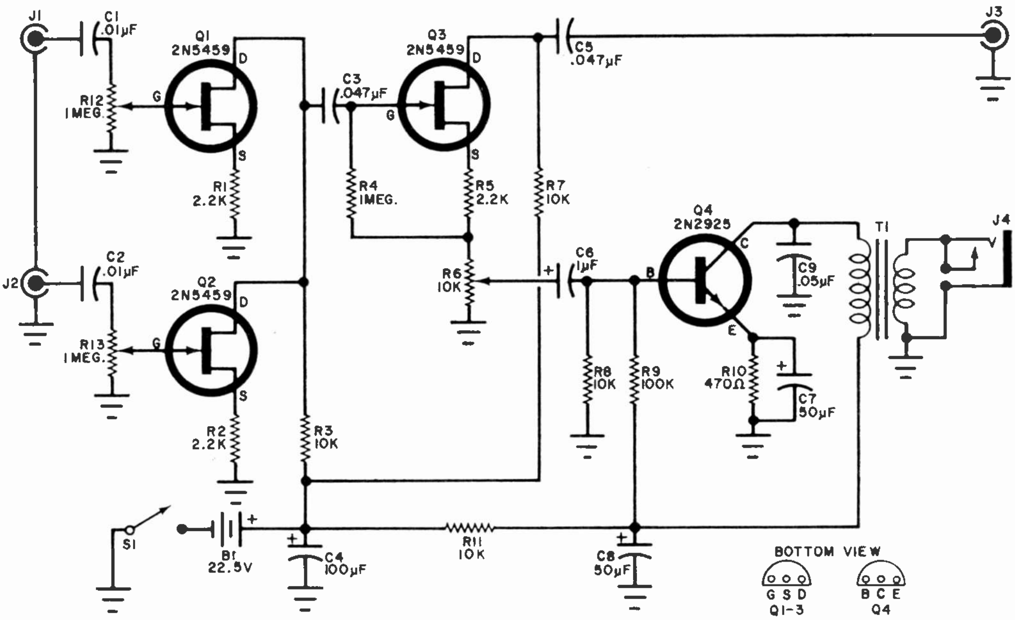
WHY NOT produce "at home" recordings comparable to those of a professional studio? You can with this simple "Sound-With-Sound Mixer." The secret is in monitoring the output of the mixer and listening to what the recording is going to record—rather than using the ordinary monitoring system of guessing or listening after the tape is made.

You will find many other advantages to the Mixer besides improving the quality and versatility of your recordings. Short-wave listeners, for instance, can use it to make station reports or prepare a permanent log. (Many SWL's are preparing tape archives by recording off the air and adding personal comments—including dates, times, etc.—over the desired signal.) Or, why not spark up your blasé voice letters by mixing from two microphones or adding some novel sounds or music to the tape?

Adding a background to taped letters is far from new. But until now, the most common method of adding it to the voice track was through acoustical pickup from a speaker system. The problems encountered with this method are numerous: room acoustics may not be ideal, noise may interfere, and the frequency range is limited to that of the microphone. As a result, the background sounds "dead" because of sound degradation.

To obtain high-quality recording, a direct electrical hookup is best, and the Sound-With-Sound Mixer was designed to do just that. In addition to providing amplification and mixing, it also has a monitor output that lets you hear what you're recording before it gets into the tape recorder.

The background source can be an FM or AM tuner or short-wave receiver. No preamplification of the signal is required. You simply plug the source into one channel of the Mixer and set the level; then plug in the microphone and set its



After preamplification and mixing take place in Q1 and Q2, signal is fed to output through Q3; Q4 is monitor amp.

PARTS LIST

B1—22.5-volt battery
C1, C2—0.01-µF disc capacitor
C3, C5—0.047-µF disc capacitor
C4—100-µF, 25-volt electrolytic capacitor
C6—1-µF, 6-volt electrolytic capacitor
C7—50-µF, 6-volt electrolytic capacitor
C8—50-µF, 25-volt electrolytic capacitor
C9—0.05-µF disc capacitor
J1-J3—Phono jack
J4—Phone jack
Q1-Q3—Field effect transistor (Motorola 2N5459)
Q4—Transistor (General Electric 2N2925)
R1, R2, R5—2200-ohm
R3, R7, R8, R11—10,000-ohm
R4—1-megohm
R9—100,000-ohm
R10—470-ohm
(*All resistors ½-watt*)
R6—10,000-ohm linear-taper potentiometer
R12, R13—1-megohm audio-taper potentiometer
S1—S.p.s.t. switch (part of R6)
T1—Impedance-matching transformer, 1000-ohm primary, 8-ohm secondary
Misc.—Printed circuit board; battery clip; ½" metal spacers; 7"x3⅜"x3½" aluminum utility box; wire; solder; knobs; hardware; etc.

level so that the voice signal can easily fade in and out or override the background.

The Mixer can be used with virtually any tape recorder, tape deck, or audio amplifier that has a high-impedance input (usually the microphone input). It can also be used as a two-channel microphone or guitar-pickup mixer. It can even be used as a private listening system so that you don't disturb others around you.

Construction. The use of a printed circuit board (etching guide shown full-size in Fig. 1) greatly simplifies and speeds construction of the Mixer. All components, except for input and output jacks, the controls, and the battery mount directly on the circuit board as shown in Fig. 2.

Except that the signal leads between the circuit board and the jacks and controls must be as short as possible, construction is not critical. When you have mounted all components on the board, mount the circuit board, using four sets of machine hardware and ½" metal spacers as shown in Fig. 3. Then mount *J1*, *J2*, and *B1* on the rear apron of the metal box and *J3*, *J4*, and the controls on the front apron.

Assemble the metal box, and identify the various controls and jacks with a tape writer or a dry-transfer lettering kit, and the Sound-With-Sound Mixer is ready.

How To Use. Since high impedances are involved, it is necessary that you use

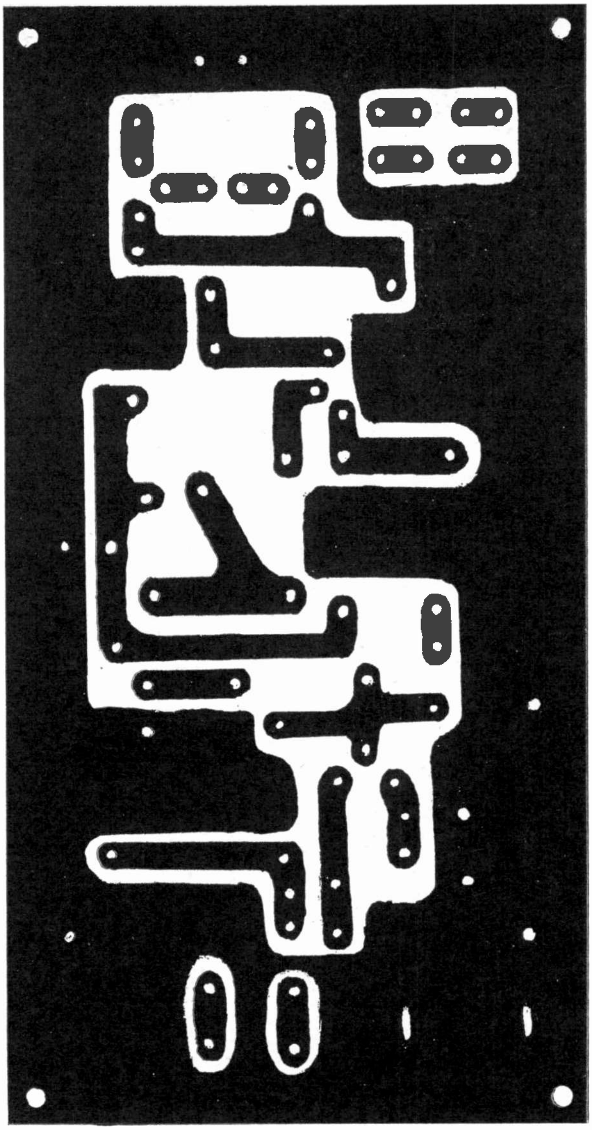


Fig. 1. In this actual-size printed circuit board etching and drilling guide, minimum amount of copper is removed from the board. Extra copper provides good heat sink during soldering and helps economize on etchant.

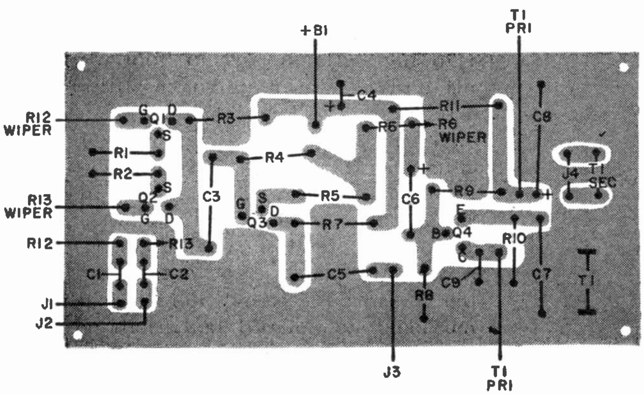


Fig. 2. In wiring circuit board, connect negative lead of B1 and remaining terminal of control R6 to chassis ground or ground foil on the board. Insert and solder tabs of T1 in oblong holes that are designated for T1 in drawing.

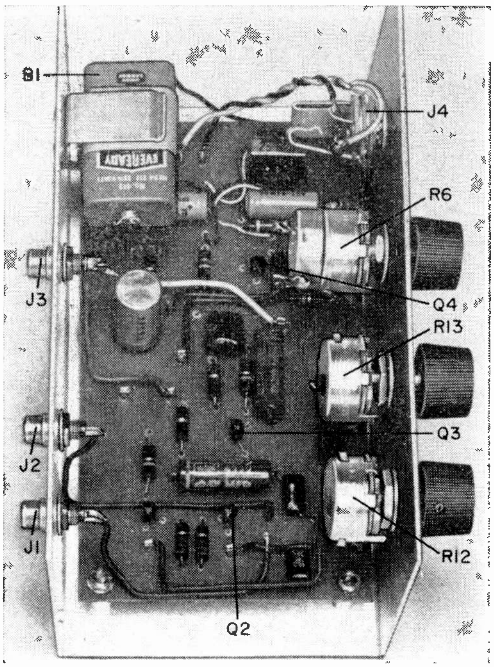


Fig. 3. Metal spacers should be used to support the circuit board away from the chassis. Mount the board as shown; then wire the controls, battery, and jacks into the circuit.

HOW IT WORKS

Each input stage of the mixer contains a field effect transistor (*Q1* and *Q2* in the schematic) that preserves the proper high-impedance match required by the input transducers (microphone, guitar pickup, etc.). With power applied to the Mixer, separate audio signals fed in through *J1* and *J2* are amplified by the respective FET stages. The amount of gain for *Q1* is controlled by *R12*, while *R13* controls *Q2*'s gain. (Each channel produces about 6 dB of gain, suggesting that the mixer could be used as a straight preamplifier should the need ever arise.)

Since the drain leads of *Q1* and *Q2* are parallel connected, after amplification the two discrete signals from these transistors mix, producing a single composite signal. The new signal is then coupled into phase-splitter *Q3*, then out to the tape recorder through *J3*.

Additionally, a portion of the composite signal is coupled to monitor amplifier stage *Q4* to provide a convenient source-monitor output through *J4* to low-impedance headphones. Any amplification provided by this stage is in addition to that obtained from *Q1* and/or *Q2*, and overall amplification is independently controlled by *R6*.

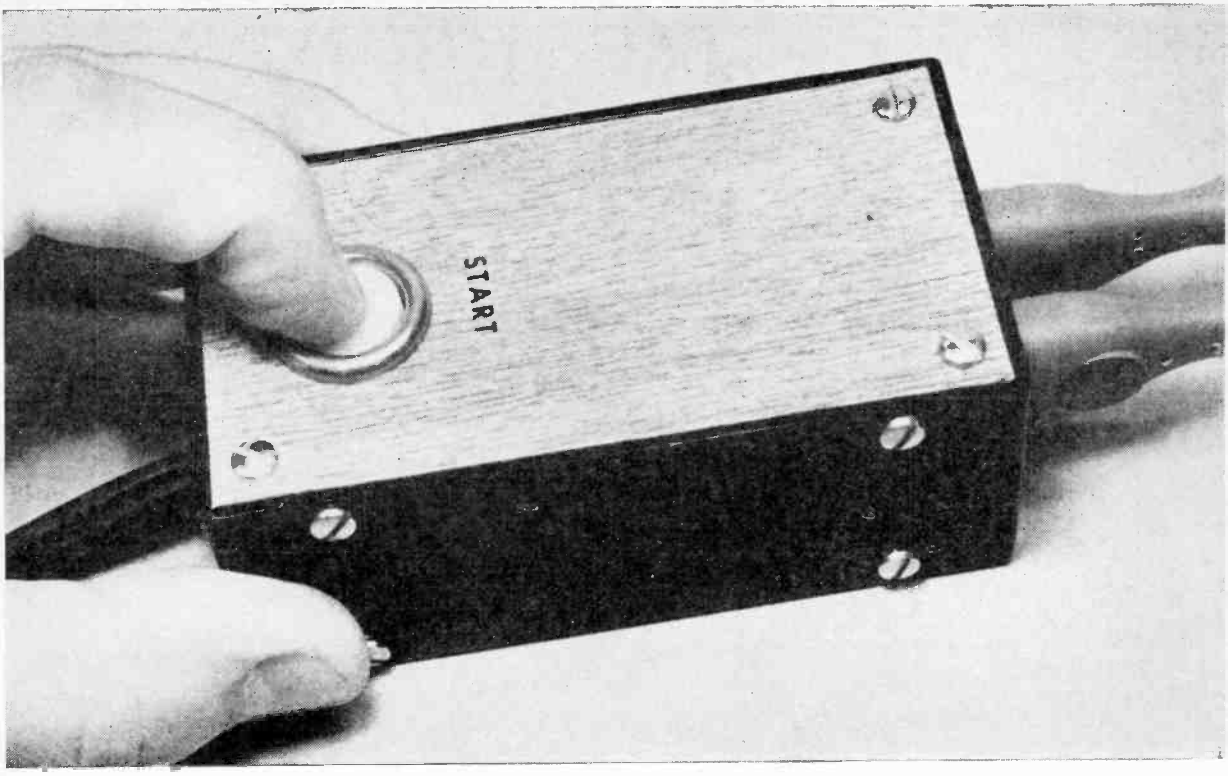
shielded cables for interconnections between the Mixer and other equipment to minimize hum pickup. Also, these cables should be as short as practical.

When using the Mixer with a tape recorder or deck, always set the "Record Gain" control as suggested for normal operation with a microphone. Then, while feeding the desired signals into the mixer, adjust the gain control of the channel you want to predominate for full recording level as indicated on the recording monitor.

The level of the remaining Mixer channel can then be adjusted while you listen through the monitor amplifier output. Then any further adjustments of gain, such as for fade-ins and fade-outs, should be made with *R12* and *R13* on the Mixer.

If you should encounter any high-level hum problems when using the mixer with a line-operated recorder or amplifier, reverse the a.c. plug. Should this fail to clear up the problem, connect a separate grounding lead from the chassis of the mixer to the chassis of the recorder or amplifier.

The Sound-With-Sound Mixer is capable of a fairly wide frequency range, and its output signal is free of most noise and distortion. Current drain under normal operation is on the order of 8 mA, so battery life should be long—provided the power is turned off when the Mixer is not in use. –30–



BUILD

200-WATT DUAL FLASHER

Off-On-Off Blink Incandescent Bulbs

BY JOHN S. SIMONTON, JR.

THERE ARE few devices which the electronics experimenter can build that have a wider variety of uses than light flashers. Alternately blinking lights attract attention to displays in store windows, guide the seafarer home to a safe harbor, and warn the unwary of all types of obstacles and perils.

Whether your need for a lamp flasher is serious or just for fun, the "SCR Dual Flasher" can handle it easily and economically. Using only a few components, this simple circuit (Fig. 1) will alternately flash two 117-volt light bulbs with ratings up to 200 watts each. The bulbs need not be the same wattage, and their ratings do not noticeably affect the flash rate. The component values shown produce a cycle of about one second on and one second off for each lamp.

Construction. The circuit can be assembled using any conventional wiring techniques, but a circuit board simplifies the job and lends a professional appearance to the finished product. A board can be etched using Fig. 2 as a guide or one can be purchased (see Parts List). Install the individual components as shown in Fig. 3.

The author's prototype was built in a 1⅝" × 4" × 2⅛" plastic enclosure. Metal housings can be used, but every precaution must be taken to prevent any part of the circuit from coming in contact with the metal case. Because 117-volt

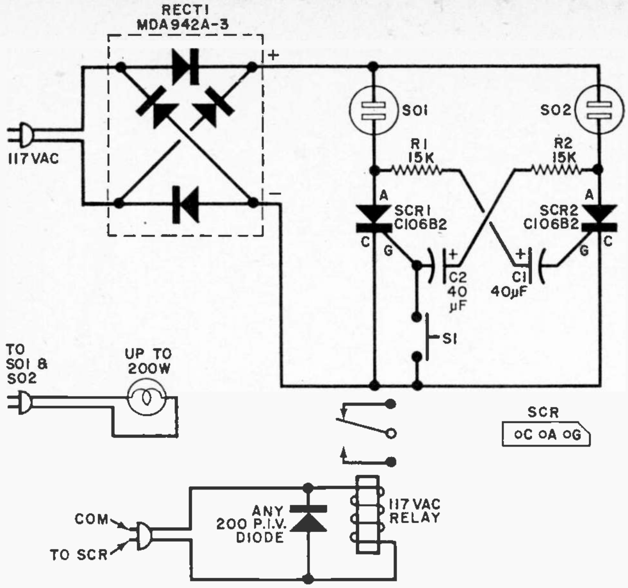


Fig. 1. The circuit is basically a high-power flip-flop using SCR's instead of transistors. Because of the high current capability of the SCR, it will load up to 200 watts.

PARTS LIST

C1, C2—40-µF, 150-volt electrolytic capacitor
R1, R2—15,000-ohm, ½-watt resistor
SCR1, SCR2—Silicon controlled rectifier (General Electric C106B2)
SO1, SO2—117-volt socket
RECT1—Bridge rectifier (Motorola MDA942A, see text)
S1—S.p.s.t. normally open pushbutton switch
Misc.—1⅝" x 4" x 2⅛" plastic case, line cord, 117-V. a.c. relay (optional), 200-PIV diode (optional), pair of 117-V lamps (any wattage up to 200 watts including line cord and plugs), hardware, etc.
Note—An etched and drilled printed circuit board is available from PAIA Electronics, Inc., Box 14359, Oklahoma City, Okla. 73114 for $1.50. A complete kit of parts, including the PC board, is available for $11.95. All orders are postpaid continental USA. Oklahoma residents please add 3% sales tax.

a.c. line power is used in this device, be very careful of component polarities and short circuits, as a wrong connection can easily destroy components or vaporize the conducting path on the circuit board.

The author used a Motorola MDA-942A-3 bridge rectifier assembly because it is compact and the price compares favorably with the cost of individual components. However, if you have a supply of four rectifier diodes with an inverse voltage rating of 200 volts or better and an average current rating of at least 1 A (such as 1N4721), they will work just as well.

Operation. All you have to do to operate the Flasher is to plug a pair of incandescent lamps (up to 200 watts) into *SO1* and *SO2*. If alternate bulb blinking does not occur immediately, momentarily depress *S1* to start the operation.

To create an eye-catching effect, use two lamps of different wattage (150 and 25, for example) and put them in the same frosted-glass enclosure. When the

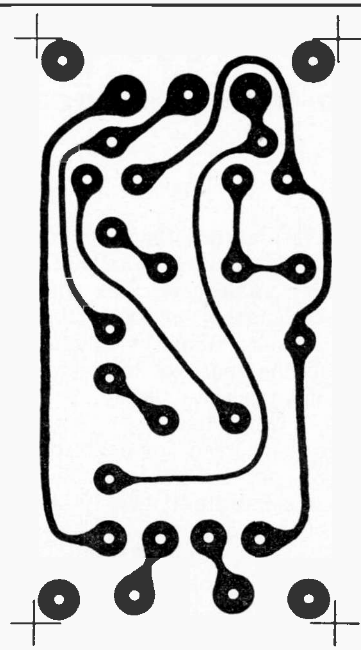


Fig. 2. You can make an actual-size PC foil pattern by following this layout.

HOW IT WORKS

The circuit of Fig. 1 is an astable multivibrator using SCR's as the active elements. Plug incandescent lamps into *SO1* and *SO2*. Their wattages need not be equal. To visualize the operation of the unit, assume that *SCR1* is conducting and *SCR2* is not conducting (*SO1* powered and *SO2* unpowered). The voltage drop across *SCR2* causes a current flow through *C2*, *R2*, and the gate-cathode junction of *SCR1*. As long as this current is above the value required to hold *SCR1* in its conducting state, lamp *SO1* remains powered; but, as *C2* charges, the current decreases until it is below the minimum needed for triggering. At this point, *SCR1* turns off, removing the power to *SO1*, and the voltage drop across *SCR1* jumps to line potential. This causes a current to flow through *C1*, *R1*, and the gate-cathode junction of *SCR2*. This current turns on *SCR2*. The operation is now the mirror image of the sequence when *SCR1* was on, *C1* charges, and *SCR2* turns off placing the circuit back at the starting point. As each SCR is triggered, it places the positive end of the capacitor which was being charged at ground potential. Because of the stored charge, the gate of the non-conducting SCR is held at a more negative voltage than its cathode, assuring that it will remain off.

If the unit has been off several hours, both lights may go on when it is first plugged in. This is caused by the initial surge of current through *C1* and *C2*, turning on both SCR's simultaneously, and will only happen if both capacitors are completely discharged. Depending on more or less random conditions, this may or may not be a stable state and the lamps may both remain on. Pushbutton *S1* provides a means of initiating oscillation if this situation arises. Closing *S1* shorts the gate of *SCR1* to ground and causes it to stop conducting. The resulting voltage drop across *SCR1* causes *C1* to begin charging and starts the flashing sequence. Since it takes several hours for the capacitors to discharge completely, power failures of up to an hour or more will not prevent the unit from flashing when power is restored.

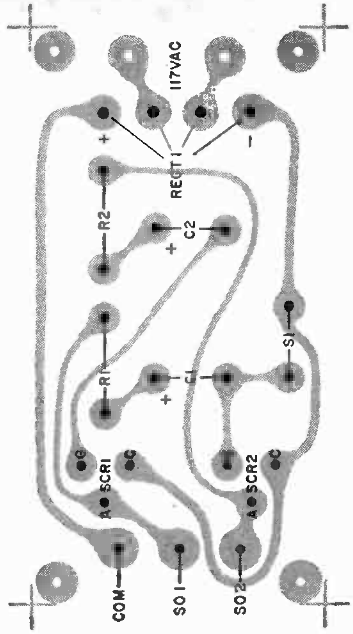
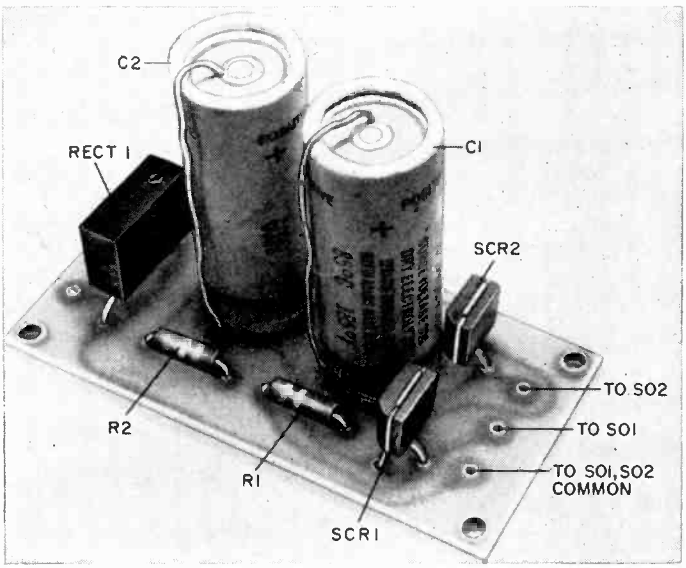


Fig. 3. When installing the components, make sure all polarities are observed.

flasher is operating, you will get the distinct impression of a rotating beacon as a bright flash is followed by a dim flash.

If one or two 117-volt a.c. power relays are substituted for the lamps, external devices can be operated alternately. To prevent damage to the relay coils, don't forget to include the diode as shown in Fig. 1. —30—



Physical arrangement of a finished PC board. Note that both capacitors are vertical to the board while other components are conventionally installed. Two connections to S1 are hidden behind the capacitors. When installing, remember that the circuit is "hot" to ground and you can get shocked if not careful.

Low-Cost A.C. Ammeter

Measures up to 5 amperes with $3 outlay

BY NEIL JOHNSON, W2OLU

YOU SEE all sorts of meters and indicating instruments in ham shacks and electronics experimenters' workshops, but you very seldom see an a.c. ammeter. Obviously, lots of people could put one to good use—the trouble is, they are too expensive.

A reasonably good a.c. ammeter sells for about $12 and, in most cases, at least two of them are required in order to make a broad range of measurements. This is because the commonly used a.c. instrument works on the moving vane principle and the low end of the scale is severely compressed. On most 0-5-ampere a.c. ammeters, indications below 1 ampere are next to useless. So, in addition to a 5-ampere meter, you have to have a 1-ampere instrument to cover the full range adequately.

You can build yourself a good, wide-range ammeter very inexpensively, if you take advantage of some government surplus items that are widely available. Part of every "command set" used in airplanes at one time was an "Antenna Current Indicator" (military nomenclature: BC-442). The current meter used in this device has a nonlinear scale and is more sensitive at the low end of the scale than at the high end. This prevents crowding at the low end of the scale—a feature not found in conventional a.c. indicating instruments.

The BC-442 comes with a built-in thermocouple about the size of a small domino. When the thermocouple is heated (in any way), it generates a small d.c. current at its output. An input to the thermocouple of half a volt generates enough current to deflect the companion d.c. meter to full scale—about 5 milliamperes. When operating together, the thermocouple and d.c. meter are reasonably accurate over a wide range of frequencies and essentially linear over a large part of the meter scale.

To extend the meter range to 4.5 amperes, a meter shunt of 0.1375 ohm is required. This resistance can be fabri-

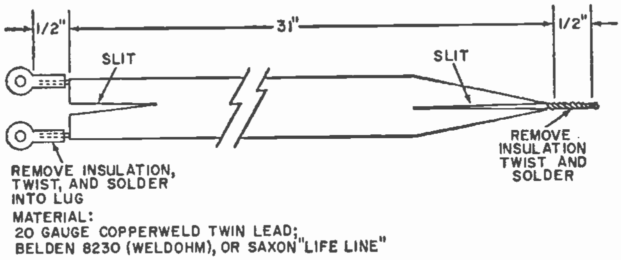
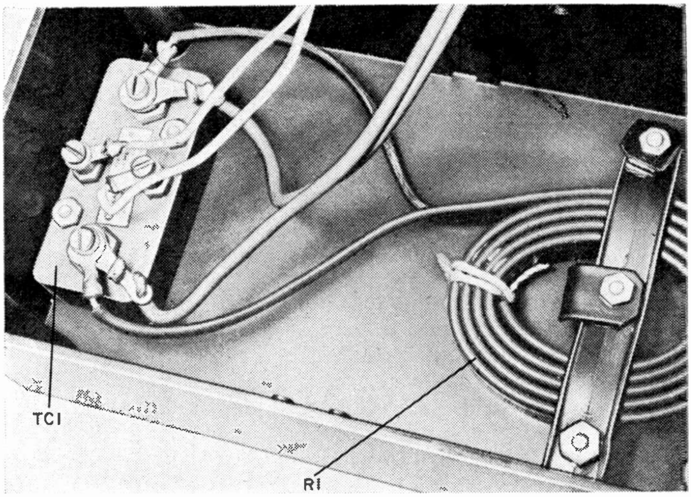
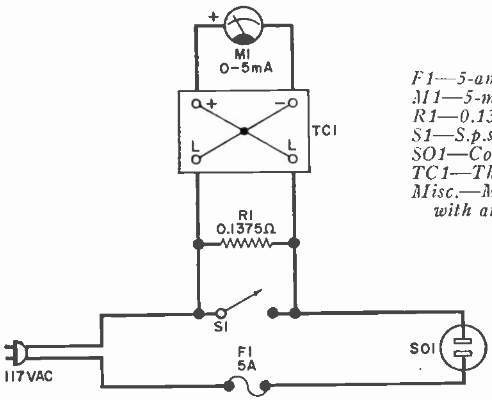


Fig. 1. Though primarily used as TV lead in, twin lead can be used to make a high-quality, low-value resistor (0.1375 ohm).

The shunt can be rolled up and mounted at one end of the case. This makes for a non-inductive resistor that can be used at frequencies far above 60 Hz.

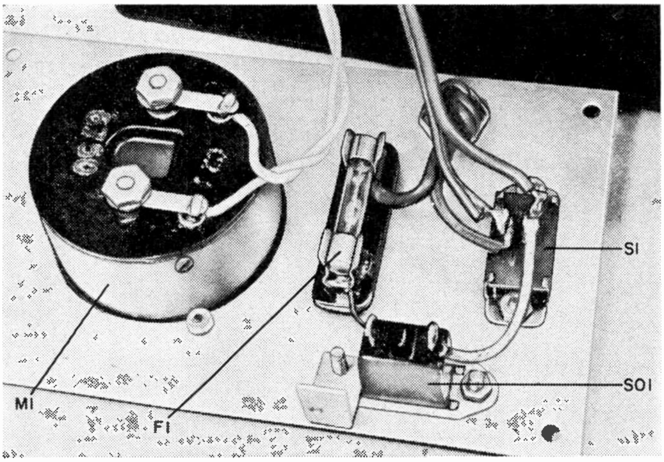




PARTS LIST

F1—5-ampere fuse (not slow-blow)
M1—5-mA meter from BC-442
R1—0.1375-ohm precision resistor (see text)
S1—S.p.s.t. switch 3-ampere rating
SO1—Conventional a.c. outlet
TC1—Thermocouple from BC-442 (0.75-A r.f.)
Misc.—Mounting cabinet, fuse holder, line cord with attached plug.

Fig. 2. Circuit operation is simple. Current passing through the thermocouple heats the dissimilar metal junction producing a small current which is indicated on the meter. The low-value shunt resistor (R1) bypasses most of the heavy current.



Other than the shunt and thermocouple, the remainder of the components are mounted on the metal front panel as shown here.

cated at a meter shop at high cost or you can use a series-parallel arrangement of 10 one-ohm precision resistors —also at a high cost. A cheaper way is to use a length of ordinary TV twin lead of Copperweld fabrication. The two conductors are well insulated and the wattage developed at maximum current is easily handled. Best of all, a "precision" resistor can be made using only a ruler. Instructions for making the shunt are given in Fig. 1. Follow the measurements carefully. It is recommended that you make up the shunt and solder it to its connector lugs at some distance from the thermocouple since the thermocouple calibration can be affected by soldering heat. When the shunt is finished, coil it into a small circular form and secure it with plastic insulating tape. The coiled-up shunt can be mounted on the rear of the meter case using a bolt and some scrap plastic to support it. Since this homebrew resistor is noninductive, the completed instrument can be used at frequencies much higher than 60 Hz.

Wire the shunt, the thermocouple and the meter as shown in Fig. 2. Note that, for safety's sake, a fuse and a shorting switch have been added to the circuit. Any 5-ampere fuse can be used as long as it is not a "slow-blow" type. The shorting switch shorts out the meter when first trying an unknown load. Once the device has been built, recalibrate the meter face to the values shown in the table.

Depending on where you buy the BC-442, the total cost of the meter will run about $3. At a nominal 117 volts, the meter will measure loads varying from 60 to 540 watts. If desired, and if you are using only the normal 117-volt power line, you can calibrate the meter in watts instead of amperes. —30—

METER CALIBRATION TABLE

METER SCALE	AMPERES
0.5	0.6
1.0	0.75
1.5	0.90
2.0	1.00
3.0	1.25
4.0	1.50
5.0	1.80
6.0	2.20
7.0	2.50
8.0	3.00
9.0	3.70
10.0	4.50

BUILD A "DIFFERENT" METAL LOCATOR

Use audio-frequency coupling for increased stability

BY LESLIE HUGGARD

TREASURE HUNTERS use all kinds of schemes and gimmicks in trying to find their fortune—divining rods, extra-sensory perception, ancient pirate maps, and so on. Experience has shown, however, that the most successful treasure hunters use some form of electronic metal finder.

The operation of most buried-metal locators is based on a type of heterodyning principle with the frequency of one of a pair of interacting oscillators being changed when foreign metal is near. One of the oscillators operates at a fixed frequency and the tuning coil of the other is usually a loop of wire at the end of a non-metallic carrying handle. When the loop is brought near metal, the oscillator frequency changes and an audio beat note is created between the two oscillators. This audio signal can be picked up on a speaker or headset. Metal detectors operating on this principle require semi-critical tuning of one of the oscillators for best results. Their operation can often be disturbed by nearby electrical noise sources or powerful radio stations in the vicinity.

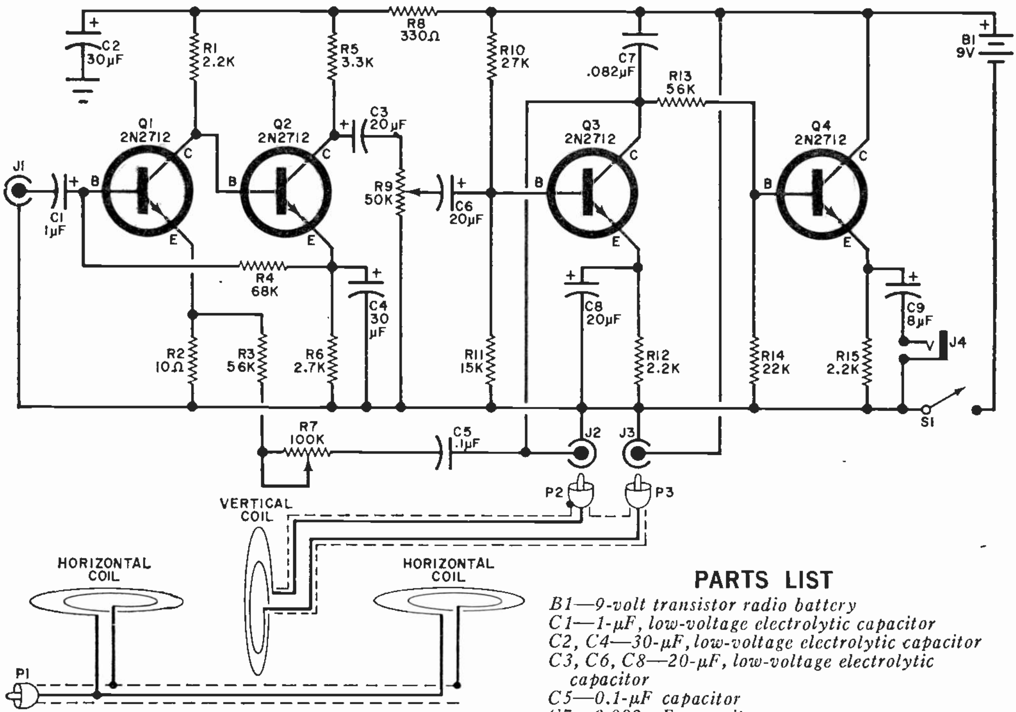


Fig. 1. Basically an unstable high-gain audio amplifier, the circuit breaks into oscillation when metal is detected between horizontal and vertical coils.

PARTS LIST

B1—9-volt transistor radio battery
C1—1-μF, low-voltage electrolytic capacitor
C2, C4—30-μF, low-voltage electrolytic capacitor
C3, C6, C8—20-μF, low-voltage electrolytic capacitor
C5—0.1-μF capacitor
C7—0.082-μF capacitor
C9—8-μF, low-voltage electrolytic capacitor
J1-J3—RCA phono jack
J4—Headphone jack
P1-P3—Phono plug
Q1-Q4—2N2712 or similar
R1, R12, R15—2200-ohm
R2—10-ohm
R3, R13—56,000-ohm
R4—68,000-ohm
R5—3300-ohm
R6—2700-ohm
R8—330-ohm
R10—27,000-ohm
R11—15,000-ohm
R14—22,000-ohm
(All resistors ½-watt)
R7—100,000-ohm potentiometer
R9—50,000-ohm potentiometer
S1—S.p.s.t. switch
Misc.—Headphones greater than 2000 ohms impedance, metal enclosure, perf board, spacers, battery connector, ½ lb #32 wire, wood for coil assembly and handle, six nylon screws, knobs, paint or varnish, plastic electrical tape, etc.

In spite of the considerable publicity that metal locators have received in the past few years, one type of locator has received very little attention because it has been used only in high-priced commercial equipment. The locator described here is of this type; it uses an "inductance bridge" method of detection. Audio-frequency coupling is used rather than r.f. The inductance bridge consists of two sets of coils, at right angles to each other, forming the input and output circuits for a high-gain audio amplifier. If the coils are constructed so that they are very close to being at right angles to each other, there is not enough inductive coupling between them to produce the feedback required to make the amplifier oscillate. However, if the coil set is brought near any metal, the metal forms a coupling between them, the amplifier oscillates, and an audio signal is produced.

Because the intensity of a magnetic field falls rapidly with distance and the influence on the magnetic field produced by a metallic conductor within it decreases rapidly as the conductor gets smaller, it is very difficult to make a device that will detect small objects at a distance. In the detector which uses a loop to locate the metal, varying the size of the loop can produce problems. For a given number of turns and a given amount of current in the loop, the field at a distance along the axis of the loop depends on the diameter of the loop. The greater the diameter, the farther the field extends. However, the greater the

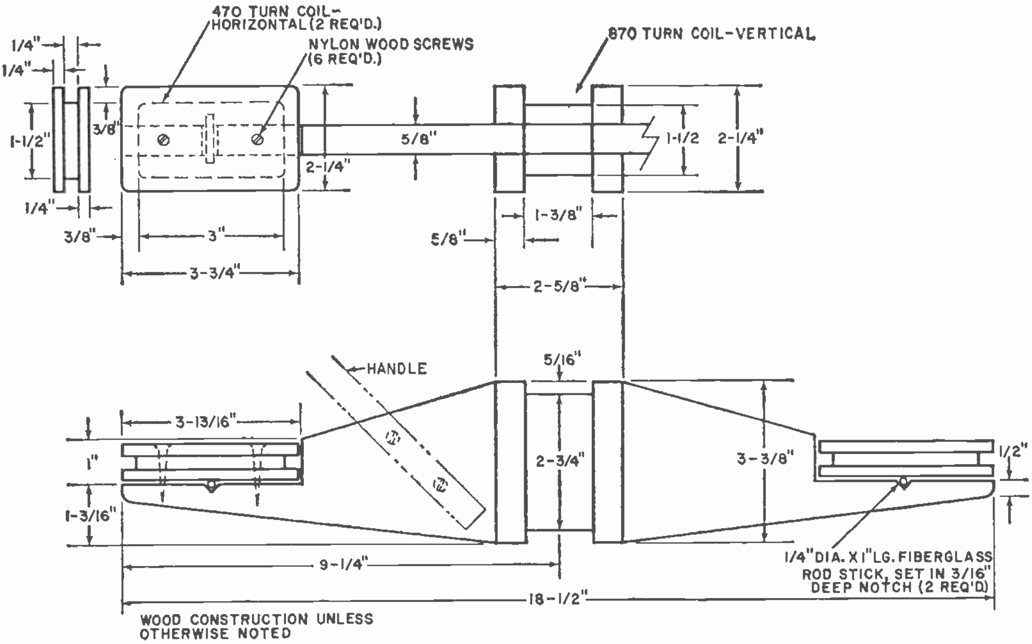
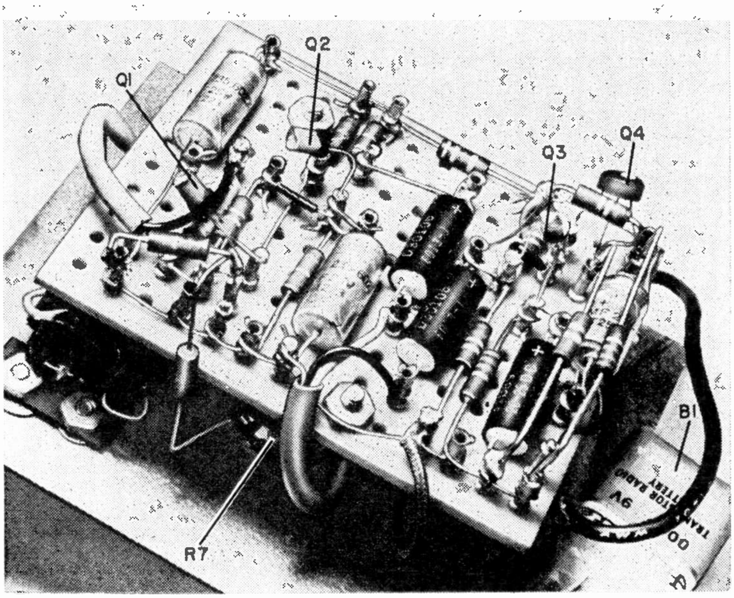


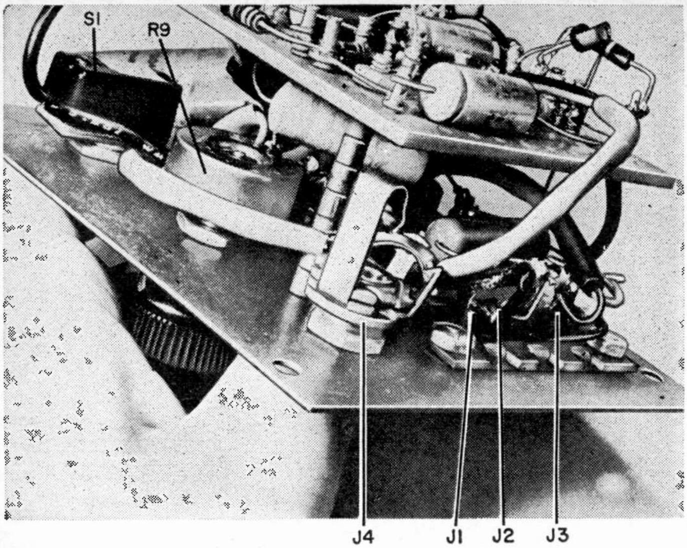
Fig. 2. Except for copper wire in the three coils, no metal is used in the search head construction. Nylon screws secure the two horizontal coils. Use a strong glue or cement for overall assembly.

loop diameter, the larger the metal object must be to have any effect on the field. Thus, in this type of locator, it is necessary to compromise between the size of the object to be located and the distance at which it can be located.

The locator described here will detect an aluminum bottle cap or a three-inch nail at a depth of 2 inches. Larger objects (such as a garbage-can lid) can be detected at a depth of 2½ feet. The locator is sensitive to ferrous materials. It is not sufficiently sensitive to detect coins smaller than a quarter near the surface.



The electronics may be assembled on perf board. Any arrangement can be used as long as the input and output circuits are as far apart as possible to prevent unwanted coupling.



The perf board is mounted on four long spacers to provide room for the front-panel components. The battery is secured in a clip affixed to the panel.

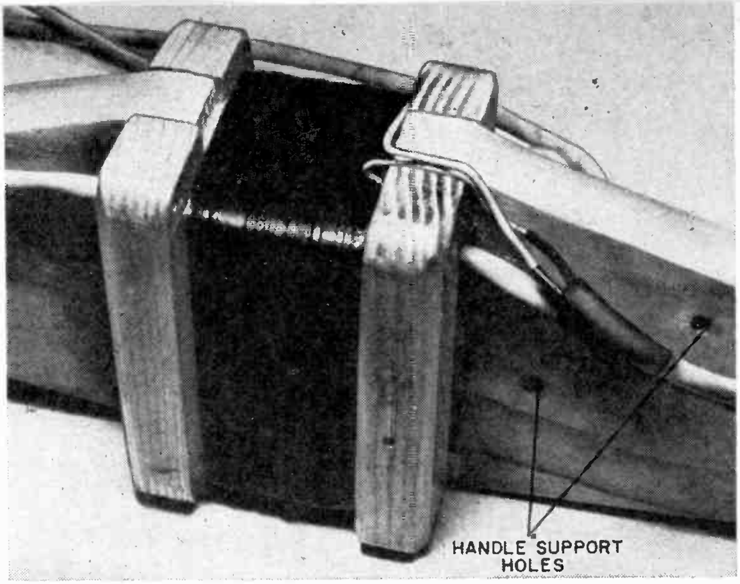
Construction. The locator consists of two principal parts: a search head which is a rigid assembly of three coils and a control box containing the electronic circuits which energize the coils and produce the audible output signal.

The electronic circuit, shown in Fig. 1, can be constructed on perf board. In laying out the components, be sure to keep the input components as far as possible from the output components to avoid unwanted feedback. The two potentiometers, *R7* and *R9*, switch *S1*, search-head jacks *J1*, *J2*, and *J3*, along with the headphone jack, *J4*, can be mounted on the front panel of a small metal box. The author used a 5″ × 4″ × 3″ aluminum enclosure. Once the front-panel controls are mounted, connect them to the perf board and mount the perf board on the front panel using insulating spacers. Use shielded leads between the three jacks and the two potentiometers. Ground the shields to the perf board common and make sure that the board common is well grounded to the metal enclosure. When wiring is complete, recheck the circuit for possible polarity errors in electrolytic capacitors and transistors and be sure that all resistor values are correct. Also check the solder connections for cold solder joints or accidental shorts.

In constructing the search head, there are three important points to remember: the assembly should be as rigid as possible, the two horizontal coils should be identical, and no metal other than the coil wire and leads should be used. This means *no* metal screws. All the parts making up the assembly are wood, and strong glue or wood cement should be used in fabrication.

Construct the wood head assembly as shown in Fig. 2. Note that nylon adjusting screws are used to tilt the horizontal coils slightly. This permits the setting of both horizontal coils exactly at right angles to the vertical coil. If you use care during the construction and make sure that the vertical and horizontal coils are as close to perpendicular as possible, the nylon screws will not have to be used. The horizontal coils should be made separately from the rest of the frame and not mounted until wound. All the wood parts should be given two coats of paint or varnish before winding the coils.

When starting to wind a coil, put a layer of plastic electrical tape around the core. Solder a length of fine multistrand plastic-covered wire to the end of the coil wire and insulate the joint carefully with plastic electrical tape. The piece of fine wire should be long enough to make one complete turn with enough left over to make a connection outside of the coil (two or three inches). Leaving this length of the fine wire hanging free (or anchored temporarily to some other object to keep it out of the way), wind the coil with the proper number of turns. Each horizontal coil requires 470 turns of #32 wire, while the single vertical coil takes 870 turns. Wind the coil wire as



Details of the vertical coil. After winding, wrap plastic electrical tape around the coil to prevent accidental damage and keep out any moisture.

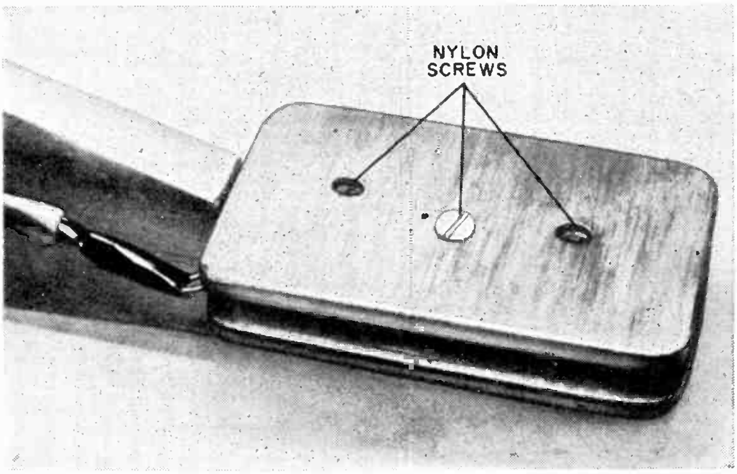
evenly and firmly as possible and avoid kinking the wire. When the winding is finished, protect it with a couple of layers of plastic electrical tape. Be sure that you can identify each end of the coil.

Winding the horizontal coil will be easier if you drill a hole in the center of the coil form and push a long machine screw through it. Anchor the screw at one end with a nut and clamp the screw in the chuck of a hand drill. Let an assistant operate the drill while you hold the wire and count the number of turns. In winding the vertical coil, drill a small hole at each end of the form and push a round nail (with the head removed) in each hole. Use one nail as a pivot and put the other in the hand drill. Be sure to remove the nails and bolts after winding the coils.

Once all three coils are wound, assemble them as shown in Fig. 2. The handle, fastened to the frame with nylon screws, can be any shape or length.

Use shielded twin-conductor cable about 6′ long to connect the coils to the appropriate jacks on the electronic package. Connect the vertical coil as shown in Fig. 1. For the horizontal coils, the two wires in the cable are connected together to form one lead with the shield used as the other lead. At this time, connect only one horizontal coil to the cable.

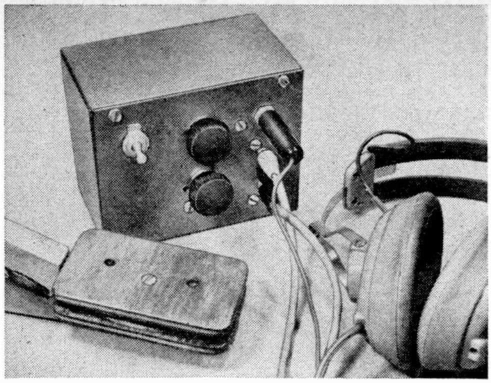
Testing. After the complete detector has been assembled, hang the search coil assembly so that it is well clear of any metal objects (about six feet). With the headphones plugged in and the power turned on (*S1*), turn up gain control *R9*.



Three nylon screws are shown here because the author trimmed the mounting for a true 90-degree fit. Normally, only the two outer screws are used and the coil form rotates about a thin plastic rod.

At some point, the circuit will oscillate and a tone of about 2000 Hz will be heard. Turn the gain down until the circuit just stops oscillating. At this point, turn up the feedback control (*R7*) until the oscillation is just audible. Bring a ferrous metal object (pliers, large screwdriver, etc.) near the coil assembly about midway between the vertical coil and the horizontal coil that is hooked up. At some short distance from the coil assembly, the circuit oscillation will increase rapidly, creating a loud tone in the phones. If it does not and the faint oscillation tone disappears instead, exchange the connections to the horizontal coil and repeat the test. Identify both leads of the horizontal coil, disconnect it, and repeat the procedure with the other horizontal coil connected. Identify these leads also and then connect both coils to the cable. After soldering the coil leads to the cable, insulate the connections with plastic tape. Then retest the entire locator head by bringing a metal object midway between the vertical coil and either of the horizontal coils. You can now experiment with various metal objects of various sizes to get the "feel" of the detector's operation.

To test for a true right angle between the vertical and horizontal coils, an external audio generator capable of delivering 2 kHz is required. Unplug both vertical coil connectors and insert a



The complete assembly consists of the search coil, a pair of headphones and the electronics package.

2200-ohm, ½-watt resistor between *J2* and *J3*.

Connect the audio oscillator, set at 2 kHz, to the vertical coil connectors, *P2* and *P3*. Rotate the feedback control, *R7*, fully counterclockwise (maximum resistance) and set the gain control, *R9*, at about its midpoint. Adjust the output of the audio generator until a tone is heard in the headphones. Very carefully tip one horizontal coil about the horizontal until the tone is minimized. Fix the coil in this position using the nylon screws. Repeat the procedure with the other horizontal coil. When the tone is at a minimum, the coils are at right angles and should be fixed that way. When this test is complete, attach the wooden handle with the two remaining nylon screws.

HOW IT WORKS

The electronic circuit is basically a high-gain audio amplifier whose gain is controlled by *R9*. Positive feedback is provided through *R7* and *C5*. A tuned circuit consisting of the vertical coil and *C7* is connected to the collector of *Q3*.

The two horizontal coils are connected to the amplifier input. Because the coil sets are at right angles to each other, coupling and feedback are at a minimum. However, there is always some slight electrical noise in an amplifier, and this is sufficient to set up a weak magnetic field around the vertical coil.

The lines of flux along the axis of the vertical coil are parallel with the planes of the horizontal coil. If a metal object comes within this field, the lines of flux are distorted so that some of them link with a horizontal coil. The coils are connected so that the signal input to the amplifier is in phase with the output of the amplifier when there is a disturbance in the magnetic flux. When this happens, the circuit breaks down with positive feedback and the output is similar to the feedback obtained between an audio amplifier speaker and a microphone. The oscillation has a frequency of about 2 kHz. Unlike most r.f. beating systems used in metal locators, this circuit requires no tuning.

Operation. With the detector assembled, earphones plugged in and on the head, turn on the power. Hold the coil assembly up in the air so that it is well clear of the ground and any metal. Rotate the feedback control to full counterclockwise and turn up the gain control until oscillation is just heard. Then back it off slightly until the oscillation just stops. Adjust the feedback control until the circuit just trembles on the edge of oscillation. Now proceed with a search pattern, bringing the coil assembly down to ground level and making wide sweeping motions in arcs over the top of the ground. When a metal object is detected, the barely audible tone will suddenly increase in volume as the hidden metal reaches an area just midway between either horizontal coil and the vertical coil. -30-

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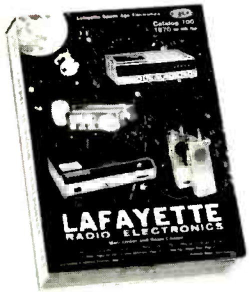

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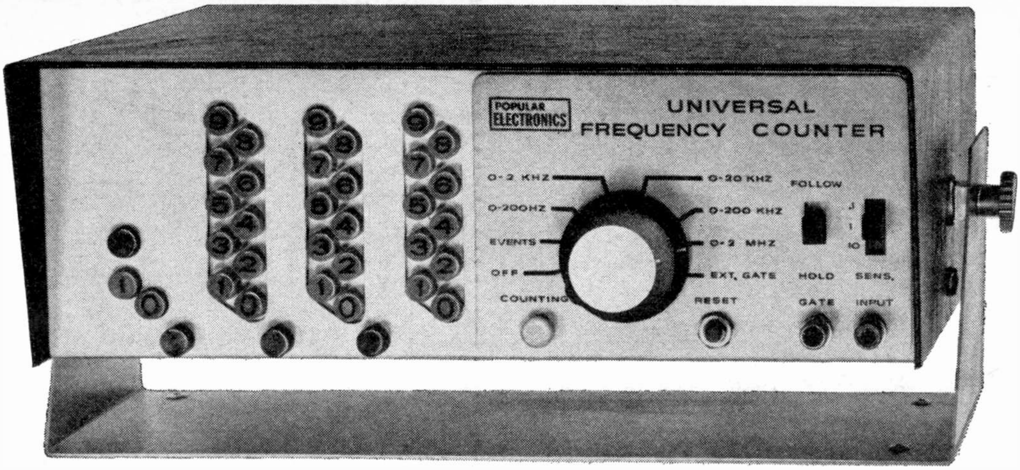


BUILD THE

Popular Electronics Universal Frequency Counter

HIGH-ACCURACY COUNTING TO 2 MHz

BY DON LANCASTER

HOW OFTEN do you come across a frequency counter like this: maximum range—2 MHz; cost—less than $125.00? The answer is very rarely, and that's why the EXPERIMENTER'S HANDBOOK Universal Frequency Counter will be of prime interest to project builders in all areas. Its list of attributes doesn't end, however, with frequency range and price: it has seven counting ranges (200 Hz to 2 MHz), a choice of three automatically sequencing time bases (0.1, 1 and 10 seconds), and a comparator with built-in noise immunity and guarded input. The latter provides excellent sensitivity to sine waves, square waves or narrow pulses of either polarity, regardless of duty cycles. A special electronic synchronizer eliminates last digit bobble and an overrange light indicates when the counter's capacity is exceeded.

With the Universal Frequency Counter, you can count events, measure frequencies from 0.1 Hz to over 2 MHz or you can gate the instrument externally so that it can be used as a stopwatch or to measure the ratio of two frequencies. The basic instrument has 0.1% accuracy with a 3½-digit display (3 digits plus overrange indication) and a line-operated time base similar to most commercial counters in the "under $600" category.

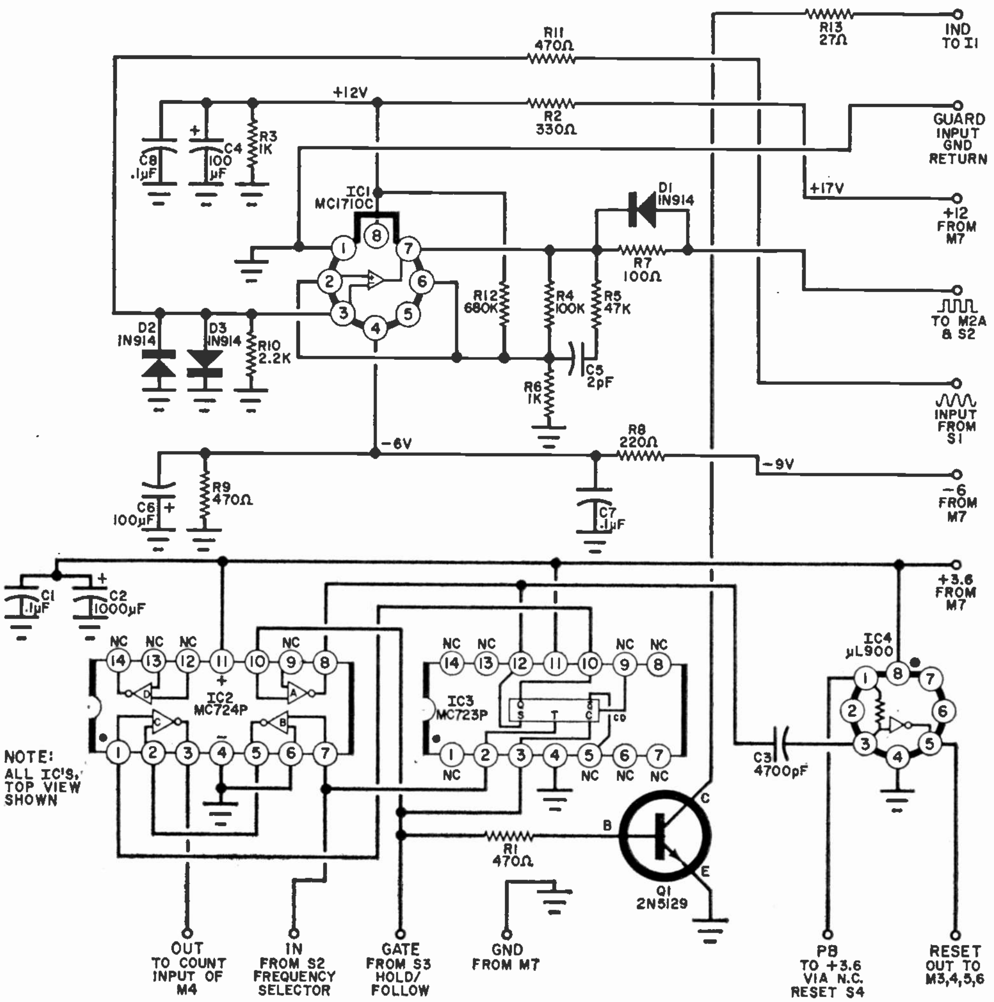


Fig. 1. The comparator module actually contains three separate circuits: input signal comparator (IC1), signal-time base synchronizing circuit (IC2 and IC3), and automatic reset generator IC4.

PARTS LIST
COMPARATOR MODULE

C1, C7, C8—0.1-µF, 10-volt disc ceramic capacitor
C2—1000-µF, 3-volt electrolytic capacitor
C3—4700-pF polystyrene, Mylar, or disc ceramic capacitor
C4, C6—100-µF, 15-volt electrolytic capacitor
C5—2-pF mica capacitor
D1-D3—1N914 silicon computer diode or equivalent
IC1—Operational amplifier (Motorola MC1710CG)
IC2—Quad two-input gate (Motorola MC724P)
IC3—JK flip-flop (Motorola MC723P)
IC4—RTL buffer (Fairchild µL900)
Q1—Transistor (National 2N5129)
R1, R9, R11—470-ohm
R2—330-ohm
R3, R6—1000-ohm
R4—100,000-ohm
R5—47,000-ohm
R7—100-ohm
R8—220-ohm
R10—2200-ohm
R12—680,000-ohm
R13—27-ohm
(All resistors ¼-watt)
Misc.—PC terminal (USECO 1310B, optional, not provided in kits, 13), #24 wire for jumper, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M1b, $3.20; complete kit of all parts required, #M-1, $14.65, plus postage, 6 oz.

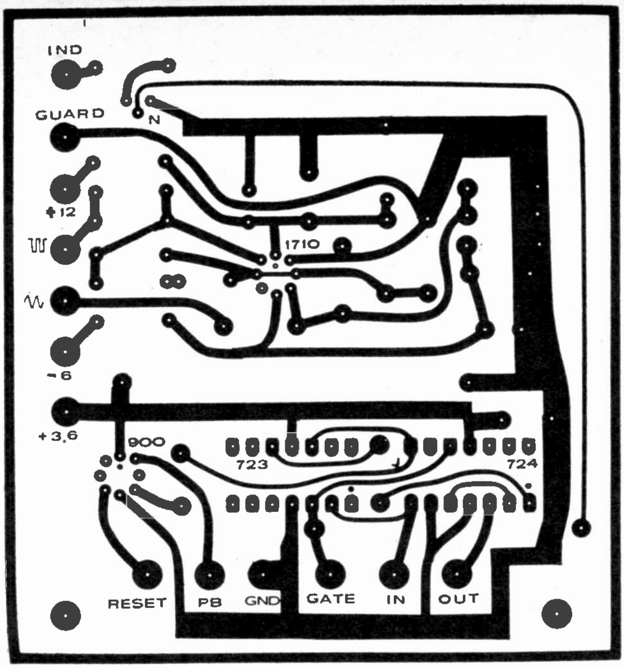


Fig. 2. Actual-size printed board for the comparator module. Because of the complexity of the circuit, printed boards are a must for this project.

Modular construction permits easy addition of extra decades or use of a more accurate, crystal time base. For instance, the time base used in the Sports Timer (ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter Edition, 1970, page 95) can be easily adapted for use in the counter. It is also possible to add divide-by-ten scalers using premium IC's to extend the counter's basic range to 20 or 200 MHz, direct reading.

While the Universal Frequency Counter is probably the most complex construction project ever presented in a hobby electronics magazine, the extensive use of integrated circuits and modular construction greatly simplifies the project. It is not a project for beginners but the procedure is relatively simple and straightforward. Parts and a complete kit are readily available as noted in the parts lists.

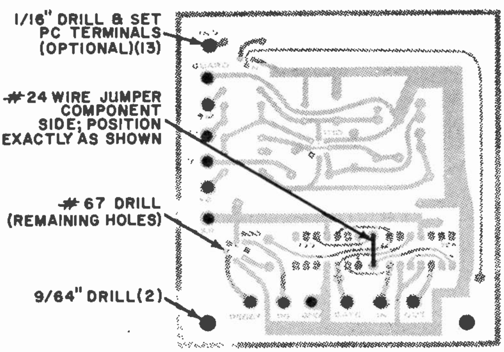


Fig. 3. Drill the board as shown here, and install the single jumper on the component side of board.

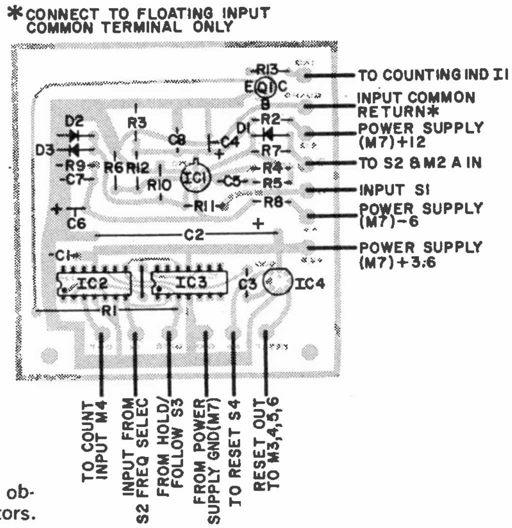


Fig. 4. Install the components taking care to observe polarities of semiconductors and capacitors.

HOW IT WORKS
COMPARATOR MODULE

There are actually three circuits in the Comparator module: a comparator, a synchronizing circuit, and a reset generator.

The comparator (*IC1*) is a high-gain operational amplifier that compares two input signals and provides a digital output signal generated by the difference between the signal input and a reference signal. The reference is derived from the output of the comparator by positive feedback and is either 10 or 30 millivolts positive. When the instantaneous value of the input signal is more than 30 millivolts, the output of the comparator goes to ground, helped along by a dropping reference voltage through positive feedback. If the input signal drops below 10 millivolts, the comparator output goes positive, again aided by feedback. This two-level action is called hysteresis, and it permits the comparator to operate with inputs that are noisy or are very low-frequency sine waves without producing a noisy output.

The comparator is protected on the input side by diodes *D2* and *D3*, which also act to restore the d.c. level for narrow pulse inputs. Feedback is provided by *R4*, *R5*, and *C5* and is both a.c. and d.c. Other components in the comparator circuit provide power supply decoupling and output load matching.

The synchronizing circuit consists of four gates and a JK flip-flop. The circuit delays the input measure command until the first input signal arrives and holds the measure command until one more input signal passes through the switch, *after* the measure command ceases. In this way, the measuring interval is locked to the signal to be counted. This eliminates a one-count bobble that might take place if the measurement command were turned on at random either just before or just after an input signal arrived. Transistor *Q1* is used to drive the COUNTING indicator light.

The reset generator, *IC4*, is a buffer connected as a half-monostable circuit. It generates a 2-microsecond reset pulse at the beginning of the measure command to reset the counters to zero. Operation of the RESET pushbutton, interrupts the positive supply to pin 1 of *IC4* and provides a longer positive output voltage. Either the automatic pulse or the manual reset causes the readouts to drop to zero.

Construction. The Universal Frequency Counter consists of seven modules, plus the case and some panel components. Module 1 is the comparator, module 2 is the Scaler, module 6 is the Gate, and module 7 is the Power Supply. The construction of these modules is given in detail here. Modules 3, 4, and 5 are decimal counting units that are fully described in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK and the details of their construction will not be given here.

It is advisable to build each module separately following the instructions carefully. Each module has its own schematic, parts list, and circuit board pattern. Note that round IC's are identified by a tab, flat, or color dot beside pin 8, while the rectangular (inline) units have a notch or dot at one end. In the schematic diagrams, they are shown from the top and the pins are numbered counterclockwise from the identifying mark. Be sure that all IC's are properly positioned before soldering connections. Also be careful to observe the polarities of diodes and electrolytic capacitors. Use fine solder and a low-power (25-35 watts) soldering iron.

Comparator (M1) The schematic for this module is shown in Fig. 1. A printed circuit board is a must. You can make your own, using the foil pattern in Fig. 2 or purchase one etched and drilled (see Parts List for Fig. 1). Install the single jumper on the component side as shown in Fig. 3. To mount the components on the board, follow the layout in Fig. 4.

Scaler (M2) The schematic for the Scaler is shown in Fig. 5. Construction will be greatly simplified by use of the circuit board whose pattern is shown in Fig. 6. Install the 12 jumpers on the component side of the board as shown in Fig. 7. The four jumpers marked with an asterisk should be insulated with small pieces of sleeving. Install the nine IC's and two capacitors as shown in Fig. 8.

Gate (M6) The Gate module schematic is shown in Fig. 9. Once again, construction will be greatly simplified by the use of a PC board. You can make your own using the pattern in Fig. 10. Mount the four jumpers on the component side as

A NOTE ON DCU'S

The Universal Frequency Counter can only use the new, low-power decimal counting units described fully in the Winter 1969 edition of ELECTRONIC EXPERIMENTER'S HANDBOOK. Module kits sold by Southwest Technical Products since October 1968 are of the new type.

Here's how to tell what you have: (1) if your DCU has only three IC's, you have the new unit; (2) if it has four IC's but no 1-watt resistors, you have a medium-power unit, modification of which is suggested but not essential; (3) if it has four IC's and two 1-watt resistors, you have the original version which must be modified if it is to be used in the counter. Modification kits with complete instructions are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216, for $1 per module.

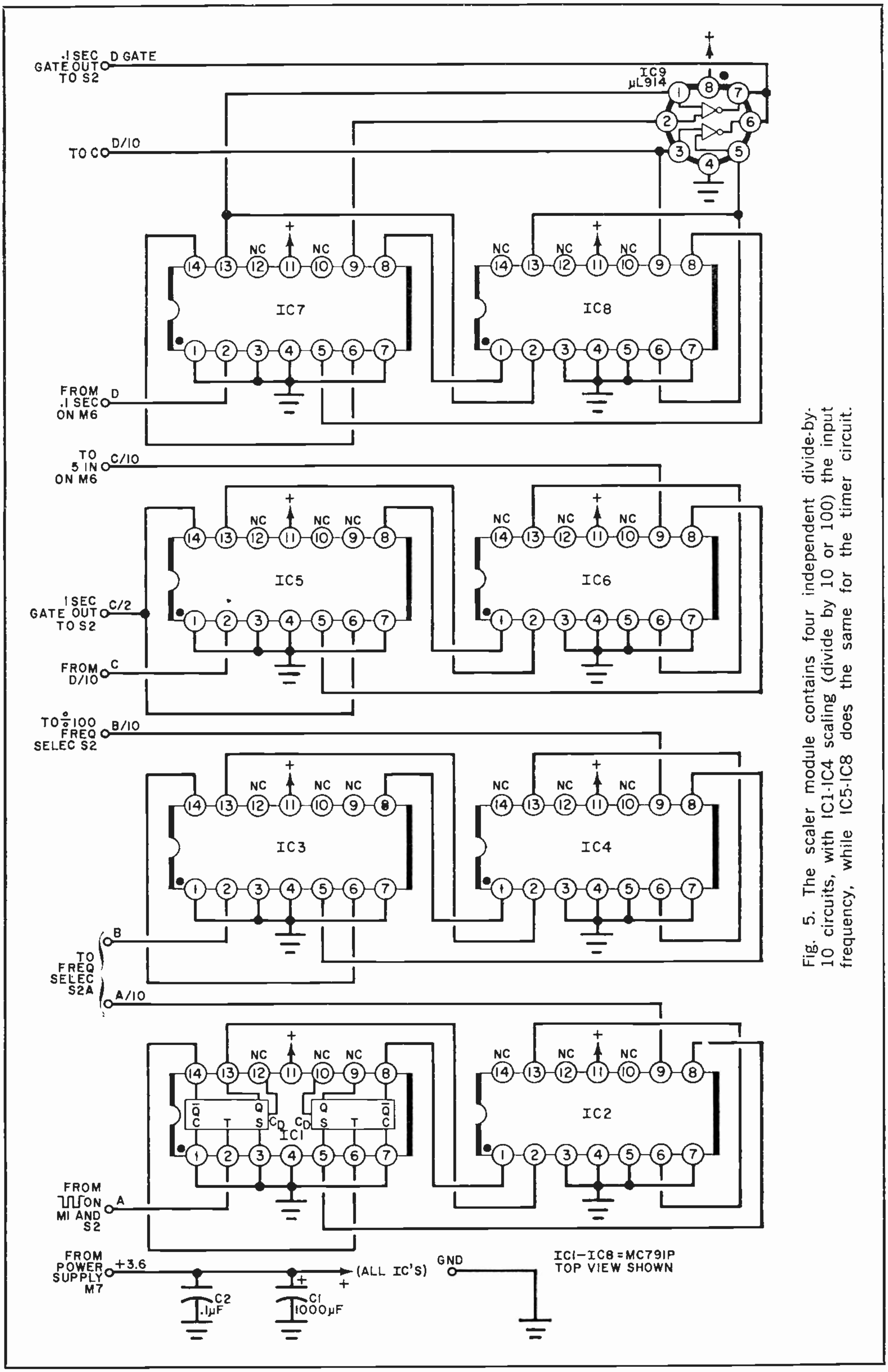


Fig. 5. The scaler module contains four independent divide-by-10 circuits, with IC1-IC4 scaling (divide by 10 or 100) the input frequency, while IC5-IC8 does the same for the timer circuit.

PARTS LIST
SCALER MODULE

C1—1000-µF, 3-volt electrolytic capacitor
C2—0.1-µF, 10-volt disc ceramic capacitor
IC1-IC8—MRTL dual JK flip-flop (Motorola MC791P)
IC9—RTL dual two-input gate (Fairchild µL914)
Misc.—#24 wire (12 jumpers), insulated sleeving for jumpers (4), PC terminals (USECO 1310B, optional, 12, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-2b, $2.85; complete kit of all parts required, #M-2, $21.90, plus postage, 6 oz.

HOW IT WORKS
SCALER MODULE

There are four independent divide-by-ten or decade counters in the Scaler module. Each counter, or scaler, consists of four JK flip-flops in a "modulo-10 minimum-hardware" circuit, the simplest possible decade divider.

Of the four scalers, units A and B are used to divide the input frequency by a factor of 10 or 100 as necessary. Scalers C and D are used in the timing circuit to generate measure commands. Scaler C has a divide-by-two output, which provides the 1-second measure command; scaler D has a 1-of-10 decoder (*IC9*), which provides the 0.1-second measure command.

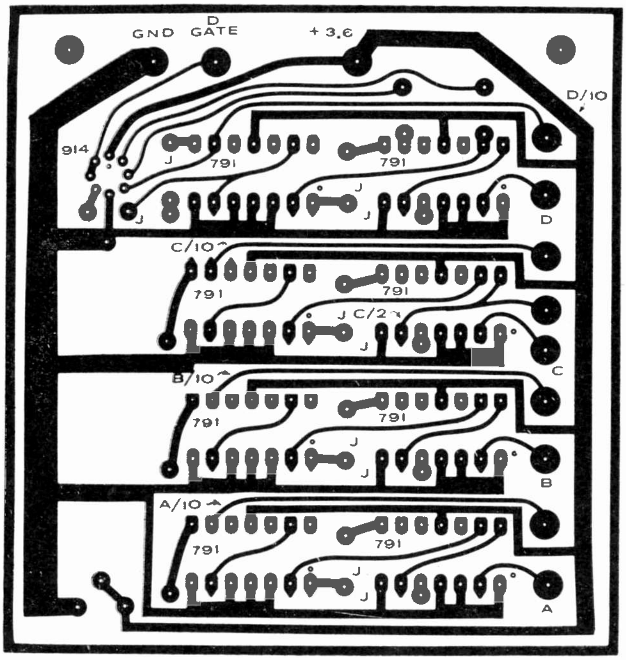


Fig. 6. Actual-size foil pattern for scaler module. This board, like all others is available etched and drilled (see Parts List).

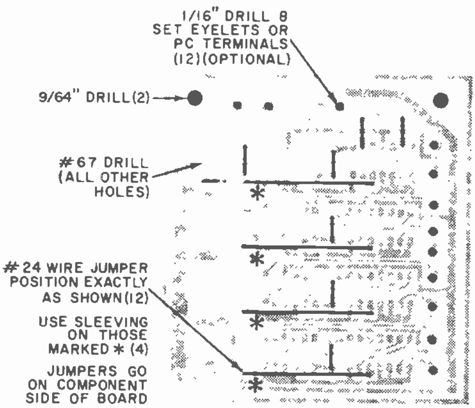


Fig. 7. After drilling the PC board, install the 12 jumpers on the component side in positions shown.

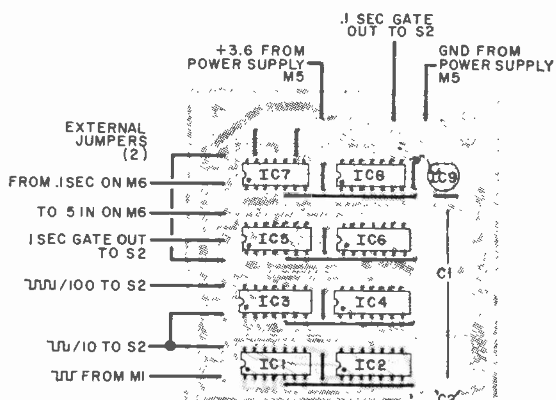


Fig. 8. When installing in-line IC's, observe the notch and code dot. Round IC has a flat at pin 8.

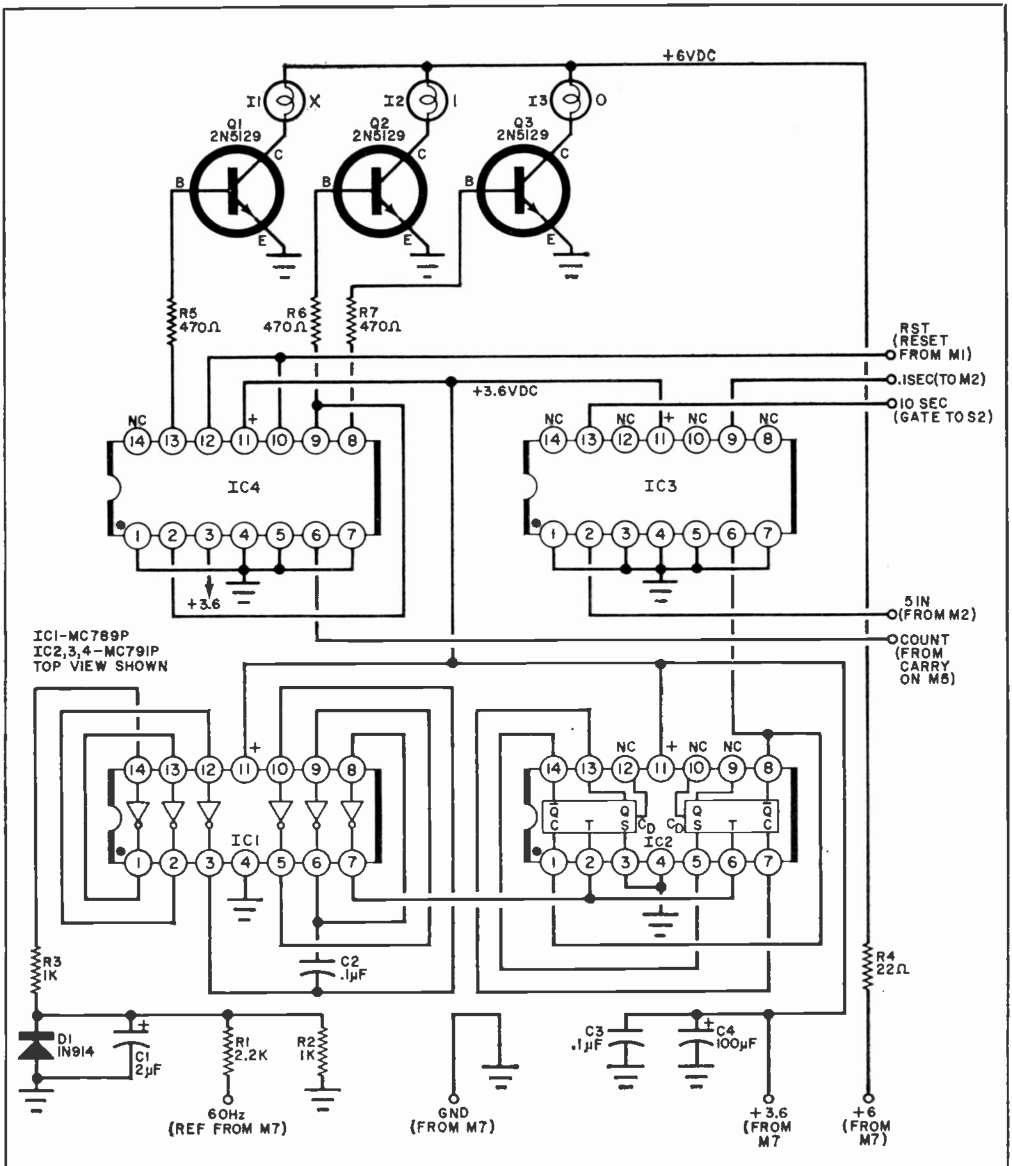


Fig. 9. The gate module performs three functions: accepts, shapes, and converts 60 Hz to 20 Hz; produces .1- and 10-second gates (IC3); and mounts 0-1 and overflow circuit (IC4, Q1, Q2, Q3).

PARTS LIST GATE MODULE

C1—2-μF, 10-volt electrolytic capacitor
C2, C3—0.1-μF, 10-volt disc ceramic capacitor
C4—100-μF, 15-volt electrolytic capacitor
D1—1N914 silicon computer diode
I1-I3—6.3-volt, 50-mA indicator lamp assembly, two orange, one red (Southwest Technical 0-6.3 and R-6.3, respectively, or similar)
IC1—MRTL hex inverter (Motorola MC789P)
IC2-IC4—MRTL dual JK flip-flop (Motorola MC791P)
Q1-Q3—Transistor (National 2N5129)
R1—2200-ohm
R2, R3—1000-ohm
R4—22-ohm
R5-R7—470-ohm
(All resistors ¼-watt)
Misc.—#24 wire (4 jumpers), insulated sleeving (1 inch), bracket and mounting hardware for lamps, PC terminals (USECO 1310B, optional, 9, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled circuit board, #M-6b, $2.35; complete kit of all parts required, #M-6, $13.85, plus postage, 5 oz.

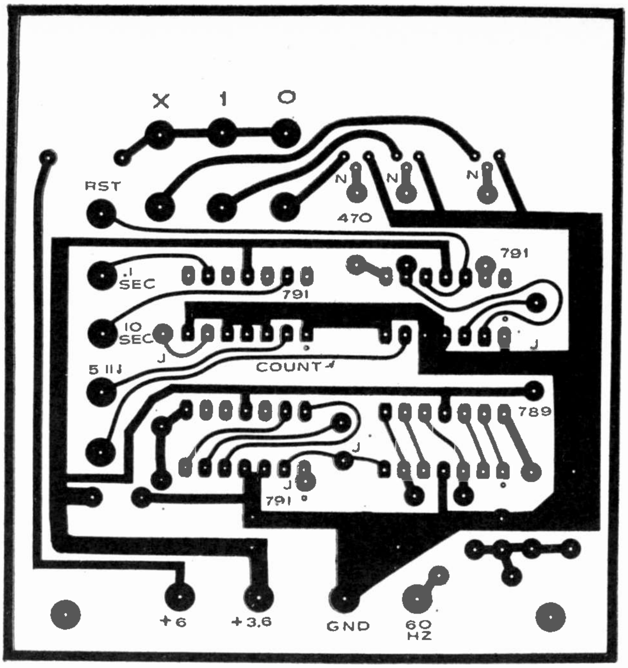


Fig. 10. Actual-size foil pattern for the gate module. As in the other foil patterns, each input-output termination and semiconductors are marked.

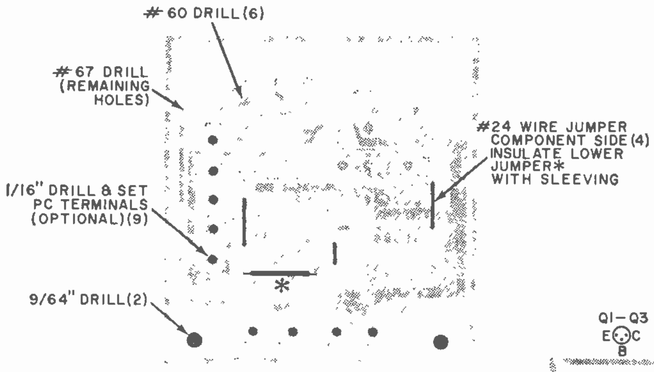


Fig. 11. Mount four jumpers on the component side of the board, making sure the indicated jumper is insulated to prevent short circuiting IC2.

shown in Fig. 11. Insulate the lower jumper with suitable sleeving. Mount the components as shown in Fig. 12.

A mounting bracket is required for this module to hold the three indicator lights. Details for this part appear in "Low-Cost Counting Unit," ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969 and "Digital Volt-Ohmmeter," EXPERIMENTER'S HANDBOOK, Winter 1970. The bracket is mounted by match drilling to the PC board, then pop-riveting using #4 hardware. An orange plastic lens can be used for both the 0 and 1 indicators and a red lens for the overrange indicator.

Power Supply (M7) Most of the power supply, whose schematic is shown in Fig. 13, is assembled on the PC board shown

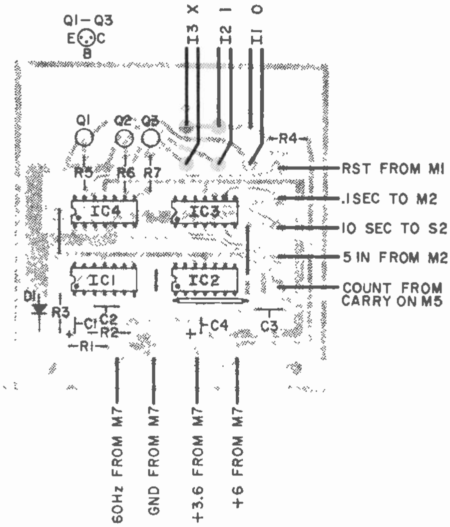


Fig. 12. Mount the board components as shown here, once again taking care to observe all polarities.

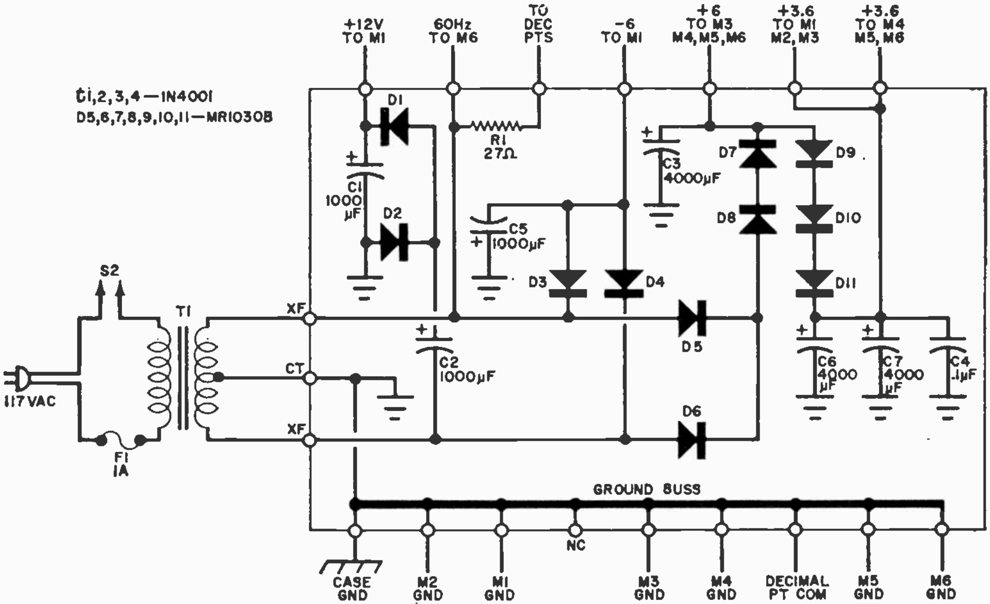


Fig. 13. Note the eight connections to the ground buss. This is done to reduce stray coupling between the various modules. Each module ground should be run on a short, heavy lead.

PARTS LIST
POWER SUPPLY MODULE

C1, C2, C5—1000-µF, 25-volt electrolytic capacitor
C3, C6, C7—4000-µF, 6-volt electrolytic capacitor
C4—0.1-µF, 10-volt disc ceramic capacitor
D1-D4—1-ampere, 50-PIV silicon diode, 1N4001 or equivalent
D5-D11—3-ampere average, 24-ampere peak, 50-PIV silicon rectifier (Motorola MR1030B, do not substitute)
F1—1-ampere fuse
R1—27-ohm, ¼-watt carbon resistor
T1—12.6-volt center-tapped, 2-ampere filament transformer
Misc.—PC mouting spacers and hardware, PC terminals (USECO 1310B, optional, 19, not provided in kit), line cord with strain relief, fuse-holder and mounting hardware, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-7b, $3.50; complete kit of all parts required, #M-7, $19.10 plus postage, 3 lb.

HOW IT WORKS
GATE MODULE

The Gate module contains three circuits: the gate generator, the 10-second measure command generator, and the 0-1 counter and overflow latch with indicators. The first two circuits, together with scalers C and D in the Scaler module, provide the time base, while the last circuit extends the range of the counter by half a digit and provides an indication to call attention to the fact that the input signal has exceeded the full counter capacity.

The gate generator accepts the 60-Hz powerline reference from the power supply module, filters and clamps it, and then applies it to a hex-inverter squaring circuit, *IC1*. Positive feedback, via *C2*, provides additional edge steepening, to provide the 100-nanosecond rise and fall times required by the next stage.

A divide-by-three counter (*IC2*) uses a pair of flip-flops to reduce the 60-Hz input to a 20-Hz square wave. This circuit is twisted slightly from a "normal" divide-by-three circuit to save some PC board jumpers. The first flip-flop in *IC3* divides the 20-Hz time-base signal into 10 Hz (a 0.1-sec period) which is the reference required to run scalers C and D on the Scaler module. The second flip-flop converts the output of scaler C which has a 10-sec period into a 10-sec on and 10-sec off measure command as required for the 0-200-Hz range.

The 0-1 counter and overrange latch is made up of *IC4* driving transistors *Q1* through *Q3*, which supply power to the appropriate front-panel indicator lamps.

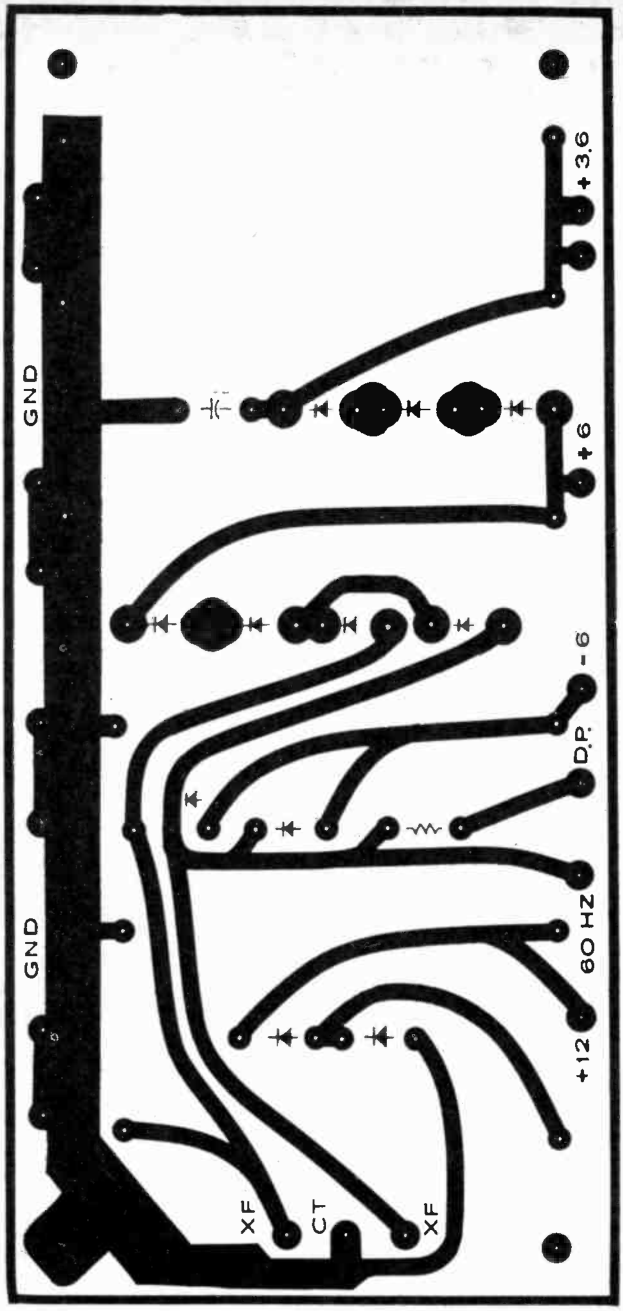


Fig. 14. Power supply foil pattern is the largest one in the instrument. It should be made on fiberglass to avoid heat damage from power diodes. To assist cooling, mount all diodes slightly off the board to allow cool air to circulate around them to dissipate the heat. Also, do not allow the diodes to touch the capacitors.

in Fig. 14. The power transformer (*T1*) and the fuse (*F1*) are mounted on the counter chassis. Use a G-10 fiberglass base for this circuit board so that it can withstand the heat generated by the power diodes. Drill holes as shown in Fig. 15.

To avoid stray coupling between modules through ground connections, it is very important that all module grounds be isolated from each other and at very low impedance. For this reason, a wide ground buss is provided on the power supply circuit board, with a separate terminal for connections to each of the other modules. A separate #16 (or other heavy-gauge) wire should be run from each module to the ground buss. All

HOW IT WORKS
POWER SUPPLY

The power supply must provide more than an ampere of current at 3.6 volts d.c. and other lower current supplies at +6, −6, and +12 volts. It also provides a.c. to the decimal point lamp and the Gate module.

To obtain all these voltages from a single power transformer requires a few more diodes than would normally be needed with a multi-winding transformer.

The +12-volt supply is derived from a voltage doubler consisting of *D1, D2, C1,* and *C2.* The supply is actually about 17 volts at the output terminal; it is reduced to 12 volts by the decoupling network in the Comparator module. Similarly the full-wave rectifier made up of *D3, D4,* and *C5* provides about −9 volts, which is reduced to −6 volts in the Comparator.

A second full-wave rectifier (*D5* and *D6*) produces +6 volts with diodes *D7* and *D8* acting as a dynamic regulator. This supply is reduced by *D9, D10,* and *D11* to provide +3.6 volts for the integrated circuits. While the average current through diodes *D5* through *D11* is about one ampere, the peak current is much larger—high enough to damage ordinary silicon power diodes. That is why three-ampere silicon rectifiers are specified in the Parts List.

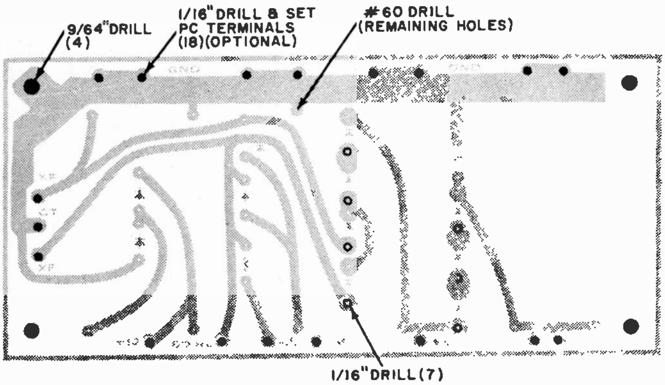


Fig. 15. There are no jumpers on the power supply board. After it is drilled, mount the components.

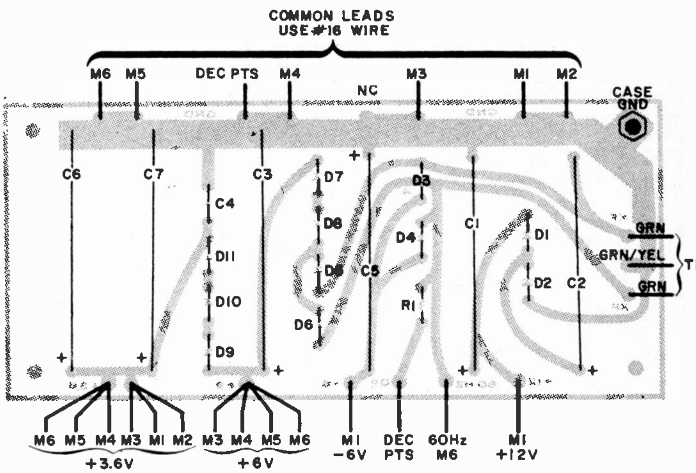


Fig. 16. Finish the power supply by mounting the components. Note that each module ground is made via an independent #16 gauge wire and one connection is made to counter case (upper right).

ground leads should be kept as short as possible.

Components are installed on the power supply board as shown in Fig. 16. Note that *C5* is upside down with respect to the polarity of the other capacitors. Note also that all diodes point in the same direction. Be sure that there is sufficient cooling space between the diodes and the electrolytic capacitors since the latter can be damaged by diode heat generation.

Connect the power supply module to the case through a single ground lead. Do not run any other ground leads to the chassis except the return for *J1.*

Assembly of Complete Unit. The circuit for the overall counter is shown in Fig.

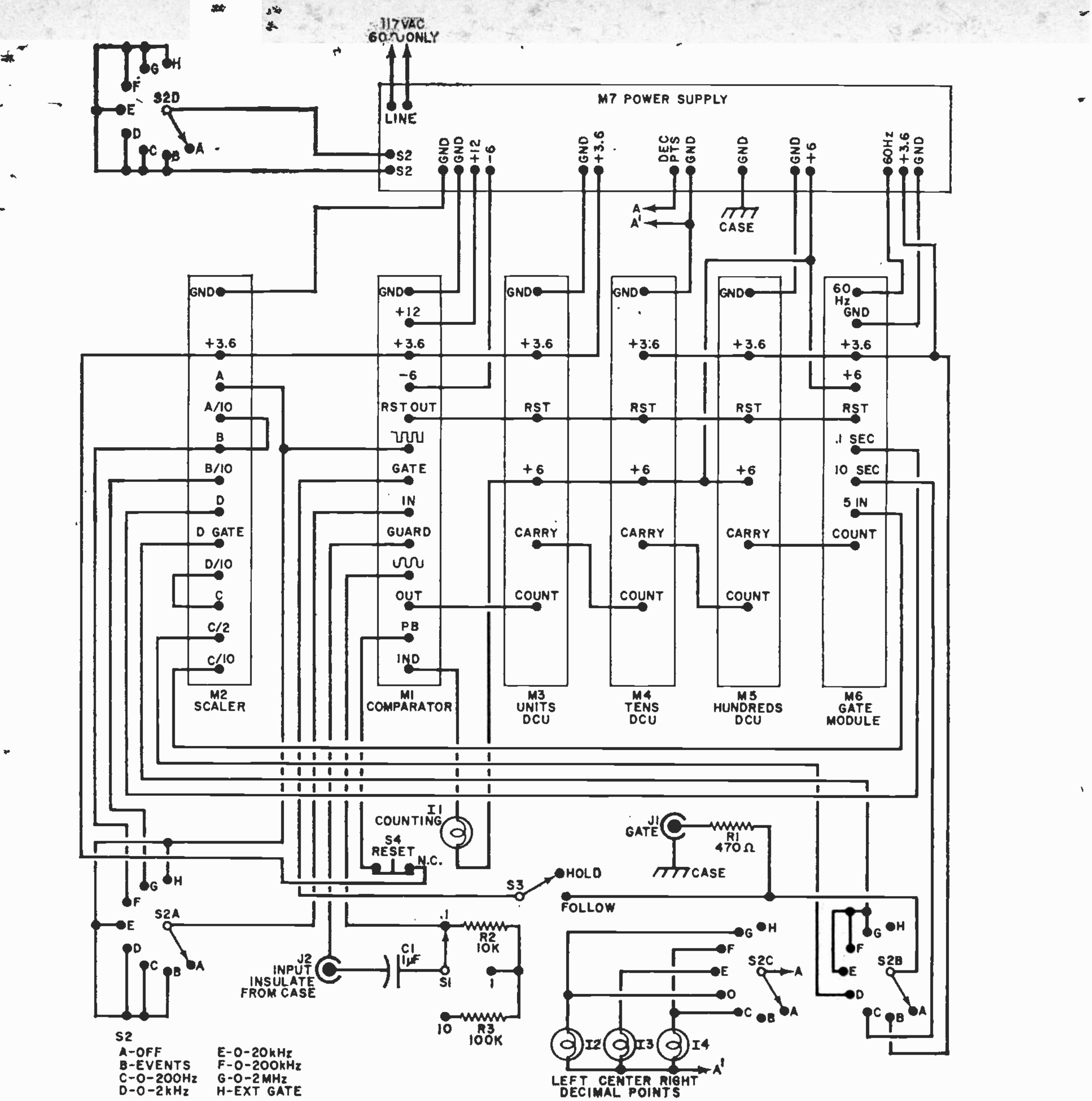


Fig. 17. Interconnections for complete frequency counter. Signal input jack J2 is insulated from chassis to prevent internal noise interference with the input signal.

17, while Fig. 18 shows the interior of the chassis. The vinyl-clad case that comes with the complete kit is punched and machined, and includes assembly instructions. If you select another type of enclosure, use Fig. 18 as a general layout guide. An optional dialplate (see Parts List for Fig. 17) adds a professional touch and also serves as a front-panel layout template.

Modules *M1* through *M6* are arranged in a line along the front of the case, supported by brackets similar to those used on the "Digital Volt-Ohmmeter" (EXPERIMENTER'S HANDBOOK, Winter 1970). The three decimal-point indicator

PARTS LIST
COMPLETE COUNTER

C1—1-µF, 400-volt Mylar capacitor
I1-I4—6.3-volt, 50-mA pilot lamp and lens assembly, three green, one white (Southwest Technical G-6.3 and W-6.3, respectively or similar)
J1—Phono jack
J2—Phono jack and nylon insulated mounting kit
M1—Comparator module
M2—Scaler module
M3-M5—DCU module (see text)
M6—Gate module
M7—Power supply module
R1—470-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R3—100,000-ohm, ¼-watt resistor
S1—Three-position, single-pole slide switch
S2—Four-deck, four-pole, eight-position, non-shorting miniature selector switch. Close space first three decks, isolate fourth with ¼" spacers. (Southwest Technical SW111S1 or equivalent)
S3—S.p.s.t. slide switch
S4—S.p.s.t. normally closed pushbutton switch
Misc.—3" x 5½" x 10" vinyl-clad, prepunched case and support assembly, dialplate, 1½-inch knob, mounting brackets for modules, mechanical hardware, #16 wire for grounds, #22 hookup wire, solder.*
**Anodized dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Arizona 85014; in black and silver $3.00; red, gold, or copper $3.45, postpaid in USA.*
Note:—Complete kit of parts to build counter including case but not dialplate is available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216. Order # 165C, $120, plus postage, 7 lb.

lamps are placed between the decade units as shown in the photo, while the Power Supply module (*M7*) mounts on the rear wall of the chassis with spacers and #6 hardware. The fuse (*F1*) and power transformer (*T1*) are mounted on the bottom of the chassis.

Note that the frame of input jack *J2* is isolated (insulated) from chassis ground and has an independent ground lead, called a "guard," running directly to the *M1* board. This lead is very important since it prevents any internally generated ground noise from interfering with the input. Use nylon washers to insulate the jack from the chassis.

Don't forget the individual ground leads from each module to the power supply ground buss.

The main selector switch (*S2*) has four decks, one of which is isolated from the other three by spacers. The isolated deck controls the 117-volt, 60-Hz power, while the other three (starting from the front) select the frequency, the timing, and the decimal point.

HOW IT WORKS
COMPLETE COUNTER

The frequency to be counted is applied to the sensitivity control, which reduces the input level by 1 or 10 to the approximately 100 millivolts required for normal operation. The signal is then sent to the Comparator module (*M1*) where it is converted from a sine wave to a square wave of the same frequency with sharp rise and fall times. Any noise that might be present in the input is also rejected in the Comparator. The Comparator output is fed directly to the range selector switch *S2* and also to a pair of decade scalers that provides divide-by-ten and divide-by-one-hundred outputs. The latter are also connected to the range selector switch.

The output of the Comparator (f) is selected for the EVENTS function, 0-200 Hz, 0-2 kHz, 0-20 kHz and for the external gate (EXT. GATE) operation. The output from the first decade scaler (f/10) is used for the 0-200 Hz position, and the output of the second scaler (f/100) is used for the 0-2 MHz position.

The time base starts with a 60-Hz reference from the power supply. This signal is filtered, squared, and divided by six (all in module *M6*) to obtain the 0.1-second gating reference. Two divisions by ten produce the 1-second and 10-second time references. These time intervals, along with a positive voltage for EVENTS and no input for EXT. GATE are routed to the range selector switch.

From the selector switch, the time commands go through the HOLD-FOLLOW switch which permits a choice of automatically updating the reading or holding the last reading.

Both the measure command and the selected input frequency go through the synchronizing circuit in the Comparator module. The measure command turns the electronic switch on and off, but it does it in such a way that only whole cycles of the input frequency are counted. This eliminates the one-digit bobble in the counting. The time-base gated frequency then goes to the counting and display circuits.

The counter can be reset to zero at any time by operation of the manual RESET pushbutton, but in normal modes of operation, the counters are automatically reset just before a new count begins.

The operation of the counter is fully automatic. The available measure commands are 10-s measure and 10-s display for 0-200-Hz operation; 1-s measure and 1-s display for 0-2-kHz operation; and 0.1-s measure and 0.9-s display for the other ranges. To keep the display on longer, flip switch S3 to HOLD.

Preliminary Checkout and Operation. The frequency counter requires no calibration and has no internal adjustments. It is only as accurate as the 117-volt a.c. power-line stability and display resolution permit it to be. The following tests can be performed to check the general assembly for proper operation.

Plug the counter into a source of 117-volt 60-Hz power and place selector switch *S2* on EVENTS and switch *S3* on FOLLOW. One, or possibly two, numerals in each decade should be illuminated.

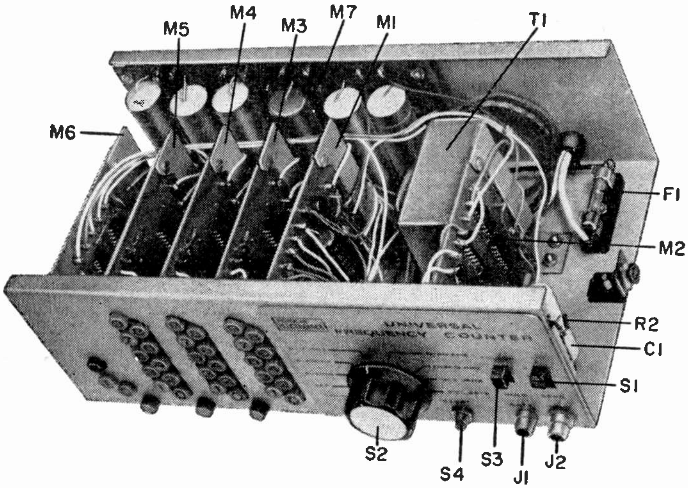


Fig. 18. Author's prototype may be duplicated or used as a guide. Because of the length of M7, the Power Supply module, it is mounted along the rear apron of the chassis. When using a different physical layout, remember that the Power Supply generates some heat and mount it out of the way where it will not affect the heat-sensitive components that are mounted on the other modules.

Momentarily depressing the RESET button should immediately produce a 0000 reading.

Check all supply voltages, particularly the +6 and +3.6 volts, to be sure that they are within 0.1 volt of their correct values. The −6 and +12-volt supplies should be checked at their respective terminals on *IC1* of the Comparator module *M1*.

Place the range selector switch on the 0-200 Hz position and observe the COUNTING light on the front panel. It should cycle on for 10 seconds and off for 10 seconds. Place the selector switch on 0-2 kHz. The COUNTING light should now cycle on for 1 second and off for 1 second. With the selector switch on any higher range, the light should flash on for 0.1 second, once each second.

To check the operation of the decimal-point indicators, place the range selector switch on the 0-2 MHz position and note that the left decimal point indicator is illuminated. For other switch positions, lights should be on as follows: 0-200 kHz, right; 0-20 kHz, center; 0-2 kHz, left; 0-200 Hz, right.

With the counter still energized, set the FOLLOW-HOLD switch to FOLLOW, the range switch to 0-2 kHz, and the SENS. (sensitivity) switch to .1. Insert a test lead in the INPUT jack and touch the other end of the test lead. Note that the counter starts operating erratically only when the COUNTING light is lit. The display should last only as long as the COUNTING light is dark. The counting units should start to count at the same instant that the COUNTING light comes back on. Placing the SENS. switch on either the 1 or 10 position should stop the counting operation.

If the counter passes all of these tests, it is probably working properly and is ready for use. As a final check, and to gain some experience in using the counter, use a bounceless pushbutton circuit (described in "Low-Cost Counting Unit," POPULAR ELECTRONICS, February 1968, or ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969) and a low-frequency audio oscillator. When using the counter, always start with the SENS. switch down to the 1 or .1 position as required to get a stable reading. Also, do not forget that an input lead (whether it is coaxial cable or phono lead) that is too long will attenuate (and load) a high-frequency signal.

Key Waveforms. The following information can be used if trouble is experienced in getting the counter to operate properly. The waveforms at various points in the circuit vary depending on switch settings and the nature of the input. However, there are some critical points at which the waveforms can be checked to determine whether the counter is working properly.

Comparator (*M1*) When sufficient input signal is applied, the output at the square-wave terminal of this module (connected to *D1* and *R7*) should be either a square or a rectangular wave from 0 to 2.4 volts positive. The output goes positive when the instantaneous input signal drops below +10 mV and drops to zero when the input exceeds +30 mV. The rise and fall times of this waveform should be about 60 nanoseconds.

The feedback to pin 2 of *IC1* should show a steep leading edge that reaches +80 mV, followed by a rapid decay (about 90 ns) to the +30 mV level. The trailing edge of this waveform should have a rapid transition to −40 mV and a rapid decay back to +10 mV. This signal is present only when an input signal is applied to the counter. Because of the very fast switching of this waveform, you will have to use a high-quality, lab-type oscilloscope to make exact measurements although the basic signal can be seen on a conventional service scope.

The synchronizing circuit in the Comparator can be tested by using a bounceless pushbutton and observing the DCU's and the COUNTING indicator light, in the 0-200-Hz range. The first count after the COUNTING light comes on should not be counted, and the first DCU should display starting at the second count. The first count after the COUNTING light goes off should be counted and the display should remain steady after that. Correct operation of this circuit guarantees that the device will only count whole input cycles.

Scaler (M2) The input to the A scaler should be identical to the square-wave output observed on the Comparator.

Output A/10 should be a rectangular wave with a frequency 1/10 that of the input. It should be about 1.8 volts in amplitude and have a 6:4 duty cycle. This, of course, is also the input to the B scaler.

The frequency of output B/10 should be 1/10 that of A/10 and 1/100 that of the input to the A scaler. Its amplitude depends on the setting of the range selector switch, but it should range between 1.8 and 3.6 volts, positive. It should have a 6:4 duty cycle and rise and fall times of about 50 ns.

The GATE terminal of the D scaler should have a repeating waveform that goes positive about 2 volts for 0.1 second and to ground for 0.9 second.

The output at C/2 should be a repeating signal that is positive for 1 second and ground for 1 second, with an amplitude of about 2 volts.

The output at C/10 should be a repeating symmetrical square wave with a frequency of 0.2 Hz (5-second period), with an amplitude of about 2 volts, positive.

(*Continued on page* 76)

COUNTER SPECIFICATIONS

Function: Measuring frequency, events, events-per-unit-time, or the ratio of two frequencies. It is also a source of precision 0.1-, 1-, and 10-second timing signals.

Ranges: 0-200 Hz, 0-2 kHz, 0-20 kHz, 0-200 kHz, 0-2 MHz, events, and externally gated events or ratio.

Accuracy: Power-line stability plus or minus one-half count. Typical accuracy is 0.1%.

Resolution: One part in 2000 to full scale. 0.1 Hz on 0-200-Hz scale.

Sensitivity: Switch adjustable from nominal 0.1, 1, or 10 volts. For sine waves—30 mV r.m.s. from 50 Hz to 3 MHz; 300 mV r.m.s. from 5 to 50 Hz. For pulses—symmetric pulse, 100 mV p-p; narrow positive pulse, 50 mV p-p; narrow negative pulse, 700 mV p-p.

Input conditioning: Automatically provided for all but mechanical contacts. High-gain IC comparator provides snap action, 10-mV noise offset, and 20-mV hysteresis. Any reasonable wave shape is acceptable, including sine or square waves, or rectangular pulses of either polarity.

Input protection: D.c. blocking to 200 volts. Combination dual-diode limiter and d.c. restorer allows safe measurement in practically all test situations.

Input impedance: 10-volt range, 112,000 ohms; 1-volt range, 12,500 ohms; 0.1-volt range, 2500 ohms. Typical shunting capacity is less than 30 pF.

Gating: Fully synchronized master gate used to eliminate the one-count ambiguity associated with older counter designs. Last digit is constant rather than bobbling between two values.

Display: Switch selects hold or follow. Infinite display in hold function, automatic updating in follow. For 0-200 Hz, 10-second measure, 10-second display; for 0-2 kHz, 1-second measure, 1-second display; for higher frequencies, 0.1-second measure, 0.9-second display.

Miscellaneous: Automatic overrange indicator comes on when full-scale count is exceeded. Floating decimal points. Manual reset and override. Time gate outputs available at gate terminal during measurement. Modular construction adaptable to crystal time base for higher accuracy. Extendable with input scaling to 0-20 MHz or 0-200 MHz. All solid-state circuit uses 26 IC's, 43 transistors, and 14 diodes.

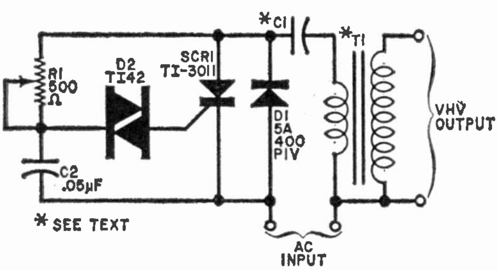
Build VHV Supply

10,000 VOLTS FROM COMMONLY AVAILABLE COMPONENTS

BY PAUL H. FUGE

THERE STILL EXISTS a real need for very-high-voltage power supplies even in this era of low-voltage solid-state electronics—especially in the area of experimenting. A casual look around the various school science fairs will reveal that interest is still high for such projects as air ionizers, Van de Graaff generators, Tesla coils and the like. (One practical use for a VHV supply was given in "The Not Altogether Forgotten Electret" in the March 1969 POPULAR ELECTRONICS.)

In most cases, the VHV power supply is required to deliver currents on the order of only a few microamperes. So,



By driving the very-high-voltage power supply with a variable-voltage transformer, output voltage can be made to vary above and below 10,000 volts.

to meet this requirement with maximum economy, the VHV Supply described here consists of an SCR, a capacitor, a common automobile spark coil, and a simple triggering circuit. Operated from any 117-volt a.c. house line, the supply produces an output on the order of 10,000 volts which will jump a ⅜" spark gap and melt an electrode made of solder.

How It Works. Referring to the schematic diagram, when line power is applied to the circuit, *D1* conducts only when it is forward biased, allowing *C1* to charge up. Then, when *D1* becomes reverse biased, *C2* charges up through *R1*. At some point during the charge cycle, the potential across *C2* reaches and exceeds the breakover voltage of trigger diode *D2*. When this happens, *D2* conducts and delivers a triggering pulse to the gate of *SCR1*, turning it on.

The instant *SCR1* fires, it forms a series circuit with *C1* and the primary of spark coil *T1* across the power line. As a result, the charge on *C1* rapidly discharges through the low-resistance *T1* primary, inducing a much higher voltage across the secondary.

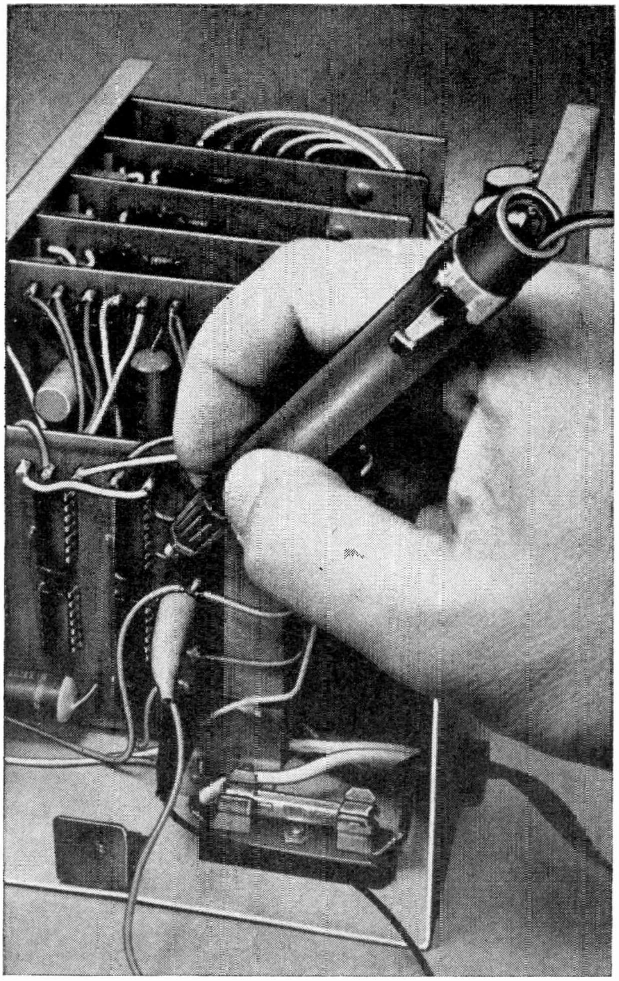
Then when *D1* again becomes forward biased on the next cycle of the applied a.c., *SCR1* cuts off, and the charge-discharge cycle repeats itself until the a.c. power is disconnected.

While the output of the VHV Supply is a.c., it can easily be converted to d.c. by installing a high-voltage TV (silicon) rectifier and filter capacitor across the high-voltage secondary of *T1*. However, if you do this, be careful to limit the value of *C1* to a small figure to prevent damaging the rectifier by high-current spikes when *C1* discharges. If an a.c. output is required, the value of *C1* can be anywhere between 2 and 100 μF, although the larger values will draw more current.

Construction. Parts location and orientation are left to your discretion when assembling the VHV Supply. However, since potentials on the order of 10,000 volts are developed by the supply, fully encapsulate all connections in a silicone potting compound after soldering. Then, for added protection, mount the entire circuit inside a perforated steel or aluminum cabinet.

When the supply is fully assembled, you can adjust the setting of *R1* for maximum output power. Then, if desired, the optimum setting of the potentiometer can be measured and a fixed ½-watt resistor substituted for it in the circuit.

Finally, if you wish to vary the output voltage above or below the designed 10,000-volt level, you can use an adjustable auto-transformer between the a.c. line and input of the supply. —30—



IC Telltale

Two-way system to check digital circuits

BY C. P. TROEMEL

THE INCREASING use of digital IC's in many experimenters' projects has created a need for a low-cost in- or out-of-circuit tester for these complex semiconductor devices. Up to now, most experimenters have done their best using a conventional voltmeter to trace the on-off signal on a circuit board. This is a difficult process at best. Making contact with a narrow foil strip and looking at a meter at the same time is trouble enough, but most of the time the pulses are so short that they don't even register on the meter. It is even more difficult to test IC's that are not connected into known operating circuits.

The "IC Telltale" described here was designed to solve many of these testing problems. It will test, in or out of the circuit, the RTL (resistor-transistor-logic) IC's such as the Motorola MC700P series and the Fairchild μL900 series that are used in a number of projects such as that on page 37.

The IC Telltale consists of two assemblies: a 10,000-ohm input-impedance probe for checking IC's mounted on a circuit board; and a test set with a built-in 2- and 10-Hz trigger pulse generator with 14-pin in-line and 8-pin round IC sockets for out-of-circuit tests. The oscillator circuit in the test set can also be used as a trigger source for finished IC boards, if desired.

The readout is built in the probe and consists of a small pilot lamp that is on when the logic is at, or near, ground level and goes "off" when the logic is at, or near, +3.6 volts. The probe can be used to trace a digital signal through foil patterns and integrated circuit connections.

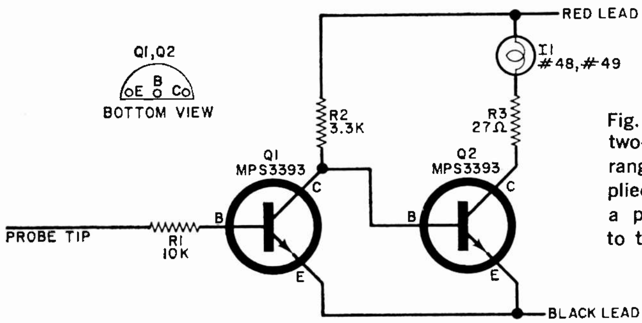


Fig. 1. The probe is a simple two-transistor lamp driver arrangement. With no signal applied, the lamp is lit. When a positive voltage is applied, to the tip, the lamp goes out.

PARTS LIST

I1—2-volt, 50-60-mA pilot lamp (#48, #49, or similar)
Q1,Q2—Transistor (Motorola MPS3393)
R1—10,000-ohm, ½-watt resistor
R2—3300-ohm, ½-watt resistor
R3—27-ohm, ½-watt resistor
Misc.—Plastic tube or felt-tip marker pen ½" inside diameter; 1½"-long brass screw with lockwasher and nut; flexible test leads 18" long (one red, one black); small alligator clips; insulation.

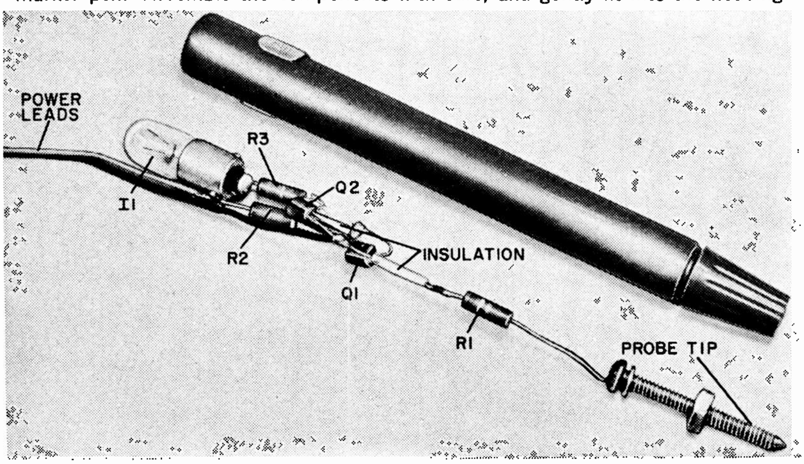
Probe. The electronic part of the probe (Fig. 1) is assembled to fit inside a plastic tube whose inside diameter is just large enough to hold the pilot lamp, *I1*. The author used the empty plastic case of a large cheap felt-tip marking pen.

If you use a similar case, take out the insides and clean it thoroughly. Use a #27 drill to enlarge the hole at the pen tip so that it will pass a 6-32 screw. Place a nut on a 1½" 6-32 brass screw about ¾ of the way down its length. Using a file, make a sharp point of the end of the screw. The nut, which will secure the finished probe within the pen, will clean the threads as it is removed.

Lay all the probe components beside the pen case as shown in Fig. 2. Trim the component leads and assemble the circuit, making sure that you don't exceed the inside diameter of the plastic case. Use insulating tubing on leads where required to prevent accidental shorts. Note that the indicating lamp does not require a socket and the leads are soldered directly to its base.

When you have the components assembled, slide them into the case from the rear until the pointed end of the screw comes out as far as possible. Use a lockwasher and the 6-32 nut to secure the screw to the case. Be sure that you

Fig. 2. The complete probe is housed in a plastic tube, in this case, an old felt-tip marker pen. Assemble the components with care, and gently fit into the housing.



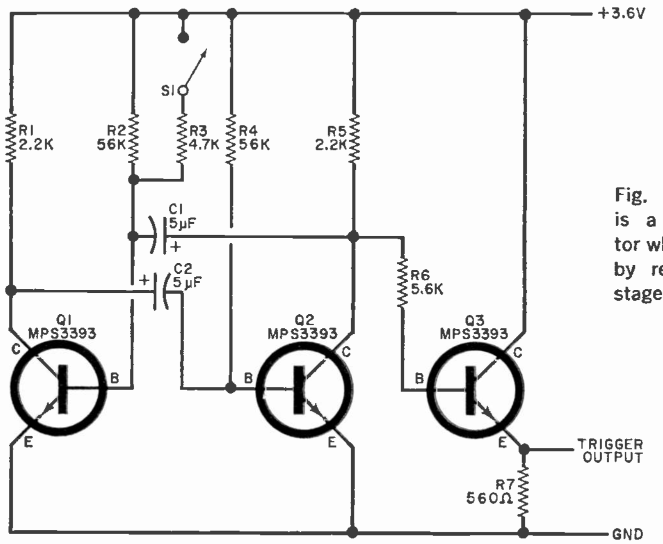


Fig. 3. The trigger generator is a conventional multivibrator whose frequency is changed by resistor variation. Output stage is an emitter follower.

PARTS LIST

C1,C2—5-µF, low-voltage electrolytic capacitor
Q1,Q2,Q3—Transistor (Motorola MPS3393)
R1,R5—2200-ohm, ½-watt resistor
R2,R4—56,000-ohm, ½-watt resistor
R3—4700-ohm, ½-watt resistor
R6—5600-ohm, ½-watt resistor
R7—560-ohm, ½-watt resistor
S1—S.p.s.t. switch
Misc.—5¼" x 3" x 2⅛" enclosed metal box (Bud CU2106-A or similar); 8-pin IC socket (Cinch-Jones 8-ICS, Allied #47D0155 or similar); 14-pin in-line IC socket (Augat 314-AG5D-2, Allied #47D6225 or similar); spring-clip terminals (Vector T30N2, 12 needed); three lengths of color-coded flexible test leads; three small alligator clips; small rubber grommet; 2" bare stiff wire; mounting hardware; etc.

do not rotate the screw as this may break the solder connection to it. The lamp should be slightly recessed within the pen case so that it is protected and yet can still be seen. The two flexible test leads (red for positive and black for ground) can be brought out of the probe beside the lamp. These leads can be a couple of feet long if desired (18" is about ideal) and should be terminated with small alligator clips.

To test the probe, connect the black lead to ground and the red lead to a

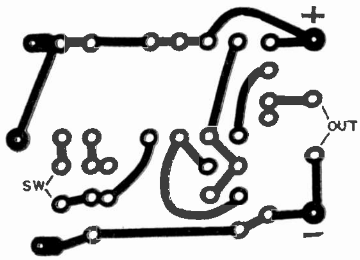


Fig. 4. Actual-size foil pattern for the oscillator.

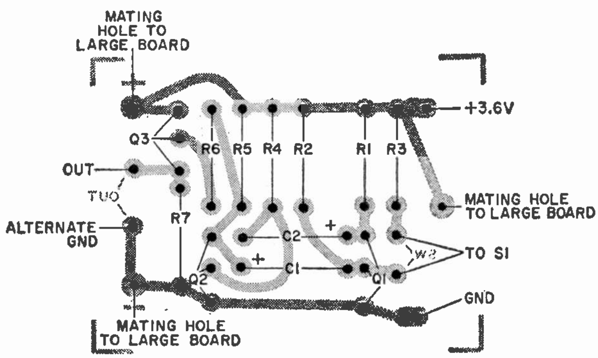


Fig. 5. Component installation on the oscillator board. This board is supported from the large board by three stiff wire leads whose locations are also shown here. Two of these leads carry the power supply.

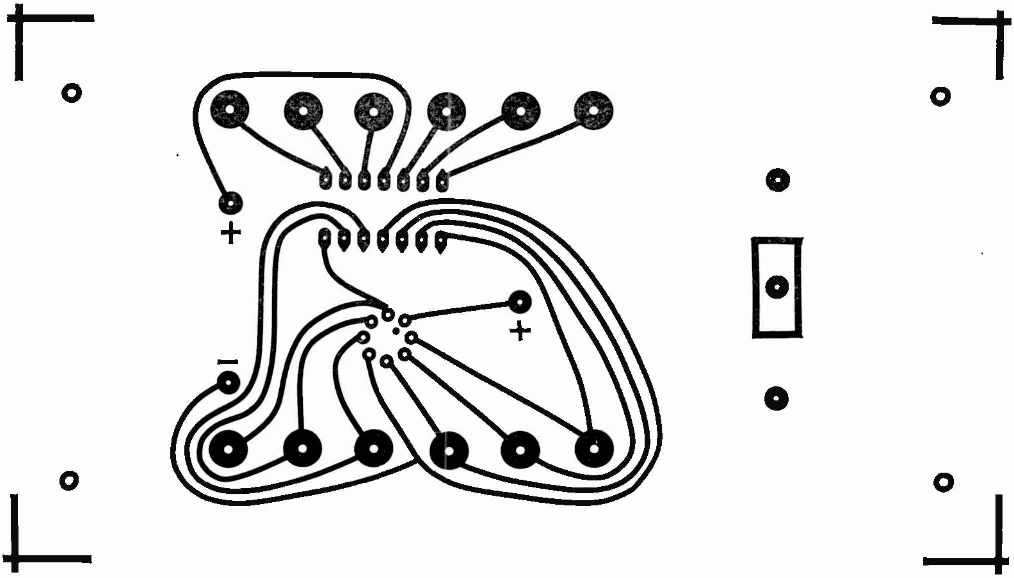


Fig. 6. Actual-size foil pattern for the socket-contact board. Switch S1 cutout and mounting holes are dependent on the particular switch you are using.

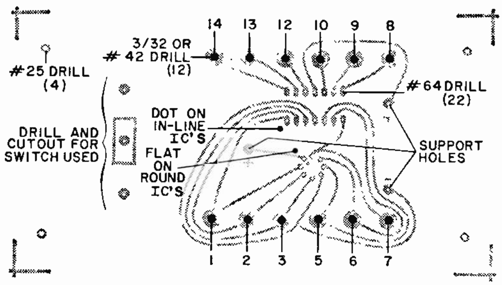


Fig. 7. Parts layout for the socket-contact board. Note the three support holes for oscillator board.

source of 3.6 volts (the same voltage used for the IC circuit). The lamp should glow and be plainly visible at the top of the probe. Touch the probe tip to the 3.6-volt source and note that the lamp goes off. If the lamp either doesn't light or doesn't go off when it is supposed to, remove the circuit from the probe and check for accidental shorts that may have occurred during assembly.

Test Set. There are two circuit boards in the test set: an oscillator and a socket-contact board. The oscillator section, whose schematic is shown in Fig. 3, is assembled on the PC board with the foil pattern shown in Fig. 4. Mount the components on the board as shown in Fig. 5.

To test this circuit, connect the board to ground and +3.6 volts at the indicated places and connect an oscilloscope across the OUT terminals. Depending on the position of *S1*, you should see either a 2-Hz or 10-Hz pulse train.

Make the socket-contact board using the foil pattern shown in Fig. 6. Solder the 12 spring-contact terminals and the two IC sockets in place as shown in Fig. 7. Looking at the top (non-foil) side of the socket-contact board, orient the 8-pin round socket so that pin 8 (identified by a small projection on the socket) is in the position shown in Fig. 7. Make some sort of marks on the board to identify pin 8 and to identify the dot and notch end of the in-line socket. At the same time, mark the LOW and HIGH frequency positions for switch *S1*. The hole for this switch can be cut to fit the switch used.

The oscillator board is mounted on the socket-contact board using three pieces of stiff wire about ½" long. Insert the three wires in the indicated holes on the smaller board (Fig. 5) and solder them in place. Insert the other ends of these wires in the appropriate holes in the larger board and solder them in place. Clip any excess wire from the top of the board. Connect *S1* to its leads.

On the upper surface of the metal chassis, cut out a rectangle 4" by 2" so that the larger board can be mounted within the chassis and secured with appropriate hardware at each corner. Drill a hole in one end of the chassis to accept a small rubber grommet. After tying them in a knot to provide a strain relief, pass the three test leads from the smaller board through this grommet. Attach a small alligator clip to the end of each lead. Use a black lead for ground, red for + and another color for trigger.

Assemble the cover on the metal chassis. Using some type of marker, identify each spring clip on the metal lip adjacent to it, as shown in the photograph. Note that pins 4 and 11 are missing since they are connected internally.

HOW IT WORKS—PROBE

Transistors *Q1* and *Q2* form a high-gain current amplifier using *R1* to limit the input base current to *Q1* and prevent loading of the IC being tested. When *Q1* is cut off, with the input either grounded or left floating, current through *R2* saturates *Q2*. Resistor *R3* reduces the voltage supplied to lamp *I1* when *Q2* saturates.

When the input to *Q1* exceeds about +0.6 volt, *Q1* conducts and removes the base drive from *Q2*, cutting off this stage and extinguishing *I1*.

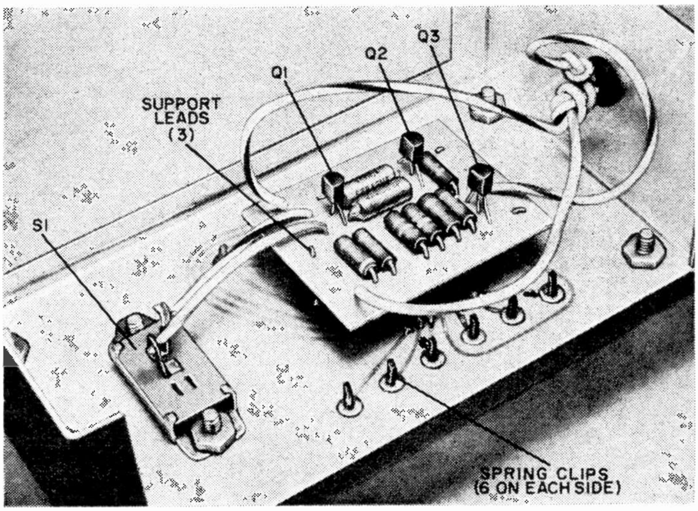
Since most RTL (resistor-transistor-logic) IC's require more than 0.8 volt to guarantee turn on and less than 0.46 volt to turn off, the 0.6-volt threshold of the IC Telltale falls in the correct place to indicate the state of the input or output.

In-Circuit Tests. To check IC's on a finished board, apply the required d.c. power to the board (usually +3.6 volts) and introduce a trigger signal. If you have no trigger source available, connect the black lead of the test fixture to the PC board ground and the red lead to +3.6 volts. Connect the test fixture output lead to the PC board's input terminal. Switch *S1* can be in either the LOW or HIGH frequency position.

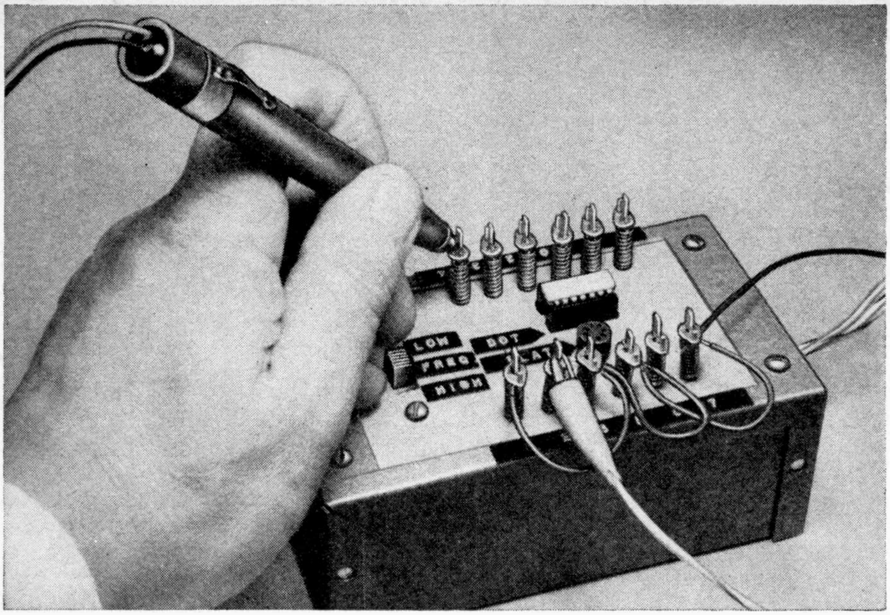
Connect the black lead from the probe to the PC board ground and the red lead to +3.6 volts. The probe lamp should be on. Check for the presence of +3.6 volts at the IC (usually pin 11 of the in-line type and pin 8 of the TO-5 can). When the probe makes contact with +3.6 volts, the lamp should go out. If it doesn't, check back along the foil pattern and locate any break. Note that, when using the probe, it isn't necessary to watch the lamp directly as it is in your line of vision when your attention is on the probe tip. Since the lamp stays on when the probe tip is grounded, it is also possible to check the ground pattern of the foil.

Once it has been determined that the positive d.c. and ground are correct, place the probe tip on the signal input terminal and observe that the lamp blinks on and off in step with the applied trigger signal. It is easier to see the lamp blinking if *S1* is in the LOW frequency position. You can now trace the trigger signal directly to the IC terminal.

When checking flip-flops, observe that the signal at the output (1 or Q, 0 or Q) is usually at a slower rate than the applied trigger. Using the probe and a schematic of the circuit board, it is possible to trace the path of the signal and



Interior of a completed test set. The three leads (one for positive, one for ground, and one for trigger output) are knotted to provide a strain relief, before being passed through the rubber grommet.



When testing an IC out of the circuit, plug it into the proper socket, make the connections called for in the test table, apply power, and use the probe to test device operation.

TEST TABLE FOR IC'S* OUT OF CIRCUIT

Function	Input				Output**	
Inverter	signal				blinks	
Gate	all gnd				off	
	any +				on	
	one to signal, others to gnd				blinks	
Flip-flop	Reset	S	T	C	1 or Q	0 or $\overline{Q}$
	gnd	gnd	signal	gnd	blinks	blinks
	gnd	+	signal	gnd	off	on
	gnd	gnd	signal	+	on	off
	gnd	+	signal	+	on or off	
	+ then gnd	gnd	gnd	gnd	on	off

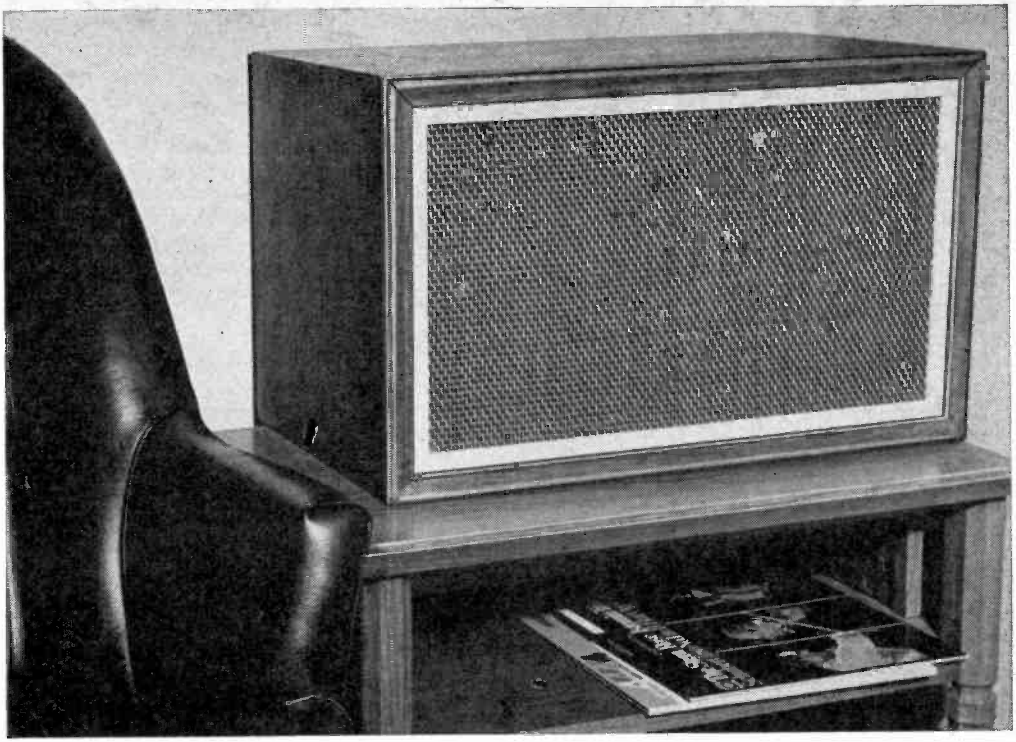
**For Motorola MC700P and Fairchild μL900 series IC's.*
***As indicated by probe lamp.*
+Indicates +3.6 volts.

note where the signal stops (if the board is faulty). If a number of flip-flops are involved (as in a countdown circuit), the probe lamp will blink more slowly as you move down the chain. In this case, place *S1* in the HIGH frequency position to speed up the counting. You can trace the signal through gates or inverters by observing the presence of signals at the inputs and output.

Out of Circuit Tests. To test unmounted (loose) IC's, remove the power from the test fixture and insert the IC in its socket, observing the notch and dot code on in-lines and the flat, tab, or color dot on round IC's.

The only direct connections to the IC's are +3.6 volts to pin 11 of the in-line and pin 8 of the round socket and ground to pin 4 of both types. The rest of the contacts to the IC are made through the 12 spring clips.

Apply power to the test fixture by connecting the black test lead to ground and the red test lead to a source of +3.6 volts. Test the IC using the accompanying table as a guide. Use small lengths of insulated wire with bare ends to make any necessary interconnections. The two-speed oscillator built into the test fixture serves as the signal source. -30-



BUILD THE THRIFTY 3-WAY

FULL-RANGE HI-FI SPEAKER SYSTEM FOR $35

BY DAVID B. WEEMS

IF YOU THINK a "full-size" compact three-way speaker system has to be expensive, you're wrong. By doing most of the work yourself—putting together a sturdy cabinet and winding a couple of coils—you can be in business for $35.00 or less.

The "Thrifty Three-Way" speaker system described here is built around an unusually designed 12" woofer. The woofer has a "poly foam" suspension that brings its free-air resonance down below 25 Hz. According to the manufacturer, the woofer's suspension will not harden with the passage of time as do conventional "accordion" type suspensions. (Tests conducted by the author show that the suspension is also not affected by changes in humidity.)

Build an enclosure, add a midrange speaker, a tweeter, homemade crossover networks, and you have a real money saver. The frequency range and performance of the system are similar to these of much more expensive 3-way systems. And the midrange and tweeter controls, refinements not found in bargain systems, allow you to adjust the system response to suit your listening tastes.

Enclosure Assembly. The enclosure can be assembled with the aid of common hand tools if you can get your lumber yard to miter the joining edges of the top, bottom, and side plates of the enclosure at 45° angles. Then, referring to the three-dimensional drawing provided

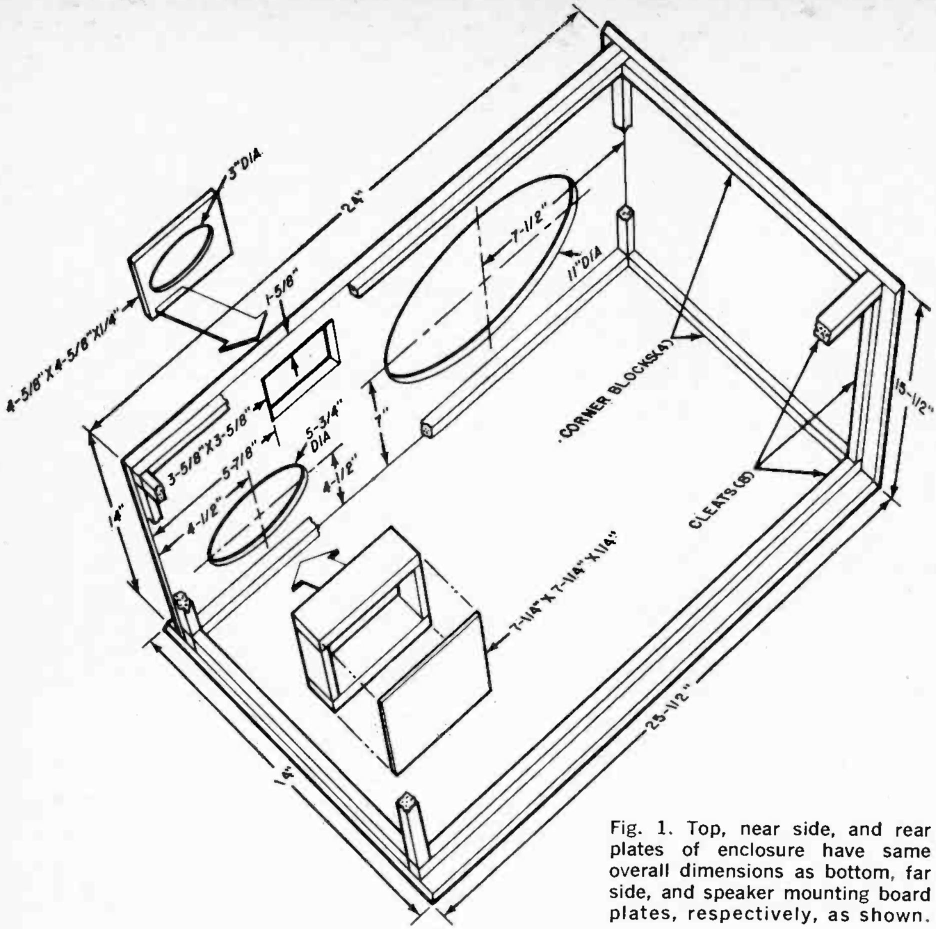


Fig. 1. Top, near side, and rear plates of enclosure have same overall dimensions as bottom, far side, and speaker mounting board plates, respectively, as shown.

in Fig. 1, prepare the main enclosure's rear plate, speaker mounting board, and cleats and corner blocks. (Note: Only one side, the bottom, and the speaker mounting board are illustrated in the drawing. The remaining side is the same size as the side shown; the same applies to the rear and top plates, which are identical in size to the speaker mounting board and bottom plate respectively.)

Before starting assembly, it is a good idea to drill the screw guide holes through the cleats and corner blocks. For the corner blocks, drill the holes through in both directions, while for the cleats drill in only one direction.

Now select one of the long plates for top or bottom, and glue and screw a long cleat in place ¾″ in from the rear edge. Measure 1⅝″ in from the front edge, draw a line along this mark, and glue and screw the other long cleat's outer edge along the line. Now, glue and screw the two 10″ corner blocks along the edges of the short sides of this plate.

Proceed with assembly by gluing and screwing the other three plates together, framing each with the appropriate cleats and corner blocks as you go. Set the assembly aside to allow the glue to set.

Meanwhile, prepare the speaker mounting board, tweeter mounting board, and midrange speaker enclosure as shown. The midrange speaker enclosure is made up of lengths of pine (sides) and a ¼″ plywood back plate (see Bill Of Materials for dimensions). After preparing the tweeter mounting board, chamfer the outer edge of the speaker cutout to remove any sharp edges.

Apply glue to the front surfaces of the midrange speaker enclosure, and sym-

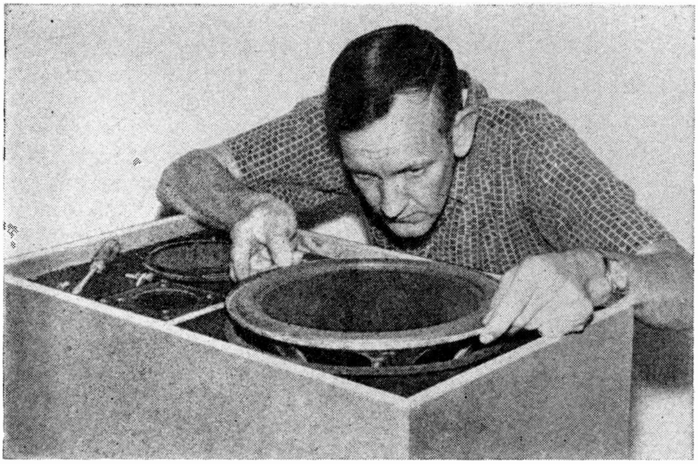


Fig. 2. To insure proper air seal, be sure to place rubber, felt, or other adequate gasket material between speaker rims and speaker mounting board.

metrically locate the enclosure over its hole on the speaker mounting board. Now, anchor the enclosure in place with screws driven from the front of the speaker mounting board into the sides of the enclosure.

Apply a coat or two of flat black paint to the front surfaces of the tweeter and speaker mounting boards. Then sand and stain or paint the outside surfaces of the previously prepared assembly. When both assemblies are dry, drop the speaker mounting board into place, and anchor it down with screws and glue.

Now, peel off the backing from a length of foam rubber weather strip, and carefully press it down around the woofer cutout, bending it as necessary to form a circle. Do the same for the midrange speaker cutout. The speakers are front mounting types, so the weather stripping must be placed on the front surface of the speaker mounting board.

Next, install the tweeter on its board, and solder a 3' length of zip cord to its lugs (do NOT bypass the capacitor). Then mount the speaker board assembly symmetrically over the square cutout in

BILL OF MATERIALS

1—12" woofer* (No. 12RUB 16-8)
1—6½" Cinaudagraph "Special Design" midrange speaker* (No. C-6-1½MR)
1—Cinaudagraph "Special Design" tweeter* (No. TS 6070)
1—25-µF nonpolarized capacitor for C1
1 lb—#18 magnet wire (Belden No. 8075 or similar)
2—8-ohm L-pads (Calrad No. LP-8 or similar)
2—25½" x 14" pieces of ¾" plywood for top and bottom of enclosure (sides only are miter cut)
2—15½" x 14" pieces of ¾" plywood for sides of enclosure (sides miter cut)
2—24" x 14" pieces of ¾" plywood for speaker mounting board and rear of enclosure
1—4⅝" x 4⅝" piece of ¼" plywood for tweeter mounting board
1—7¼" x 7¼" piece of ¼" plywood for rear of midrange speaker enclosure
1—8" x 2¼" piece of ½" plywood for crossover network
2—7¼" x 1⅝" pieces of ¾" pine } midrange enclosure sides
2—5¾" x 1⅝" pieces of ¾" pine } midrange enclosure sides
4—24" pieces of ¾" x ¾" pine for top and bottom cleats at front and rear
4—12½" pieces of ¾" x ¾" pine for side cleats at front and rear
4—10" pieces of ¾" x ¾" pine for corner blocks
1—7' length of ¾" x ¾" pine for grille frame
1—7' length of 1⅜" x ¼" plain trim for grille frame
1—7' length of 1⅛" channeled "cabinet" molding
2—1½"x1" diameter wood dowels for coil forms
4—2¼" x 2¼" pieces of ⅛" Masonite for coil forms
1 box—#8 x 1¼" flathead wood screws
1 doz—#8 x ¾" flathead wood screws for tweeter mounting board and rear of midrange enclosure
8—#12 x 1" panhead screws for woofer
4—#8 x 1" panhead screws for midrange speaker
1 roll—10' x ⅜" x 3/16" sponge rubber weather strip tape for speaker gaskets
6—#8 x ¾" brass screws for coil forms and crossover network mounting
2—#4 x ½" brass screws for terminal strips
1—2-lug terminal strip
1—4-lug terminal strip
Misc.—Grille cloth; glue; wire brads; zip cord; paint; stain; solder; fiberglass wool; sandpaper; etc.
*Speakers are available from McGee Radio Co., 1901 McGee St., Kansas City, Mo. 64108, for $19.95 (includes cost of 25-µF nonpolarized capacitor); stock numbers are given in parentheses above.

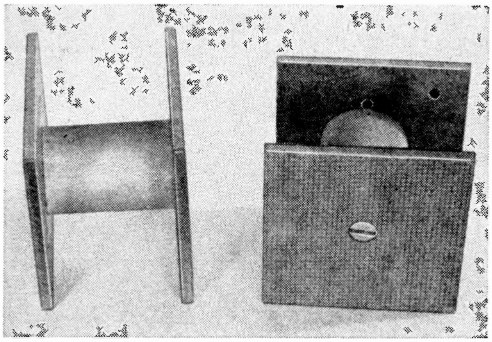


Fig. 3. Each Masonite section is $2\frac{1}{4}$" square by $\frac{1}{8}$" thick; wood dowel is $1\frac{1}{2}$" long by 1" diameter.

the speaker mounting board. Mount the midrange speaker and woofer in their respective holes, as shown in Fig. 2.

Drill two holes in the rear plate of the midrange speaker enclosure, and mount a conducting bolt, two solder lugs, and a machine nut in each. Solder the leads from the midrange speaker to the solder lugs, and mark the lugs connected to the wire near the red dot. Anchor the rear plate to the enclosure, using two screws to each side, and seal the joint with aluminized duct tape.

Solder a 3′ length of zip cord to the woofer's terminals and another 3′ length to the exterior solder lugs on the rear of the midrange speaker enclosure. This concludes the assembly of the basic enclosure.

Coil Assembly and Wiring. Fabricate the two coil forms according to the details provided in Fig. 3, using glue and screws for durability. When the glue sets, wind the coils. Coil *L1* (see Fig. 4) consists of 320 turns of #18 magnet wire, while coil *L2* consists of 128 turns of #18 magnet wire.

Start winding by feeding the free end of the wire through the hole in the coil form nearest the wood dowel. Then, layer wind the coil, working back and forth one layer at a time. When you have two layers wound, wrap with masking tape to prevent unraveling.

You will find that ten neat layers will suffice for *L1*, and four layers for *L2*. When each coil is fully wound, wrap two layers of masking tape over the windings, and bring the second free end of the

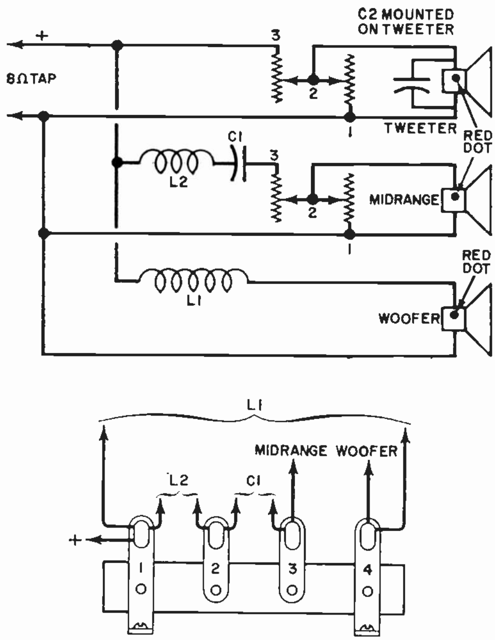
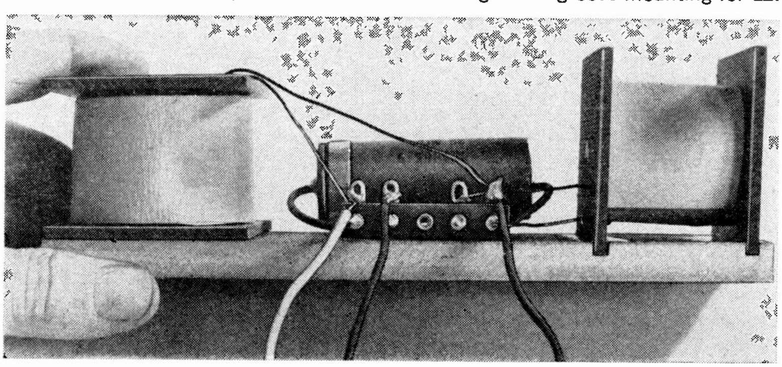


Fig. 4. Upper drawing is wiring diagram for entire system. Proper terminal strip wiring for crossover system is illustrated in lower drawing.

All elements in crossover network mount on a single board. From left to right are L1, C1 and terminal strip, and L2. Note use of tongue-and-groove mounting for L2.



wire out through the remaining holes in the coil forms. Scrape away about ½" of the insulating enamel from the free ends of the coil windings.

Now prepare the mounting board for the crossover network. This board can be any scrap piece of ½"-thick plywood or pine, cut to dimensions of 8" × 2¼". After cutting the board to size, set *L1* and *L2* on it as shown in the photo on opposite page, and mark the outlines of both coil forms.

Remove and temporarily set aside the coils. Then cut two ⅛" by about ⅛" grooves in the mounting board to accept the edges of the *L2* coil form. Glue both coils in their respective locations, and mount *C1* and a four-lug terminal strip on the mounting board.

When the glue sets, wire the crossover network together as shown in Fig. 4, and mount the assembly on the inside surface of the enclosure's rear plate. Drill two holes for and mount the tweeter and midrange speaker controls on the enclosure's rear plate, and wire the controls to the crossover networks. Then finish wiring the system, carefully observing the proper speaker polarities so that the cones are all in phase.

Connect the fully-wired speaker system to your amplifier, turn on the amplifier, and set the volume control to a low level. Check to see that the crossover networks are working properly. If satisfied, disconnect the amplifier, and loosely

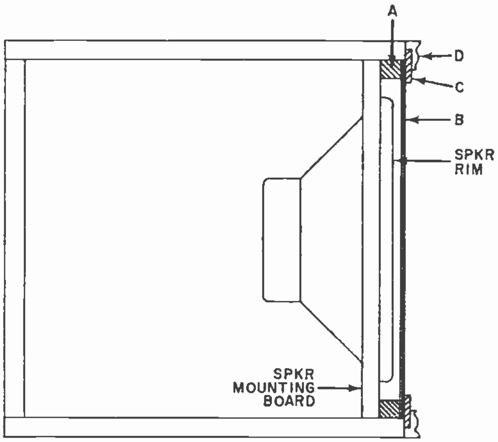
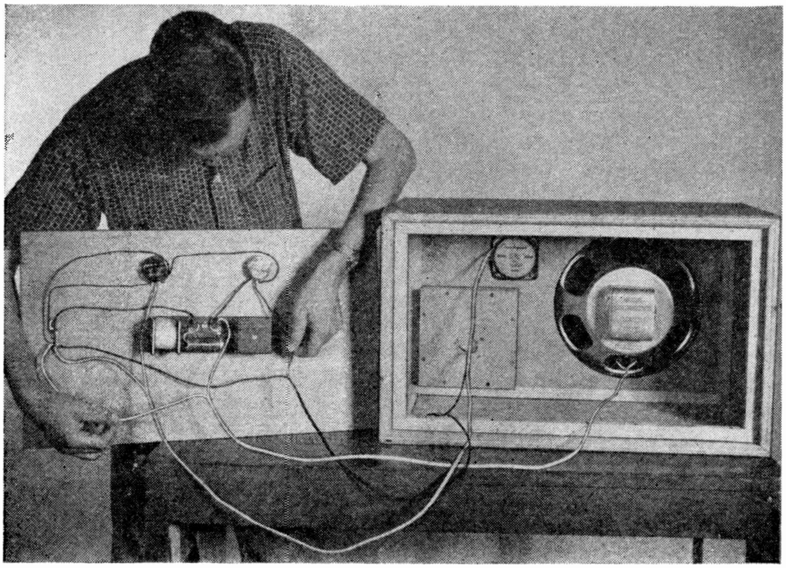


Fig. 5. In alphabetical order are the square pine frame, grille cloth, flat pine frame, and picture frame molding.

Photo shows correct placement and orientation of all system components. Tweeter and midrange controls are at top of rear plate of enclosure (left in photo).



THRIFTY 3-WAY

(Continued from preceding page)

fill the enclosure with fiberglass wool. Screw on the rear plate of the enclosure.

Finishing Touches. The front mounting speakers require that the enclosure employ a removable grille cloth to provide access to the speakers. Also, the grille cloth must be spaced about ¾″ away from the front surface of the speaker mounting board to clear the speakers.

One way to maintain the proper spacing between the speakers and grille cloth is illustrated in Fig. 5. First, construct a frame of ¾″ × ¾″ pine (A) just large enough to frame the front of the speaker mounting board and fit within the confines of the enclosure walls.

Next, cut the grille cloth (B) to size, stretch it, and tack it to the frame. Then fabricate another frame (outer dimensions approximately 24⅞″ × 14⅞″), using 1⅜″ × ¼″ plain pine molding (C). As with the walls of the enclosure, the ends of this second frame should be miter cut at 45° angles. When properly constructed, paint or stain this second frame; a good color is white for contrast.

Nail the second frame symmetrically over the first frame and grille cloth, using wire brads. At this point, the second frame should overhang the first frame by about ⅜″ on all sides.

Finally, miter cut the decorative "cabinet" molding to form a frame 25½″ × 15½″ (the same size as the enclosure). Stain and finish the decorative molding, and symmetrically glue it onto the second frame. Now, set the grille assembly into place in the front of the speaker enclosure. The fit should be a little tight to hold the assembly firmly in place. However, if the fit is too loose to accomplish this, remove the grille assembly, and add as many layers of tape to the ¾″-square frame to make a friction fit.

That's it! Construction is complete, and now all you have to do is connect the "Thrifty Three Way" to your amplifier, start a disc whirling, and adjust the tweeter and midrange controls to complement the acoustics of your listening room. Now sit back and enjoy the sound. -30-

DARKROOM TIMER

(Continued from page 15)

the SCR specified, the value of *R6* may be increased if there is not enough gate drive. Also, the value of *C16* may be increased if *SCR1* has a tendency to turn on by itself.

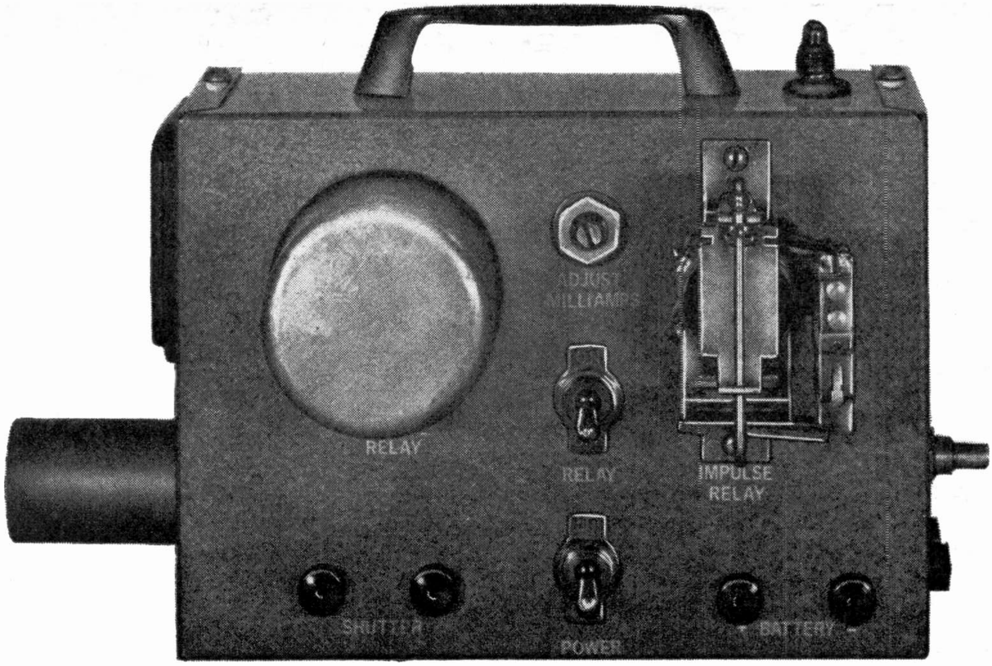
Application. When the SECONDS (ones) switch is set to any position other than 0, add the indicated time to that of the SECONDS (tens) switch. Then apply the multiplier selected by the MULTIPLIER switch.

Socket *SO4* (SAFE LIGHT) provides automatic turn on of a safe light when the timing has been completed. If manual turn on of the safe light is required, connect the safe light to *SO5* (INSTANT OFF). The safe light will then be on when *S2* is on RESET and will automatically go off when *S2* is turned to TIME. The safe light will not come on after timing. The Table shows when power is applied at each outlet.

If the load current exceeds six amperes, use a suitable external power relay controlled by the desired outlet. In other than photography use, such as a universal motor load, plug an a.c. line noise filter into the selected outlet if line noise becomes severe.

Optional Equipment. Footswitch operation of the timer is possible in the ENLARGER mode through a remote switch in series with the a.c. line cord and with *S1* set to ON and *S2* to TIME. This, however, sacrifices the safe light mode, inactivates *SO5* (INSTANT OFF), and alters the mode at *SO1* (DELAYED OFF). Reset, though no longer instantaneous, takes place in less than one-half second when the footswitch is opened.

It is possible to use a momentary-on footswitch, which gives a push-to-time operating mode while maintaining foot pressure during the timing period, or a switch which alternately latches between on and off. The latter requires an extra switch operation for reset. The timing is not altered to any practical extent. -30-



BUILD AN Electronic Shutter Control

TAKE NIGHTTIME NATURE PHOTOS

BY WALTER B. FORD

ELECTRONICS has always been an important factor in the development of new hobbies and the improvement of old ones. Photography, in particular, has benefited tremendously through the use of electronic devices that make photographic equipment and techniques more accurate, more flexible, and easier to use under adverse conditions. As an example, with the aid of a few relays and a solenoid, you can build an "Electronic Shutter Control," that will enable you to get into the fascinating field of nighttime nature photography.

The Shutter Control operates on the electric-eye principle; the subject to be photographed breaks an almost invisible beam of light to a photo-cell, triggering the shutter and taking his own picture. Once the system is tripped, a signal light that can be seen from hundreds of feet away goes on and a relay simultaneously shuts down power to the system. The power disconnect feature is a real battery saver—especially if you plan to leave the system unattended overnight.

How It Works. Power is applied to the Electronic Shutter Control circuit through *J1* and *J2* in Fig. 1. With both *S1* and *S2* closed, the beam from control light *I1* is directed at *PC1*, causing the resistance of the photocell to reduce enough to allow *K1* to be energized. When *K1* picks up, its normally closed contacts open, depriving *K2* and subsequent circuits of power.

Now, when the control light beam to *PC1* is interrupted, *K1* is de-energized and power is applied to *K2*. This results in three simultaneous operations: *K2* is latched in through its lower contacts; a pulse is applied to shutter solenoid *L2*; and power is delivered to the heater of thermal relay *K3* through the upper contacts of *K2*. After a short interval, the contacts of relay *K3* close to complete the circuit through the solenoid of *K4*.

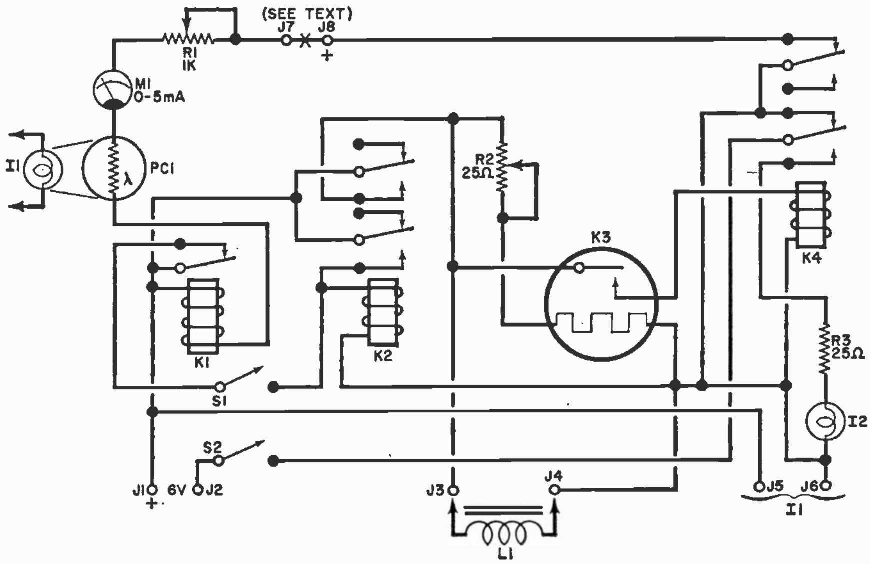


Fig. 1. Once system is tripped, relay operation is in numerical sequence. As K2 closes, it pulses shutter solenoid; K2 provides the power-disconnect feature.

PARTS LIST

I1—6-volt indicator lamp
I2—1.2-volt indicator lamp
J1-J8—Pin or banana jack
K1—2500-ohm d.c. relay (Sigma type 42)
K2—6-volt d.c., d.p.d.t. relay
K3—Thermal relay (Amperite type 6N02T)
K4—6-volt d.c., d.p.d.t. impulse relay (Potter & Brumfield No. PC11D or similar)
L1—6-volt d.c. solenoid (Dormeyer B24-255 A1)
M1—0-5-mA milliammeter
PC1—Photocell (General Electric No. B46)
R1—1000-ohm potentiometer
R2—25-ohm, 5-watt potentiometer
R3—25-ohm, 2-watt resistor
S1,S2—S.p.s.t. switch
Misc.—Flashlight; magnifying lens; 7" x 5" x 3" metal utility box for chassis; camera lens filter; nine-pin miniature tube socket; pin or banana jack (to match J1-J8, 8 needed); eight-pin octal socket; indicator lamp socket; 6-32 x 1½" flat-head brass machine screws; wood screws; epoxy cement; steel band; pine blocks; zip cord; rubber grommet; mailing tube; paint; hookup wire; solder; hardware; etc.

Relay *K4* is then energized, interrupting power to the other relays, turning *I1* off and *I2* on. The latter must be turned off manually.

Construction. It is recommended that you house the Electronic Shutter Control circuit in a sturdy metal chassis to protect it against damage in the field. While component placement (except for *PC1*) is not critical, the author suggests a layout similar to that shown in Fig. 2. Note

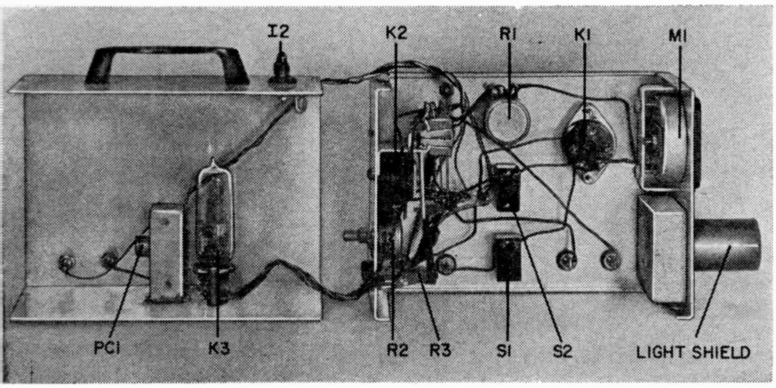


Fig. 2. In this prototype, relays K1 and K4 are mounted on outside of chassis to provide easy access. Interior parts mounting is arranged to avoid obstruction of the photocell.

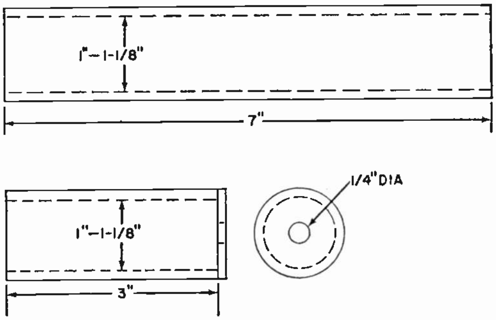


Fig. 3. Fabricate light shields illustrated here from mailing tube; note aperture disc on short tube.

that *K1* and *K4* are mounted on the outside of the chassis for easy access.

Begin construction by laying out and drilling the mounting holes for the various components. Then fabricate one or both of the light shields illustrated in Fig. 3. (The longer light shield is used for large-subject photography, while the shorter shield is best for subjects the size of a tarantula or smaller.) Select cardboard mailing tubes with 1″ to 1⅛″ *inner* diameter for the shields, and if you make both shields, use the same tube to insure uniform inner and outer diameters. Also, glue a cardboard disc through the center of which has been punched a ¼″ aperture over one end of the 3″-long shield. Then apply a coat of flat black paint to all interior surfaces.

Locate the center of the chassis cutout that is to accommodate the light shield 1¼″ above the base of the chassis and drill a hole through the chassis to match the outer diameter of the shields. Then drill the same size hole through a 2″-square by ¾″-thick pine block, and secure the block to the chassis with wood screws as illustrated in Fig. 4.

The magnifying lens which is to be cemented to the wood block as shown serves to concentrate and direct the light from *I1* onto *PC1*. This lens should be slightly larger than the diameter of the cutout in the pine block. The lens selected can be from a small reading glass, or you can order item No. 94,061 for 80 cents from Edmund Scientific Co., 600 Edscorp Bldg., Barrington, N.J. 08007.

When the cement securing the lens to the pine block has set, mount the components (except *PC1*) in place and wire them together. Then place the section of the chassis containing the lens on a flat surface, slip into place the long light shield, and aim the assembly at a light source a few feet away. Now, mount the photocell on a ¾″-square by 2″-long pine block (see Fig. 4).

Place the photocell-block assembly on a ⅛″ thickness of cardboard, and orient it behind the lens so that the concentrated beam of light from the light source just covers the entire frontal area of the photocell. Measure the distance from the side and front of the chassis to the block to determine where, on the other section of the chassis, *PC1* must be located. Then secure the photocell assembly to the chassis with a wood screw and epoxy cement, and solder the leads of *PC1* into the circuit.

The solenoid specified in the Parts List must be modified to operate the camera shutter. To accomplish this, drill a 5/32″ hole through the flat end of the plunger; then flatten the pointed end of the plunger with a file and drill and tap this end for a 6-32 machine screw (see Fig. 5 for details).

To facilitate mounting the solenoid and camera on a tripod, a bracket as illustrated in Fig. 6 must be fabricated from 1⅛″ × ⅛″ band steel The leg lengths of the bracket are not provided in the drawing since they will vary depending on the camera. The slots shown in the drawing provide a means for adjusting the solenoid position to apply proper shutter release pressure for a wide variety of cameras.

The control light shown in Fig. 7 is actually a modified two-cell flashlight, equipped with a No. 25 red camera lens filter, mounted on a 7″ × 5″ × ¾″ pine board. First, remove the batteries from

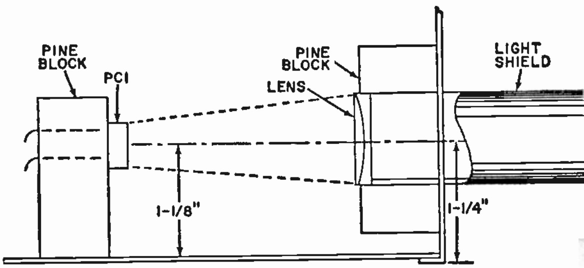


Fig. 4. Light shield, lens, and photocell must share a common axis with control light source.

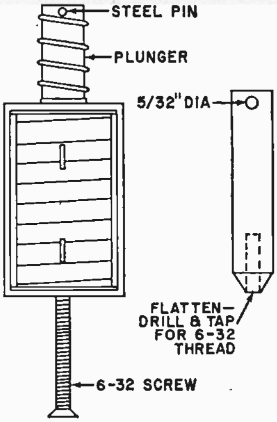


Fig. 5. For proper solenoid operation, plunger must be modified as shown at right.

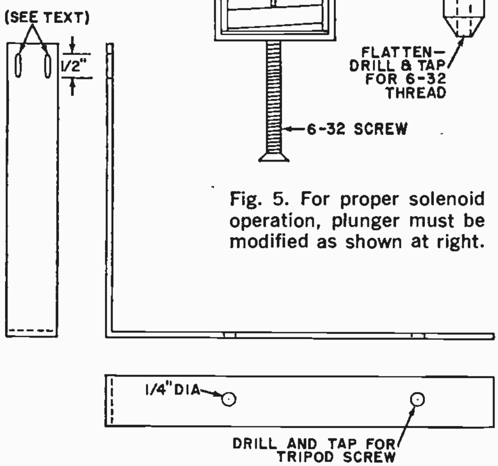


Fig. 6. Lengths of L bracket legs must be calculated for your particular camera; do not omit slots.

the flashlight. Then replace the original lamp with a 6-volt lamp of similar size, shape, and basing. Drill a ⅜″ hole through the end of the flashlight body, and place a rubber grommet in it. Now, insert one end of a length of zip cord through the grommet and connect one conductor to the base contact and the other conductor to the thread contact of the lamp.

As for the filter cell assembly, you can use a cardboard tube that fits snugly over the front of the flashlight as shown. The lens filter itself can then be glued to the tube.

How To Use. For the initial tryout, set up the camera, flash attachment, and Electronic Shutter Control in a semi-darkened room. Place *S1* and *S2* in the OFF positions, and connect a standard 6-volt battery—such as a motorcycle or an automobile battery—through *J1* and *J2*. Next, connect control light *I1* via *J5* and *J6* and shutter solenoid *L1* via *J3* and *J4*. Finally, short-circuit *J7* to *J8*.

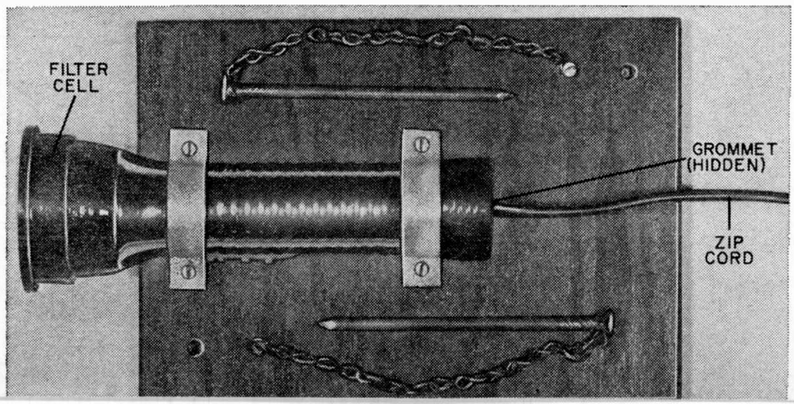
Set *S2* to the ON position (if *I2* comes on, manually reset *K4* until it extinguishes). Place the control light with the filter in place about 4′ away from *PC1*, directing the beam onto the photocell. Meter *M1* should now indicate maximum current flow. Now, without disturbing *R1* from its zero-resistance setting, adjust the armature of *K1* until the contacts just close. Then slowly rotate the shaft of *R1* until the contacts just open, and observe and record the milliammeter reading at this point. Reset *R1* to zero resistance. The minimum meter reading will be helpful in determining the maximum separation between *I1* and *PC1* in future setups.

Should it be desired to separate the control light and photocell by more than about 6′, it is suggested that you remove the short-circuiting jumper from across *J7* and *J8* and connect one or two 1.5-volt D cells in its place.

With the control light directed into the light shield, turn *S1* on and cover the front of the shield with your hand. This interrupts the beam, and if all systems are go, the shutter solenoid should actuate immediately, and about a second later *I2* should turn on.

To reset the control system, first set *S1* to OFF and then depress the armature lever of *K4* to extinguish *I2*. Now close *S1*, and the system is set for another photograph. —30—

Fig. 7. Modified flashlight with filter assembly fitted to lens serves as housing for I1. Zip cord terminates in plugs that match J5 and J6 on main relay chassis.



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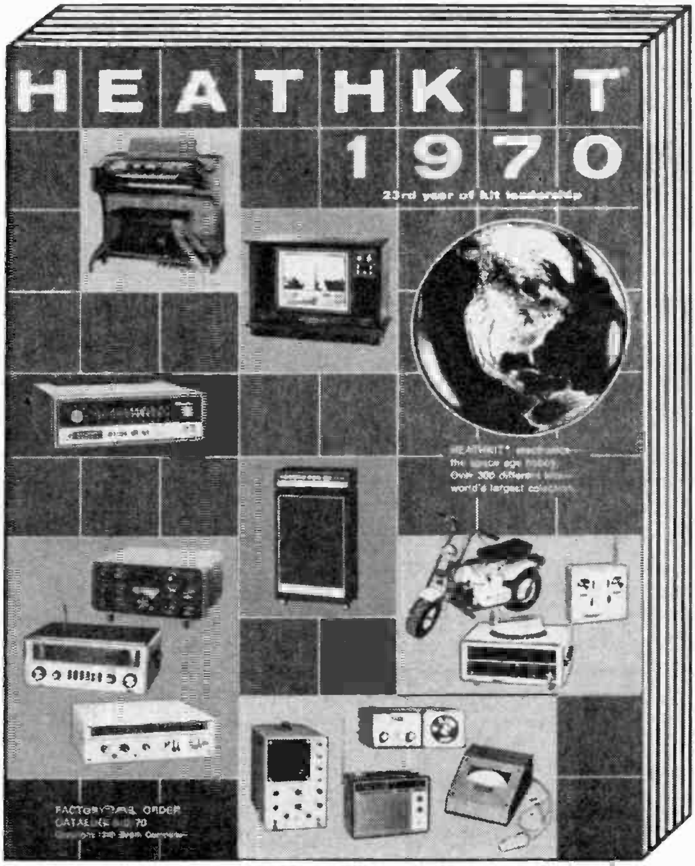

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CIRCLE NO. 7 ON READER SERVICE CARD

Build a HAPPY HYBRID

TEN WATTS FROM TUBES AND TRANSISTORS

BY DEE LOGAN, WB2FBF

IT'S NO disgrace to operate the 40-meter band with a low-power rig—in fact, many veteran hams use flea-power transmitters just to see how well they can do. The secret, of course, is knowing when and how to operate.

The "Happy Hybrid" is a low-cost, low-power 40-meter transmitter that should interest both newcomer and veteran ham. It combines a voltage-regulated transistorized crystal oscillator and buffer, coupled to a compactron vacuum tube containing both buffer and final amplifier. Despite its small physical size, the rig delivers 10 watts of clean, crisp CW.

Using a conventional half-wave dipole antenna, this transmitter has made itself heard over 700 miles away with excellent signal reports. By choosing your operating time with care, even greater distances can be reached.

A built-in power supply (see Fig. 1)

PARTS LIST

C1—68-pF silver mica capacitor
C2—82-pF silver mica capacitor
C3—110-pF silver mica capacitor
C4, C7, C8, C10, C11, C13, C14, C15—0.01-µF disc ceramic capacitor
C5, C6—100-pF silver mica capacitor
C9—5-50-pF trimmer capacitor
C12—0.001-µF disc capacitor
C16—325-pF variable capacitor (Hammarlund MC-325-M or similar)
C17—Dual 365-pF variable capacitor (both sections in parallel)
C18, C19—250-µF, 20-volt electrolytic capacitor
C20, C21—50-µF, 450-volt electrolytic capacitor
D1, D2—Silicon rectifier (GE A14F)
D3—9.1-volt zener diode (GE Z4XL9.1 or 1N1770)
D4, D5—1N5062 silicon rectifier diode
I1—6.3-volt pilot lamp (#44)
J1—Coaxial connector (SO-239)
J2—Phono jack
L1—30 turns #24 enameled wire on National XR-50 slug-tuned form
L2—20 turns #18 wire, 16 turns per inch, 1¼" diameter (B&W Miniductor 3019)
L3—7-henry, 50-mA choke (Stancor C1707 or similar)
M1—0-50-mA meter
Q1, Q2—2N3859 transistor
Q3—Thyrector (GE X14)
R1, R7—27,000-ohm, ½-watt resistor
R2—10,000-ohm, 1-watt resistor
R3—470-ohm, ½-watt resistor
R4—6400-ohm, ½-watt resistor
R5—3300-ohm, ½-watt resistor
R6—200-ohm, ½-watt resistor
R8—10,000-ohm, 5-watt resistor
R9—47,000-ohm, ½-watt resistor
R10—15,000-ohm, 10-watt resistor
R11—5.1-ohm, 1-watt resistor
R12—220-ohm, 1-watt resistor
R13, R14—20-ohm, 5-watt resistor
R15—100,000-ohm, 10-watt resistor
RFC1-RFC4—2.5-mH r.f. choke (National R-50 or similar)
S1—S.p.s.t. switch
T1—Transformer: sec, 460-0-460 V, 50 mA and 6.3 V, 2.5 A (Stancor PC-8418 or similar)
V1—6AD10 compactron
XTAL—7-MHz crystal
Z1—9 turns #16 wire on 1-watt, high-resistance resistor
Misc.—Masonite 4" x 6", metal chassis 3" x 7" x 12", crystal socket, transistor socket (2), 2-lug terminal strip none grounded (for Q3), multi-lug terminal strips, compactron socket, 7.5-watt lamp with socket and short length of coaxial cable and connector #12 bare copper wire, solder lugs, ¾" insulated standoffs, rubber grommets, mounting hardware, etc.

delivers filament, 9-volt, and B+ voltages using only one power transformer. Best of all, you can build the Happy Hybrid for about $25 if you salvage some odd parts from your junk box.

Construction. The Happy Hybrid is designed to be built in three stages: the oscillator, the power supply, and the r.f. amplifier. This method of construction permits you to test each section as it is built.

Oscillator. To make the oscillator board, cut a piece of pressed wood (masonite) into a 4" x 6" rectangle. Mount a ¾" insulated standoff at each corner,

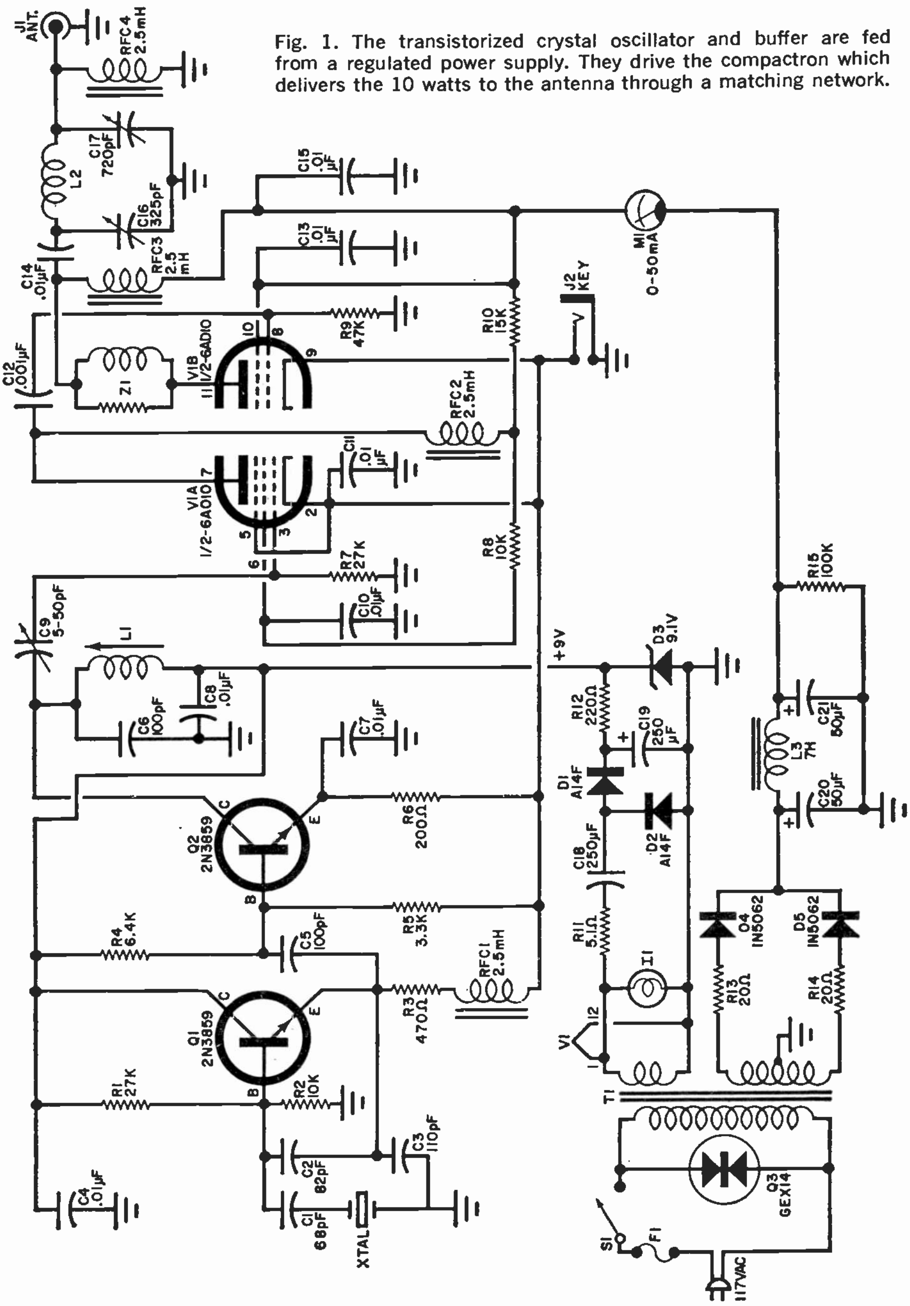


Fig. 1. The transistorized crystal oscillator and buffer are fed from a regulated power supply. They drive the compactron which delivers the 10 watts to the antenna through a matching network.

putting a solder lug between each standoff and the board. Run a length of #12 bare wire around the bottom edge of the board, attaching it to the solder lug at each standoff. This serves as a ground buss.

Mount the oscillator components as shown in Fig. 2, drilling holes in the board for each component. Use sockets for the transistors. Circuit wiring is point-to-point, with the component leads used where they are long enough. Use insulated hookup wire for the rest of the circuit. Be careful to dress all components and leads close to the board to avoid shorts when the board is mounted on the metal chassis.

Tank coil *L1* consists of 30 turns of #42 enameled wire on a National XR-50 slug-tuned form. A small piece of plastic electrical tape (or coil dope) can be used to secure the winding. Once installed in the circuit, check the resonant frequency of the coil with a grid-dip meter to make sure that it resonates in the 7-MHz band. You may have to trim the coil if a junk-box coil form has been used instead of the XR-50.

Besides the common ground connection, you will need a common tie point for the keying ground, one for the r.f. output of *C9*, and one for the 9-volt connection.

Once the oscillator is complete, install the crystal and transistors and connect a conventional 9-volt transistor radio battery between the 9-volt connection and the common ground. Test the oscillator by shorting the keying connection to ground and listening for the CW signal in a nearby receiver, tuned to the crystal frequency. Once the oscillator is working properly, put it aside and build the rest of the circuit in the metal chassis.

Power Supply. Power transformer *T1* and choke *L3* are mounted at the top rear of the chassis while power switch *S1* and pilot light *I1* are on the front apron. The keying jack, *J2*, can be placed anywhere you wish. Mount fuse holder *F1* on the rear apron of the chassis and use multi-lug terminal strips to mount the rest of the power supply components under the chassis near the transformer (see Fig. 3). When soldering the diodes in the power supply, use a long-nose pliers as a heat sink on the leads to avoid thermal damage to the semiconductors. Also, be sure to observe the cor-

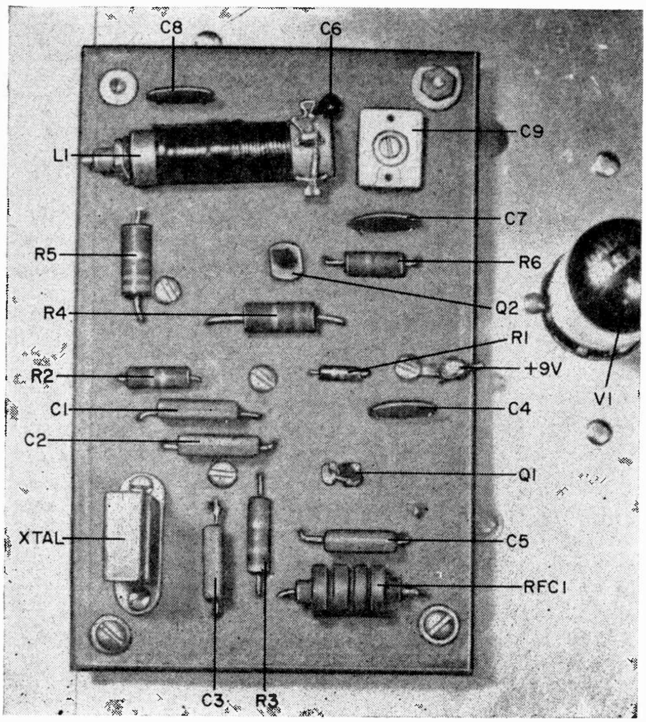


Fig. 2. The oscillator is built up perf-board style, using a piece of fiber board as the chassis. Interconnection is made via component leads or short pieces of wire. There are two different grounds, one for actual ground and the other for the keying lead. The +9 volts and the keying lead are passed through the metal chassis via a rubber grommet, as is the r.f. drive for the tube.

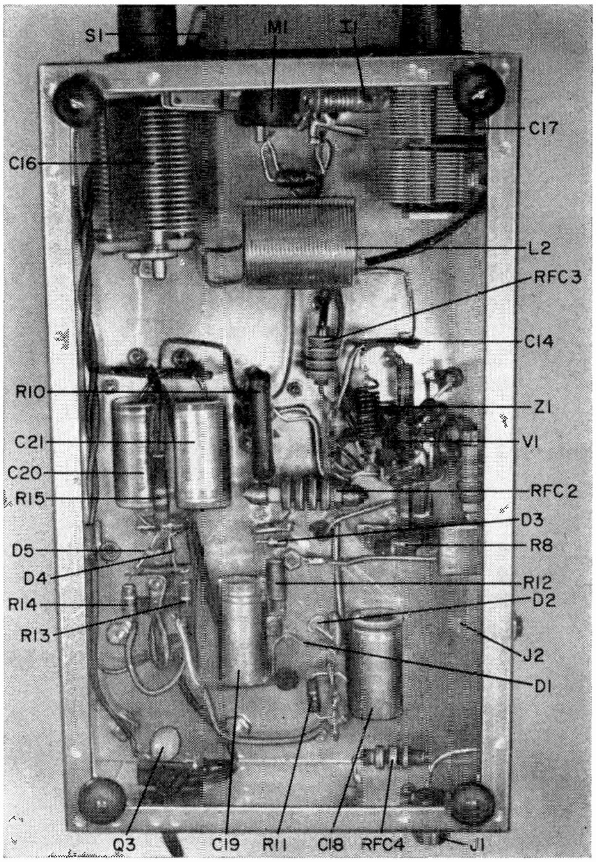


Fig. 3. Use good r.f. wiring practice when assembling the final amplifer and antenna circuit. Keep all r.f. leads as short as possible and use heavy wire from the plate of V1B to the antenna. Although the keying jack (J2) is shown at one side, it can be mounted anywhere.

HOW IT WORKS

The circuit consists of a two-transistor broad-band crystal oscillator and buffer (*Q1* and *Q2*) driving a vacuum-tube buffer and power amplifier (*V1*).

The oscillator is designed for broad-band operation with crystals in the 3- to 20-MHz range, with further experimentation possible on other amateur bands by modification of the tank circuit. The r.f. signal is generated in the circuit containing *Q1* and is buffered by *Q2* to raise it to a level sufficient to drive the vacuum tube. Trimmer capacitor *C9* is used to set the maximum driving level of the tube.

The first half of the tube, *V1A*, is a buffer pentode and the second is an amplifier which increases the signal level to feed the antenna through a pi-coupling network (*L2*, *C16*, and *C17*). This tank combination will match a fairly wide range of antenna impedances.

A conventional full-wave rectifier composed of *D4* and *D5* with associated filtering components supplies the B+ (about 250 volts) for the vacuum tube. The voltage from the filament winding of *T1* heats the filament of *V1* and is also applied to a doubler circuit (*D1* and *D2*) to generate a d.c. voltage high enough to avalanche the 9-volt zener diode, *D3*. This is the power source for the transistors.

Protection against incoming line transients that could damage the semiconductor components is provided by thyrector Q3, which effectively removes the spikes before they get into the power transformer.

rect polarities of the electrolytic capacitors and rectifiers diodes.

R.F. Section. There is nothing critical about the parts placement in this section but good pre-planning for tie points is important. The two pi-network variables (*C16* and *C17*) are mounted at the front of the chassis, as is meter *M1*. Put antenna connector *J1* on the rear apron of the chassis. Parasitic suppressor *Z1* is made by winding nine turns of #16 wire on a 1-watt resistor body. Although the resistor is used only as a coil form, it should not be too low in value or it will affect the operation of the suppressor—1000 ohms or more should do.

You can follow the author's layout of the tube socket and r.f. components, using good r.f. wiring practice. After all r.f. wiring has been completed, check the frequency of the pi network using a grid dip meter and adjusting the coil turns (if necessary) for proper frequency.

Connect the B+ to the r.f. section and the 9 volts to the oscillator board. Then make the oscillator circuit ground and connect the oscillator keying circuit to the r.f. keying circuit. Connect the two to the isolated terminal of *J2*. Check over the entire circuit for wiring errors, etc.

Before inserting *V1* in its socket, test the oscillator section. Plug a key in *J2*, turn the power on, and depress the key. You should hear a CW signal on a receiver tuned to the crystal frequency. Using a voltmeter, check the 9-volt supply to the oscillator. If it is less than 9 volts, reduce the value of *R12* slightly to get the right voltage.

Now listen to the signal on the receiver and, watching the S-meter, adjust trimmer capacitor *C9* to obtain a maximum signal. Release the key.

Using a standard socket and a short length of coaxial cable with the appropriate plug, connect a 7.5-watt light bulb to *J1*. This is the dummy load for testing. Insert *V1* in its socket and allow it to warm up. Set *C16* and *C17* to maximum capacitance (fully meshed) and close the key. The meter should indicate some current flow. Adjust *C16* until the dummy load glows and a dip occurs in the current meter reading. Slowly tune *C17* to increase the brightness of the lamp while re-adjusting *C16* for resonance (meter indication at minimum). When changes in *C17* no longer increase the brightness of the lamp, loading is correct.

Operation. For best results with the Happy Hybrid, be sure to use it with a well-matched half-wave dipole. Mismatching means that power meant for the antenna is lost in the pi network.

—30—

FREQUENCY COUNTER

(*Continued from page* 51)

Gate (M6) There should be a clean 60-Hz sine wave at the junction of *D1* and *R3* on this module (terminal 60 Hz). It should be offset with the negative peak at −0.7 volts and the positive at +2.4 volts.

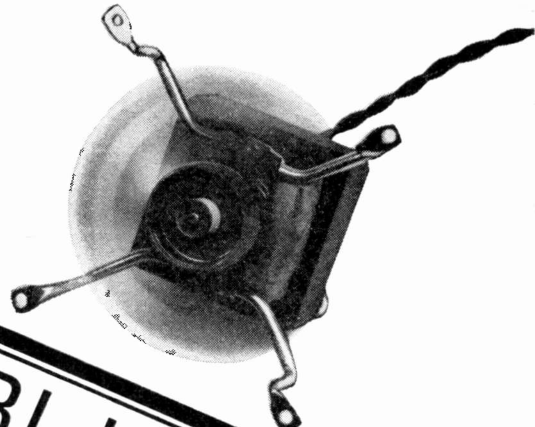
At pin 7 of *IC1* there should be a 60-Hz rectangular wave having 50-ns rise and fall times and an amplitude of about +2 volts. The output at pin 8 of *IC2* should be a 20-Hz rectangular wave with a 1:2 duty cycle and a 2-volt positive amplitude.

The 0.1 SEC output of this module should be a symmetrical, positive-going wave at 0.1 second, with 50-ns rise and fall times. The 10 SEC output should be positive for 10 seconds and ground for 10 seconds.

Reset. The reset buss (RST on all modules except *M2*) is at ground most of the time. Depressing the front panel RESET switch should raise the level of the buss to about 1.6 volts and all DCU's should promptly return to a zero indication. Also during normal operation, there is, on the reset buss, a brief pulse, about 2 microseconds long and 1.6 volts in amplitude, immediately after the leading positive edge of the selected time gate. This waveform erases the old counter indications and drops them to zero the instant a new measurement is to begin. This waveform can be seen best on a lab-type oscilloscope having both triggered sweep and vertical channel delay.

—30—

BY JOHN S. SIMONTON, JR.



BUILD "OP-TACH"

COUNT REVOLUTIONS WITH HAND-HELD INSTRUMENT

WHEREVER there is a wheel spinning or a motor shaft turning, the chances are that, sooner or later, somebody is going to ask how fast it is revolving. To find out, he'll have to use a tachometer of some sort. Most commercial and industrial tachometers are designed for a specific purpose and are either permanently installed or fairly expensive, or both.

In the home workshop, the experimenter needs a low-cost, portable tachometer that can be used with any motor or engine when he is tuning up or testing.

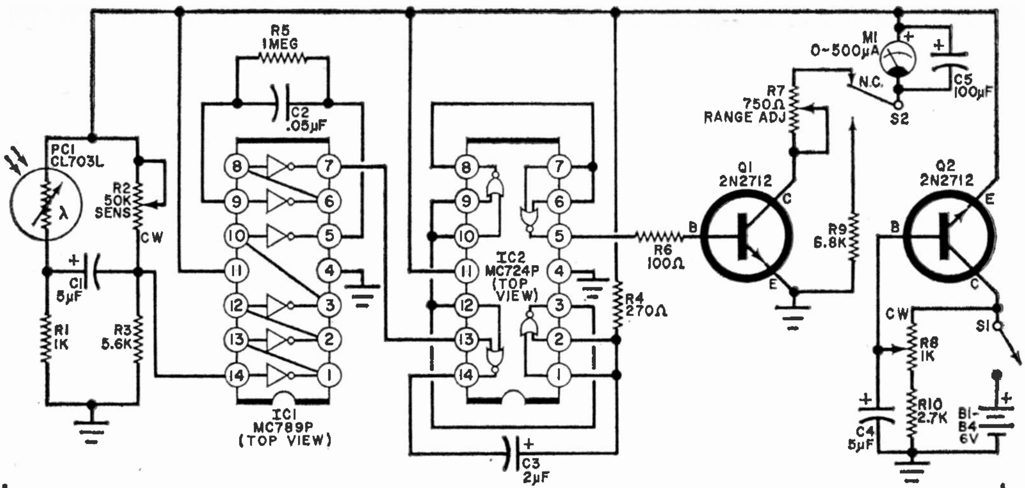


Fig. 1. The meter indicates the average current flowing through Q1 as a result of the number of light pulses striking PC1. Capacitor C5 permits the system to operate only on light pulses and not be affected by the amount of ambient light.

PARTS LIST

B1-B4—1.5-volt AA cell (penlight)
C1, C4—5-µF, 6-volt electrolytic capacitor
C2—0.05-µF, ceramic disc capacitor
C3—2-µF, 6-volt electrolytic capacitor
C5—100-µF, 6-volt electrolytic capacitor
IC1—Integrated circuit (Motorola MC789P)
IC2—Integrated circuit (Motorola MC724P)
M1—0-500-µA meter, 100-ohm internal impedance
PC1—Photocell (Clairex CL 703L or similar)
Q1, Q2—2N2712 transistor
R1—1000-ohm
R3—5600-ohm
R4—270-ohm
R5—1-megohm
R6—100-ohm
R9—6800-ohm
R10—2700-ohm
(*All resistors ½-watt*)
R2—50,000-ohm linear taper potentiometer
R7—750-ohm trimmer potentiometer
R8—1000-ohm linear taper potentiometer with switch attached
S1—S.p.s.t. switch (part of R8)
S2—S.p.d.t. pushbutton switch
Misc.—Case (6½" x 3⅜" x 2", plastic with mating aluminum cover), hardware, dual battery holder (2), wire, solder, 5-dram plastic pill container with cover, PC board, etc.*
**The following are available from PAIA Electronics, P.O. Box 14359, Oklahoma City, Okla. 73120: printed circuit board, $2.50; meter with RPM x 10 designation on dial, $5.25; complete kit of parts with PC board, hardware and case (not machined), $18.50. Oklahoma residents, add 3% sales tax.*

There are very few tachometers of this type.

Here's one, however, that will measure the speed of practically anything that rotates in the lab or workshop. It's called the "Op-Tach" and is battery-operated, wholly self-contained and handheld. A beam of light senses the speed of the rotating object. In many cases, using the Op-Tach is simply a matter of pointing the instrument at the rotating object and reading the speed in revolutions per minute directly from the meter.

Construction. The schematic diagram for the Op-Tach is shown in Fig. 1. As with any project using integrated circuits, you will be ahead of the game if you use a printed circuit board. You can make your own, using Fig. 2 as a guide, or you can buy one (see Parts List of Fig. 1). In assembling components on the circuit board (Fig. 3) be sure that both the board and your soldering iron are as clean as possible and keep them that way. In inserting the integrated circuits, notice that the notches on the IC's correspond to the semicircular locating marks on the PC board. When all soldering is complete, a coat of spray acrylic or clear nail polish will keep the copper circuit from oxidizing.

To protect the photocell from high levels of ambient light and restrict its field of view, the photocell is glued to the bottom of the inside of a 5-dram pill container which has been painted flat black on the inside. A pair of holes is drilled for the photocell leads. The pill container is then mounted in an appropriate

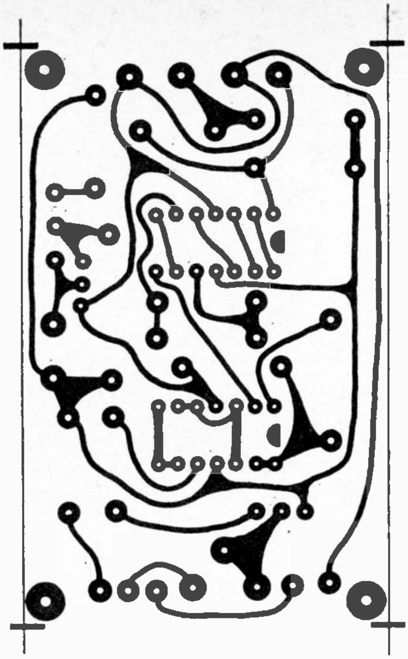


Fig. 2. Actual size printed-board foil pattern for the Op-Tach. Note the semicircular end identifiers for the IC's.

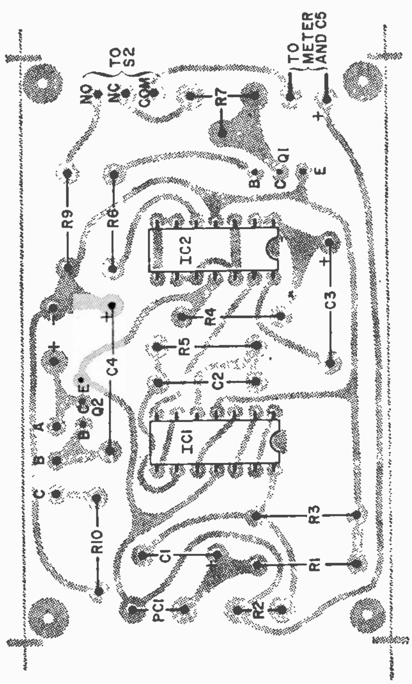


Fig. 3. Component installation. Observe correct polarity for the indicated parts.

size hole in one end of the 6½" × 3¾" × 2" plastic utility box which houses the instrument. To conserve space, mount it so that approximately half of the pill bottle protrudes from the case. Save the cap from the container and use it as you would the lens cap on a camera—to prevent dust from settling on the photocell.

The two dual-battery holders are mounted on opposite sides of the case so that, when the cover is in place, the meter is between them. The PC board should be mounted with 6-32 screws and raised from the bottom of the case with short spacers. The meter, switch *S2* and controls (*R2* and *R8*, with *S1* attached) are mounted on the aluminum faceplate of the utility box as shown in Fig. 4. In the author's prototype this faceplate was covered with a mahogany-grain, contact-adhesive paper and labels were applied using dry transfers. All wires from the PC board to the controls and meter were run through a piece of large tubing, but they could be laced together in a neat bundle. Be sure to make these leads long enough to permit removal of the front cover. Notice that capacitor *C5* is mounted directly on the meter terminal lugs and not on the printed circuit board.

The suggested meter has scale markings from 0 to 500. Carefully remove the

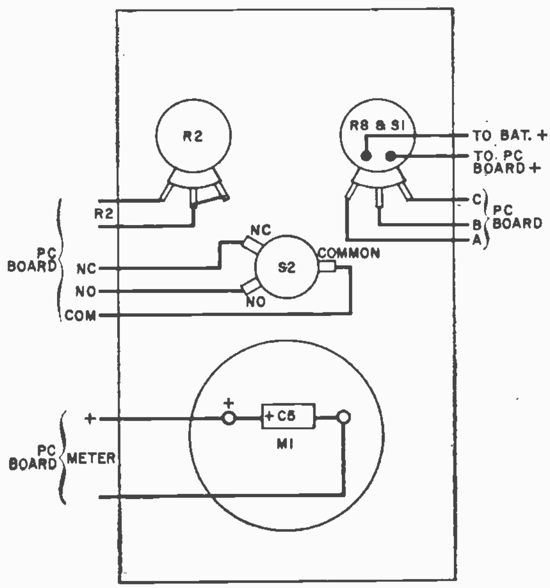
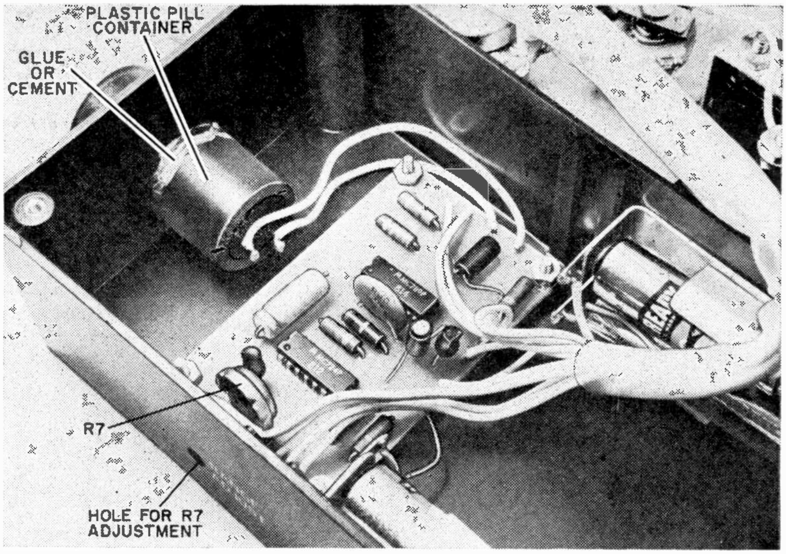


Fig. 4. Layout of rear of front panel. As circuit layout is not critical, any arrangement can be used.

Two holes must be drilled in the plastic case. One is for the pill container that mounts PC1, while the other is for making R7 adjustments. For maximum rigidity, mount the pill container half way in the case and use high-quality cement. Use the pill container cover as a cap when the Op-Tach is not in use. This keeps dust away from the photo cell.



clear plastic front of the meter and use a pencil eraser to remove the "D.C. MICROAMPERES" marking. You can then use either pen and ink or dry transfers to relabel the meter "RPM × 10". If at all possible, remove the scale before doing any lettering on it and, in any case, be very careful not to bend the meter needle or damage the movement.

Calibration. The best way to calibrate the Op-Tach is by comparing it to a tachometer of known accuracy, but if such an instrument is not available, you can use one of the following methods:

Signal-Generator Method. Figure 5 shows a calibration setup using an audio signal generator. Set the generator for an output of 50 Hz and 1.5 volts peak-to-peak. Turn on the Op-Tach and set *R8* so that the meter reads 500 with *S2* depressed. Release *S2* and set sensitivity control *R2* at its least sensitive point (counterclockwise). You may get a reading with the sensitivity control at this position but if you don't, advance *R2* slowly until the meter shows a steady reading. Adjust the range potentiometer, *R7*, to give a reading of 3000 RPM (the equivalent of 50 Hz). While you have the equipment set up, you may want to check the tachometer at several other frequencies. Remember that indicated RPM is frequency times 60.

The electronic portion of the Op-Tach is inherently linear above about 500 RPM so any nonlinearity you may find is in the meter movement. Since most inexpensive meters have a nominal accuracy of 5%, you can expect an error of less than 250 r/min on the 5000 RPM range (usually much less).

Power-Line Method. If you don't have a signal generator, the best thing to do is to use a filament transformer and a voltage divider set up as shown in Fig.

HOW IT WORKS

Each time a sharp change of light hits the Op-Tach's photocell, the resistance of *PC1* changes and a voltage pulse is created at terminal 14 of *IC1*. This pulse is amplified and shaped by the six inverters in *IC1*. SENSITIVITY control, *R2*, is used to set the amount of forward bias in the first inverter in *IC1*. Capacitor *C2* isolates the last two inverters from any cascaded d.c. bias in the first four stages; and *R5* prevents an excess charge from accumulating on *C2*, which would reverse bias the last two inverter stages.

The output at pin 7 of *IC1* triggers a monostable multivibrator composed of *R4*, *C3*, and two of the four logic gates in *IC2*. Even though the reflected light detected by *PC1* varies in duration and intensity, the output of the multivibrator is a pulse of constant height and width whose frequency is determined by the number of times that the reflected light strikes *PC1*.

The pulses are squared up and buffered by the other two gates in *IC2* and applied to the base of *Q1*. When a pulse is applied to *Q1*, it is turned on and a short pulse of current flows through meter *M1*. As the speed of the object increases, the pulses become closer together and the average value of current flowing through *M1* increases. Capacitor *C5* smooths this waveform and helps keep the meter needle from jiggling.

When pushbutton *S2* is pressed, the meter is taken out of the collector circuit of *Q1* and put in series with *R9*. The voltage across the meter is then determined by *Q2* and can be varied by adjusting *R8*. Variations in battery output due to aging are eliminated by setting *R8* for a current flow of 500 microamperes before each reading.

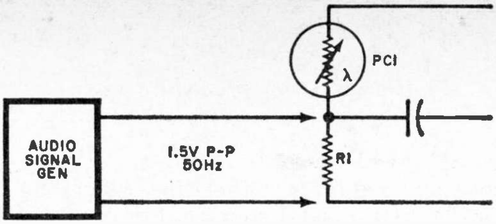


Fig. 5. To calibrate, use an audio signal generator delivering 1.5 volts peak-to-peak at 50 Hz as the input and adjust R7 (through its hole) for 3000 RPM.

6. The procedure is the same as that above except that you adjust *R7* for a meter reading of 3600. (Unless you happen to have a power line with a 50-Hz frequency; in which case, the reading would be 3000 RPM.)

Of course the meter doesn't have to be calibrated for a full-scale reading of 5000 RPM. You can set *R7* for 10,000 or 15,000 RPM and change the meter scale markings accordingly. However, you will have to use an audio signal for calibration in the higher ranges. Select a frequency near the center of the range. For instance, for a 10,000-RPM scale, use 83 Hz, which is equivalent to 4980 RPM (make the setting for 5000). Don't try to get a full-scale range of more than 15,000 RPM or you may run into serious nonlinearities.

Operation. The Op-Tach can be used in one of two ways: by reflection or by transmission of light.

Reflective. In the first method, light is reflected from a rotating spot which is of a different reflectivity from the rest of the object. The shafts of some motors have flats machined on them and these serve as good reflective spots. In most cases, however, the contrasting area must be made artificially. You can use a small piece of aluminum foil attached with clear cellophane tape or simply a piece of paper of a color which contrasts with the background. A small area painted in contrast will also be satisfactory.

Position the Op-Tach so that light is reflected from the surface of the rotating body into the photocell. A light source is not included as part of the instrument since quite often ambient light is sufficient. If it is not, use an auxiliary light such as a flashlight or drop light.

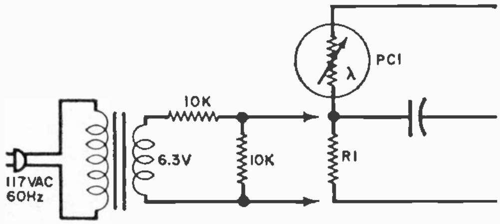
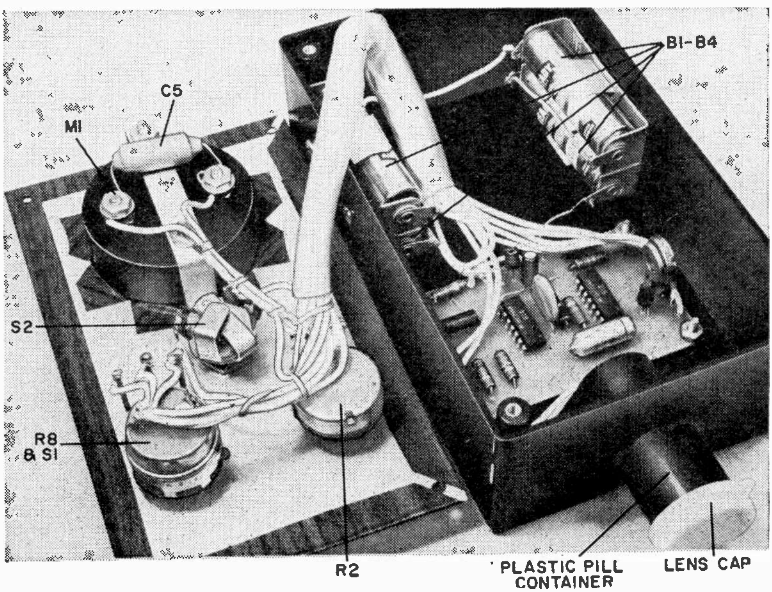


Fig. 6. You can use the commercial 60-Hz power line as a calibration source, with the divider network shown here, to calibrate the Op Tach to 3600 RPM.

Look at the rotating object from the direction and position in which the tachometer is located. If you can see a direct reflection from the light source, you can use the Op-Tach. If not, change the position of the light or the tachometer, or both. You can hold the Op-Tach in your hand if it is sufficiently steady to get



The wiring between the PC board and the front panel can be made neat by passing it through a piece of plastic tubing.

OP-TACH

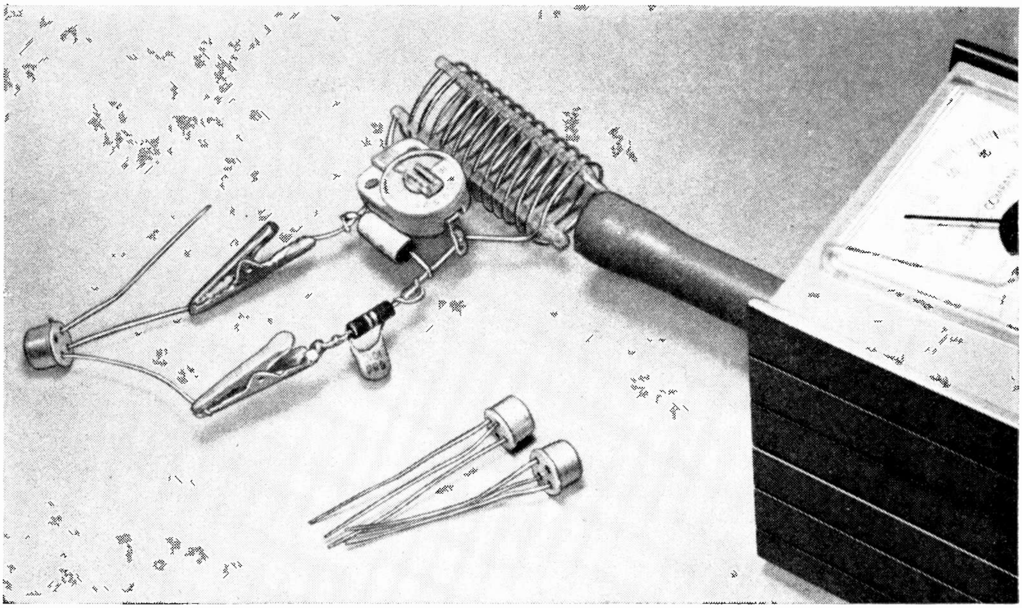
(*Continued from preceding page*)

constant readings. Otherwise, place the Op-Tach on a solid surface. For the best accuracy, always have the tachometer case in a position as close to horizontal as possible.

Turn on the Op-Tach by rotating *R8* clockwise until *S1* turns on. This supplies power to the meter. Depress *S2* and continue to rotate *R8* until you get a full-scale deflection. Then release *S2*. With the photocell pointed at the rotating body, advance the SENSITIVITY control (*R2*) until you get a steady reading. If the sensitivity is made too high, the photocell will begin to pick up minor differences in reflectivity due to surface imperfections. This results in an erratic reading on the meter, which can be cured by decreasing the sensitivity.

If the rotation being measured is below about 500 RPM the meter may "dance" somewhat. This effect is not objectionable, however, until the speed is below 200 RPM. To avoid this problem, try using more than one contrasting area on the rotating object. This has the effect of multiplying the speed of the object by the number of reflecting surfaces you add, and the speed read on the meter can be converted to true speed by dividing by that number. For instance, if you have placed six contrasting strips on a rotating object and the tachometer reads 1200 RPM. Then the true speed is 1200 divided by 6 or 200 RPM.

Transmissive. The measurement method using the transmission of light through a rotating object to the Op-Tach works extremely well for slowly rotating fans. The light source is placed on one side of the fan and the Op-Tach on the other so that each blade interrupts the beam as it passes between the source and the tachometer. The instrument is turned on and the voltage is adjusted as before. Because of the extreme difference in light levels, the sensitivity adjustment may have to be increased slightly. The indicated RPM must be divided by the number of times the beam is interrupted during one revolution of the fan (number of blades). -30-



Transistor Sorter

ARE THEY AUDIO, LOW R.F., OR VHF?
FIND OUT WITH THIS SIMPLE TESTER

BY RAYMOND F. ARTHUR

MANY ELECTRONICS hobbyists have accumulated signal transistors from bargain packs, surplus computer boards, and other sources. The problem is that most such transistors lack "2N" identification markings, and in the cases where user production numbers are provided, the problem is only compounded. Sure, almost any transistor tester will show whether an unknown transistor is *npn* or *pnp* and provide gain data. But how do you find out if it's suitable for audio or r.f. applications?

Well, if you own or can get your hands on a grid-dip oscillator, you can sort your transistors into application categories (audio, i.f., h.f., etc.). This type of sorting is possible because the shunting action of the base-to-collector capacitance of the *pn* junction causes transistor gain to drop off as frequency is increased. Relating this phenomenon to application sorting, the lower the junction capacitance (less pronounced dropoff in gain with increasing frequency), the higher the frequency at which the transistor can be operated.

In addition to a grid-dip oscillator, you will need a parallel-resonant tank circuit (*L1* and *C1* in Fig. 1) to sort transistors according to application. With the alligator clips open-circuited, *L1* and *C1* should resonate at a frequency of about 30 MHz. Any added capacitance (connected between the clips) lowers the resonant frequency of the tank circuit and causes a correspondingly lower dip point on the GDO.

The *L1-C1* tank circuit, when properly assembled, should be self-supporting as shown in photo. For *L1*, use a 16-turn length of Barker and Williamson #3015 "Miniductor" (1″ coil diameter, 16 turns/in. of #21 wire). Unwrap one turn from each end of the coil, leaving 14 complete turns and ending up with two 2″ leads oriented perpendicular to the axis of the coil.

Slip the unwrapped leads through the solder lugs of trimmer capacitor *C1* and

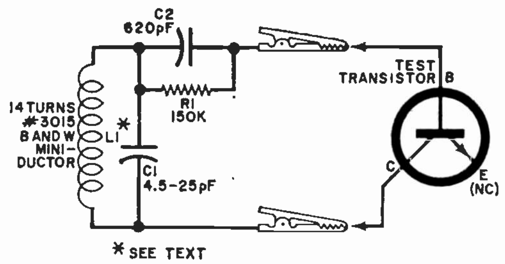


Fig. 1. The base and collector leads of the test transistor connect to the tank circuit through alligator clips. Reverse-bias voltage across the junction is developed across C2 and R1.

solder into place 1½" from the coil. Then solder a miniature alligator clip to one of the coil leads. Clip off the excess length of the other coil lead at *C1*. and solder *C2* and *R1* to *C1*; make sure the leads of *C2* and *R1* are clipped short. Finally, solder another alligator clip to the unconnected sides of *R1* and *C2*.

In use, the tank circuit should be placed in a small plastic box to permit easy alignment of the axes of *L1* and the coil of the GDO. With the alligator clips open-circuited and positioned where they can accept the leads of a transistor, gently adjust *C1* for a dip at 30 MHz. Shorting the alligator clips together should shift the dip to 3 MHz.

Connect the base and collector leads of the transistor to be tested to the alligator clips; it doesn't matter which lead goes to which clip. Now, avoiding over-coupling between the tank circuit and GDO, determine the frequency at which the GDO pointer dips.

Refer to the graph provided in Fig. 2 for measured capacitance or transistor type. This graph indicates a general trend of very low capacitance for UHF transistors to higher capacitance for audio transistors. It is not practical to indicate precise regions for various transistor types on the graph because of overlaps and other factors that might affect the high-frequency operation of transistors.

Although collector capacitance plays an important part in setting the upper frequency limit of transistors, other factors such as current gain, base resistance, and overall power gain are also important. If current gain is known and two transistors show about the same output capacitance, but have widely differing gains (say 30 and 300), the lower gain transistor should be rated downward in frequency capability.

The graph of Fig. 2 is intended for use with low-power transistors—not power transistors. With a few exceptions, all transistors you check will produce a dip on the GDO. Failure to obtain a dip may indicate a very leaky transistor, an unusually low collector-to-base breakdown voltage, or unusually low Q of the junction capacitance.

Considering its simplicity and low cost, the GDO method of sorting transistors affords the experimenter and hobbyist with a simple and useful means of judging the relative frequency capabilities of small unidentified transistors. —30—

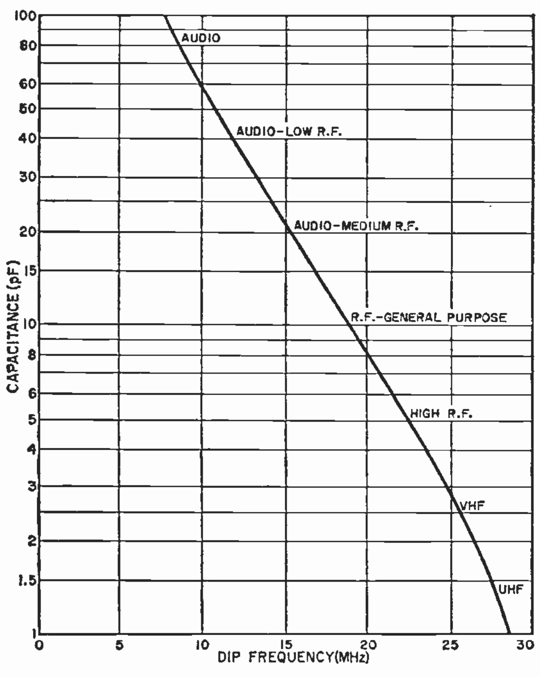
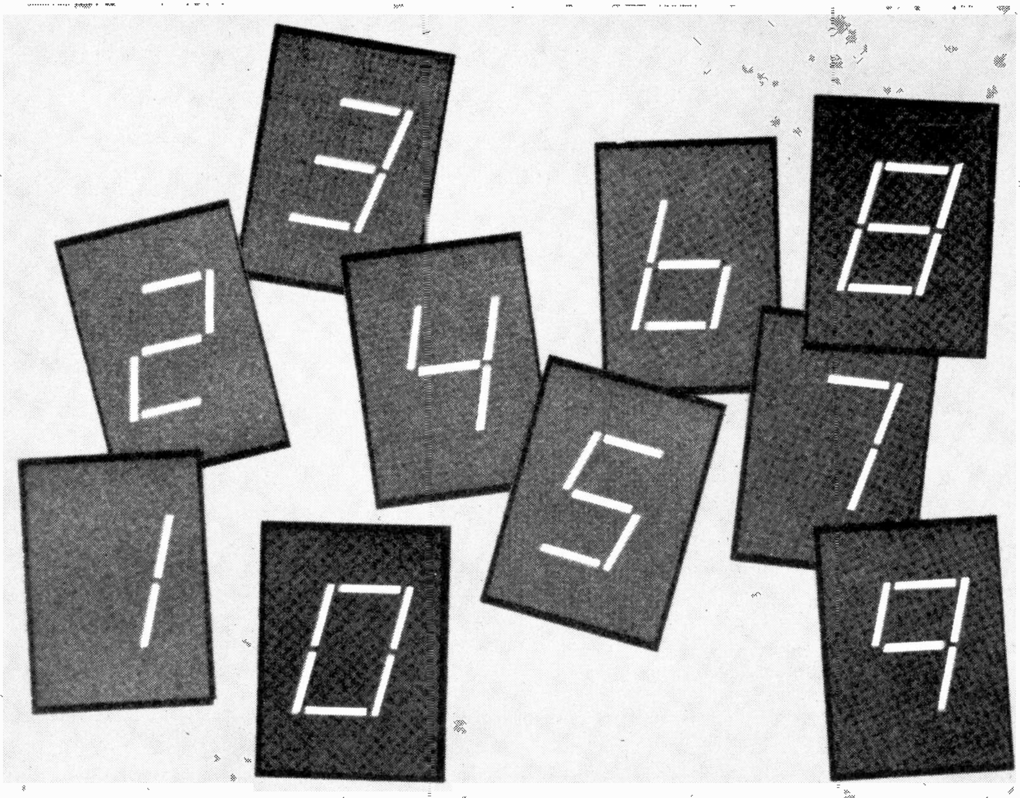


Fig. 2. For low-power transistors, junction capacitance is shown as a function of the dip frequency.



THIRD-GENERATION DCU

NEW, BRIGHT, LEGIBLE DIALCO 7-SEGMENT READOUT

BY C. P. TROEMEL

PAST ELECTRONIC EXPERIMENTER'S HANDBOOKS have introduced new approaches to the design of digital readout equipment. The first was the "Low-Cost Counting Unit" using incandescent lamps (1969 Winter Edition of ELECTRONIC EXPERIMENTER'S HANDBOOK) and the second was the "All-Purpose Nixie Readout" (1970 Winter Edition of ELECTRONIC EXPERIMENTER'S HANDBOOK). The incandescent unit costs $12.00 per decade; the Nixie readout, while higher priced, at $30 per decade, is still much less than equivalent commercial units.

In this article, we will describe a third approach to digital readout—a low-cost decade counter having a single-plane number indicator. In this type of indicator, the numerical presentation does not float up and down as it does in an incandescent display or go back and forth as in a Nixie tube. The single-plane indicator can be read from a considerable distance at viewing angles up to 150°.

How much does this third-generation readout cost? If you make your own display as described here, it is $13.50; if you use a commercially available display, about $6 more.

You have probably seen single-plane readouts on expensive test equipment and computers, in stock market quotation machines, or on airline arrival-departure boards. The basic seven-segment pattern is shown in Fig. 1. The 10 numerals created are shown above.

The counter can operate at rates up to 8 MHz, can be reset to zero at any

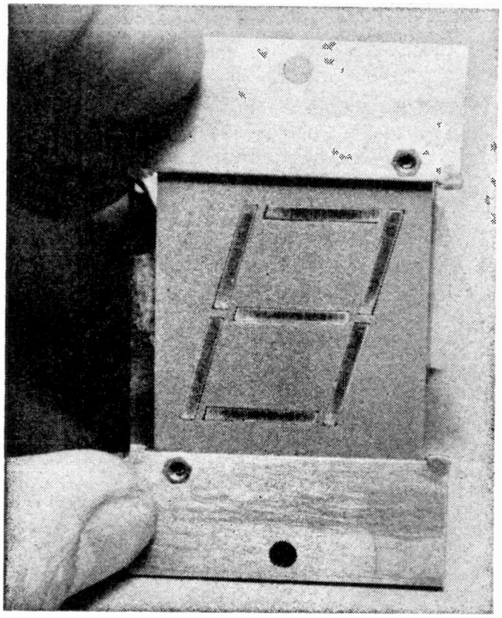


Fig. 1. Front view of the commercial seven-segment readout showing the numerical pattern. Mounting frames are available to hold several such readouts.

time, and can be cascaded to produce counts up to 99, 999, etc. Because the counting logic in the new readout uses the same integrated circuits as those of the "Low-Cost Counting Unit," it can be substituted for the incandescent lamp readouts used in other projects published in the ELECTRONIC EXPERIMENTER'S HANDBOOKS such as the Stopwatch, Sports Timer, Digital Volt-Ohmmeter, and other digital readout instruments to be described in future issues. The logic circuit for the third-generation counter is shown in Fig. 2.

Construction. While the use of a printed circuit board is not mandatory, it does make the counter much easier to build and eliminates any chance of wiring errors. A foil pattern is shown in Fig. 3, with drilling and jumper information given in Fig. 4. Components are mounted on the board as shown in Fig. 5. Be sure that the IC's are positioned as shown. The numbers on the sides of the foil pattern refer to the segments of

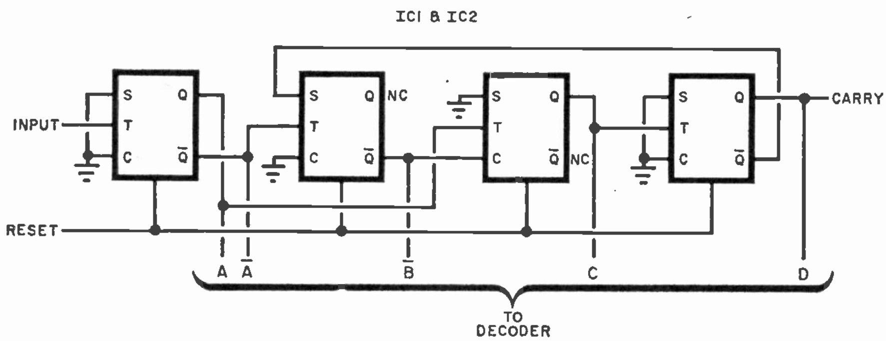


Fig. 2. The logic circuit (above) accepts the input pulses and produces certain discrete voltage levels at the outputs. The decoder (right) processes these voltages and causes only certain matrix segments to remain lit, creating a number.

PARTS LIST

*IC1,IC2—Dual JK flip-flop integrated circuit (Motorola MC790P)**
*IC3,IC5—Quad 2-input gate integrated circuit (Motorola MC724P)**
*IC4—Quad 2-input gate integrated circuit (Motorola MC717P)**
*IC6—Hex inverter integrated circuit (Motorola MC789P)**
I1-I7—6.3-volt, 50-mA pilot lamp
*Q1-Q8—MPS3393 or 2N5129**
R1—1500-ohm, ¼-watt resistor
*1—Display unit (Dialco)***
Misc.—PC board, indicator-to-board wire, #24 wire for jumpers, solder, etc.

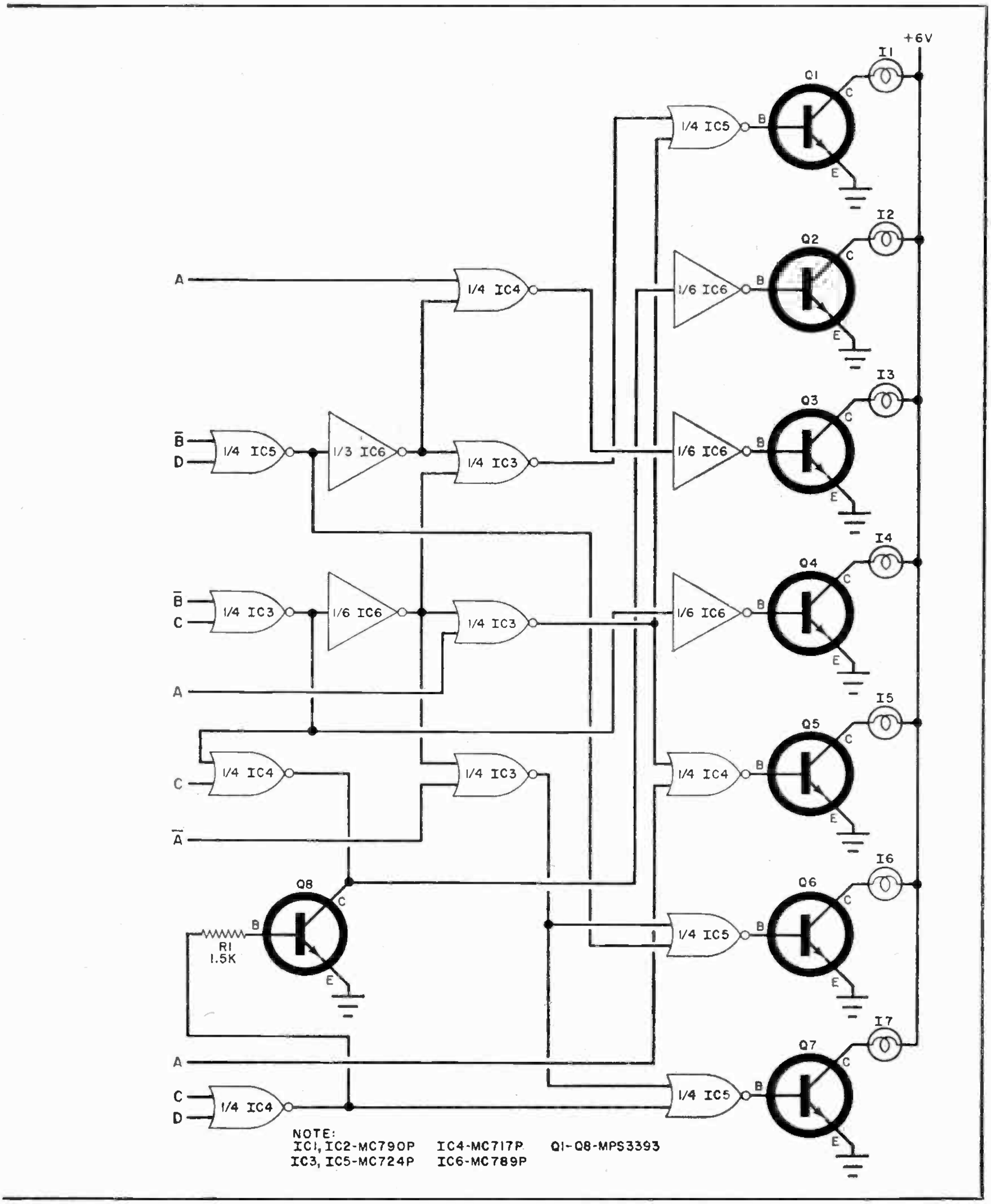
**Available from Allied Electronics, 100 N. Western Ave., Chicago, Ill. 60680. When ordering, specify as follows: 50D26—(type number)—MOT. Prices and type numbers are: MC790P, $2; MC789P, $1.08; MC724P, $1.08; MC717P, $1.08; and MPS3393, $.32.*

***Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. 11237. Order part number 710-0306, $5.46. Colored plexiglass fronts, red (712-0103-001) or green (712-0105-001) are available at $.53 each. A mounting bracket (713-0100-001) is also available at $1.33. For color filters and brackets in lengths of more than one unit, consult Dialight Corp.*

Note—An etched and drilled PC board, #159 at $3.50, and a complete kit of parts, including the PC board and seven bulbs, SEG-1 at $13.50, are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216.

the display and are used when connecting it to the board. Use a 25-watt soldering iron with a very narrow tip and thin solder (0.040" diameter) to install the IC's and transistors. Excessive heat may damage the semiconductors, while insufficient heat may result in poor connections.

You can use one of two types of displays. The first, and best, is the commercial indicator unit given in the Parts List in Fig. 2. A rear view of this display



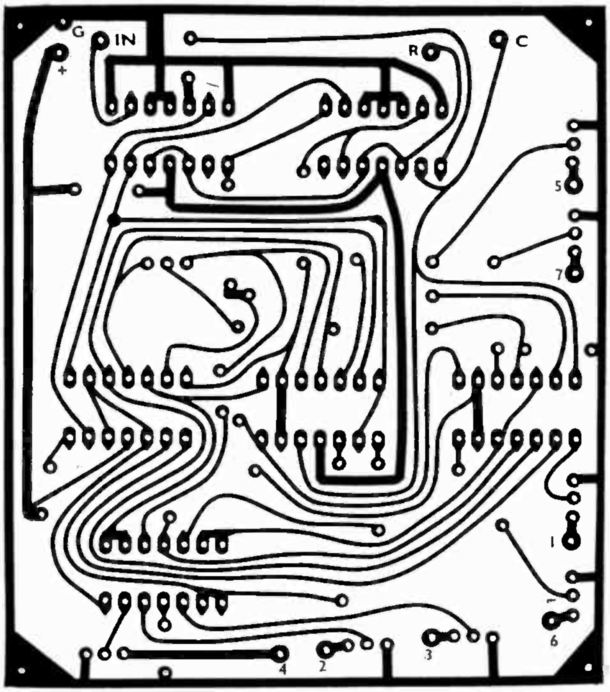


Fig. 3. Actual-size printed circuit foil pattern for the DCU. The use of this pattern is suggested because of the complexity of the circuit. Point-to-point wiring is not to be recommended.

with the appropriate lamp connections, keyed to the numbers on the circuit board, is shown in Fig. 6. Remove the rear cover of the indicator and install the seven lamps as shown in Fig. 6. One lead of each lamp is connected to a common tie point, which is connected directly to the +6-volt output of the power supply.

Using Fig. 5 as a guide, connect each lamp to its proper point on the circuit board. The eight wires from the readout can be made several inches long and laced together into a cable. This permits the mounting of the board some distance from the display. If a number of circuit boards (for a number of decades) are to be used, this approach permits low-profile stacking of the board with the displays mounted on a front panel. Almost any desired type of color filter may be used over the displays.

If you prefer to make your own display, first make a front panel as shown at the top in Fig. 7. Use thin cardboard, opaque plastic, or thin metal for this piece. Using thin cardboard and glue, isolate each segment of the front-panel as shown at the bottom of Fig. 7. The lamps can just lay in the compartments with their lead wires extending out. Plastic tape can then be placed over the rear to hold the lamps in and keep light from coming out. If desired, you can cut a piece of cardboard to fit the back of the box and punch holes for each compartment just big enough to accommodate a lamp. The lamps can then be wired from the outside of the display. Pilot lamp sockets can also be used if desired. Wire the lamps to the circuit board as described before. The front panel of the display can be covered with a translucent material of any color to diffuse the light and give the display a commercial appearance.

Power Supply. The power supply is wired point-to-point using the schematic shown in Fig. 8. There are only three connections to the rest of the instrument—ground and 3.6 volts to the circuit board and 6 volts to the display lamps. To extend the life of the lamps, one or more diodes (*D6*) can be connected in the 6-volt line to reduce the voltage slightly (to 5.0 or 5.5). This lowers the lamp brilliance very slightly. A low-value resistor can also be used for this purpose. Do not reduce the value of *C1* or the resultant ripple may cause erratic readings. Maximum current consumption of

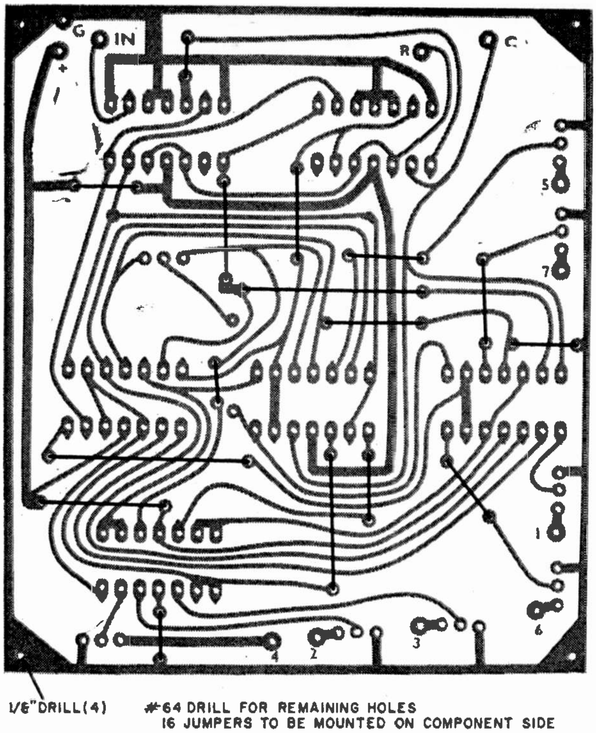


Fig. 4. Other than the four corner holes (for mounting), use a #64 drill for all holes. Wire the required 16 jumpers on the component side of the PC board.

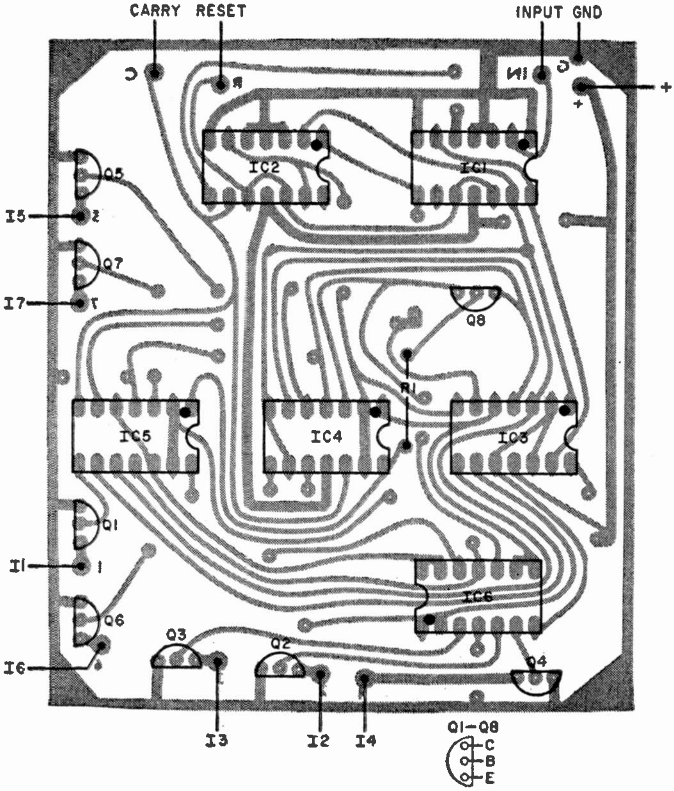


Fig. 5. Install the six IC's, 8 transistors, and R1 as shown here. Observe the notch and dot code on the IC's and orientation of the transistors. Note that each transistor is numbered the same as its segment on readout. The jumpers are not shown in this figure.

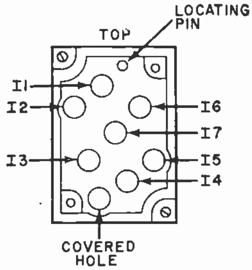


Fig. 6. Rear view of the commercial display unit showing the location of the seven segment-illuminator bulbs.

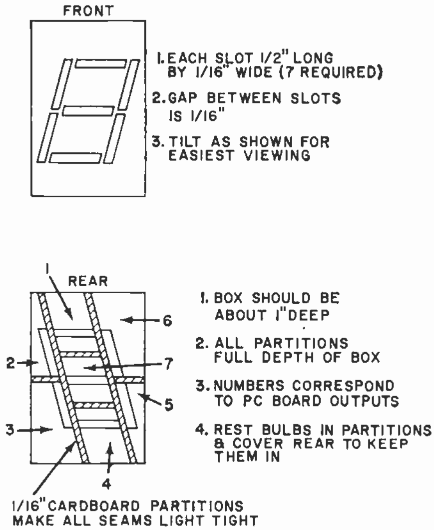


Fig. 7. You can make your own readout by following construction information shown here.

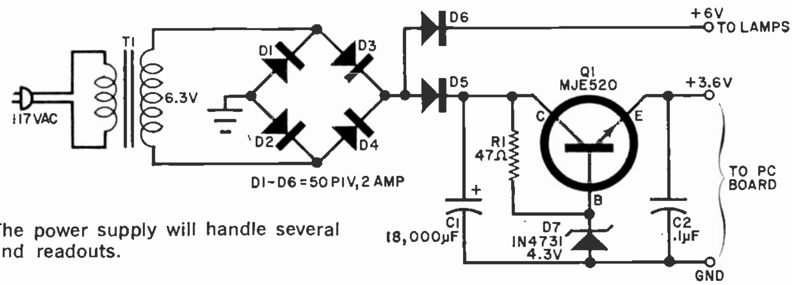
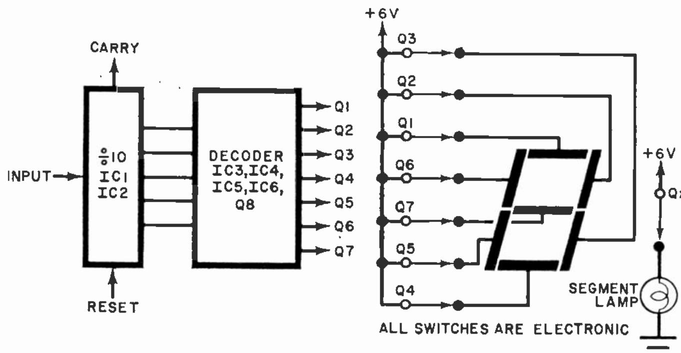


Fig. 8. The power supply will handle several DCU's and readouts.



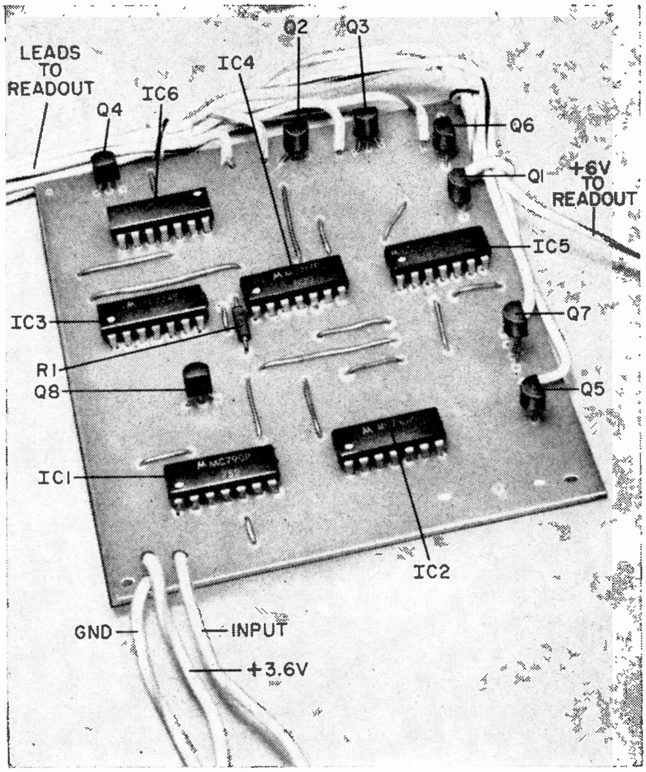
HOW IT WORKS

The heart of the third-generation counter is a single-plane, seven-segment display in which individual segments remain stationary and are illuminated in various combinations to produce the necessary numeral.

As shown in the diagram, all switches (transistors *Q1* through *Q7*) are normally closed (transistors conducting) and their associated lamps are lit. This forms the numeral 8. If *Q7* is turned off, the center bar goes dark and the numeral 0 is formed. As another example, if *Q4, Q5, Q6,* and *Q7* were all turned off, a 7 would appear on the display. Other numbers are formed by turning off other combinations of lamps.

The input signal to be counted is applied to a divide-by-ten circuit consisting of dual-JK flip-flops in *IC1* and *IC2*. Each input pulse advances the counter one state until the count of 9 is reached. The next pulse resets the counter to zero and provides a carry pulse to the next decade.

Each state of the counter (0 through 9) presents a unique set of voltage levels at the individual JK flip-flop output leads. Unique combinations of these output levels are selected for application to gating circuits which, in turn, actuate the associated transistors.



The finished boards can be stacked (using spacers between them) to form a low-silhouette package. Connection between each board and its readout is made via a neat bundle of leads.

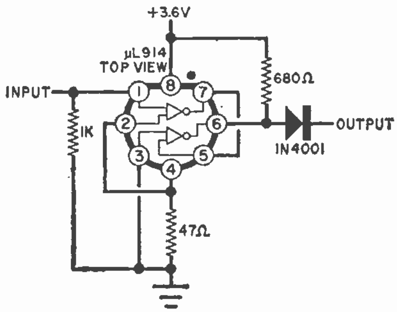


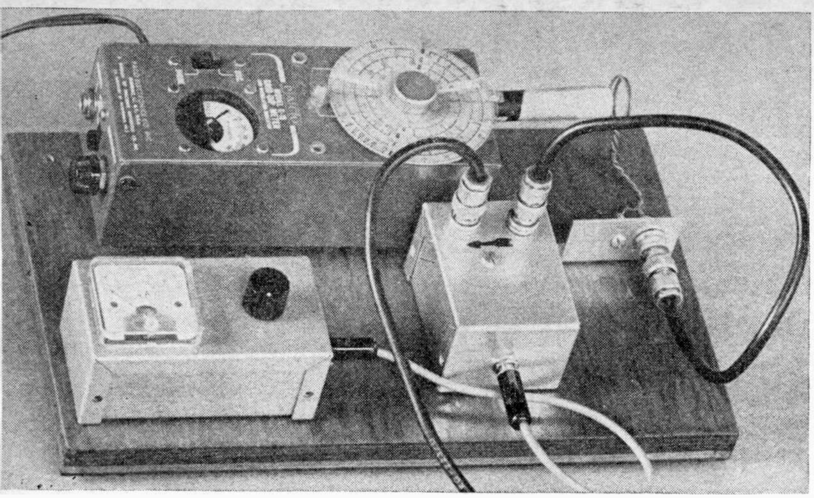
Fig. 9. This shaper will convert a sine-wave to a square wave of same frequency.

each decade is approximately 500 mA (when an 8 is displayed).

When mounting regulator transistor *Q1*, use plastic mounting hardware and mount the metal side of the transistor against the metal chassis with a mica washer and heat-sink (silicone) grease between the transistor and the chassis. If a metal screw is used, take care not to damage the transistor.

Operation. The reset lead (Fig. 2) is normally grounded. When it is raised to +3.6 volts and grounded again, the counter resets and indicates a zero on the display. The carry lead is connected to the input of the next decade to increase the count as necessary. The count of the decade unit is increased by one each time the signal level at the input drops from +3.6 volts to zero. The input signal must have a fall time of less than 0.1 microsecond. Any audio sine-wave generator can be used to test the counter. A low test frequency should be used so that the display can be observed easily. To shape the input signal properly, the circuit of Fig. 9 can be used.

There may be times when the input lead to the counter acts as a noise "antenna" and causes erratic counter operation. In such a case, connect a 1000-ohm resistor between the input lead and ground. –30–



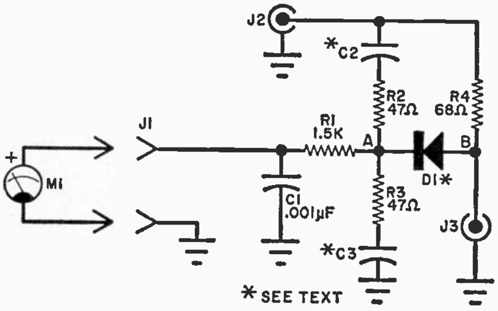
Simplest Antenna Bridge

GET THE MOST OUT OF YOUR SWL ANTENNA SYSTEM

BY JIM ASHE

THE SWL who wants to put up a home-made resonant antenna has two strikes against him to start with. More than likely, he won't have the fancy test equipment that is needed to do a respectable job. As a result, the antenna goes up, and by cutting and pruning, it might just accidentally be tuned to the proper frequencies. However 9 out of 10 SWL antennas are badly mistuned and are nothing more than so much wire strung up in the air.

In a fraction of the time you've spent digging out some of the weaker stations you could have tuned that antenna and possibly gained anything from 3 to 10 dB signal strength on that S-meter. All you need is a grid-dip oscillator (which you can maybe borrow from a friendly ham) or a r.f. signal generator covering the frequencies you want the antenna to tune. Use this signal source in conjunction with a simple little Wheatstone bridge (described below) and you are in the semi-professional antenna testing business.



With system completely set up, reactive imbalances between A and B cause up-scale meter deflection.

How It Works. Resistor *R1* and capacitor *C1* (see schematic diagram) isolate the actual bridge circuit from meter *M1* and prevent stray r.f. from getting into the bridge. In the bridge itself, *C2*, *C3*, *R2*, and *R3* function as a voltage divider that splits in half the incoming signal from *J2*. The capacitor values (typically 0.01 µF below 30 MHz and 0.001 µF above 30 MHz) should present low reactance at the operating frequency.

The two voltage dividers in the bridge must balance if a null is to be produced and prevent deflection of *M1*'s pointer. It is evident, therefore, that the load resistance at *J3* must be exactly the same as the resistance of *R4* in the second voltage divider to preserve the null condition. A 68-ohm value was selected for *R4*, but you could as easily substitute one of the more common 52- or 75-ohm values if your antenna is designed for either of these impedances.

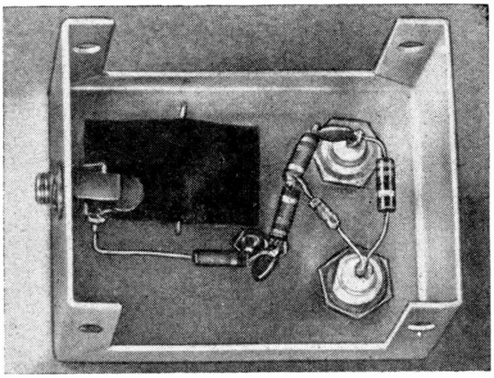
Diode *D1* rectifies r.f. only when a difference of potential or a difference in signal phase exists between points A and B in the schematic. This rectified voltage is then fed to the meter through *J1*.

Construction. Referring to the photo, mount BNC connectors *J2* and *J3* on the top of an appropriate-size metal utility box. Then mount *J1* in any location that is convenient but will not interfere with the components in the circuit. Parts placement is not too critical, but keep component leads as short as possible.

Mount a chassis solder lug as shown, and wire the components together. Be careful to observe the proper polarity when connecting *D1* into the circuit.

You can use a larger utility box than that shown in the photo if you want to mount the meter in the same box with the bridge circuit. In this case you could eliminate the extra utility box and *J1*.

When the Wheatstone Bridge circuit is fully assembled, place an arrow on the top of the utility box, pointing it from *J2* toward *J3* to indicate in which direction the r.f. is supposed to flow. (This arrow shows clearly in the photo at the beginning of this article.)



Spare alternate value resistor is kept handy with strip of electrical tape (upper left of chassis)

How To Use. The bridge is easiest to work with if you mount it, the GDO, and test meter on a board (see photo on page 92). After mounting the instruments, interconnect them with appropriate r.f. cable and connectors, and place the GDO and a pickup loop close enough together to obtain a full-scale deflection of the pointer on *M1* (no connection to *J3*).

Temporarily connect a 68-ohm carbon resistor (a 52- or 75-ohm resistor if either of these values was selected for *R4*) to antenna jack *J3*. The full-scale deflection should drop to zero to indicate the null. And varying the frequency control on the GDO should not disturb the null.

Now, remove the resistor and plug in your antenna lead-in. (This must be single-ended coax; if your lead-in is twin-lead cable, however, install a Balun or other transformer arrangement to convert from balanced to single-ended line.) Vary the frequency control of the GDO; a null indication should appear on *M1* in one and only one position of the control.

There are two signs of trouble you may encounter at the null frequency—an off-frequency null requiring the retuning of the antenna system, and a null that is neither sharp nor complete, an indication that the antenna is reactive to all frequencies.

If the null doesn't appear at the expected frequency, tune in the GDO's signal on your receiver. This will give you a closer approximation of the actual output frequency of the GDO than is indicated on the GDO dial. Then, from the receiver's dial, you will be able to determine whether the antenna system nulls at a higher or lower frequency and, consequently, which way to tune the antenna. For a first approximation, increase or decrease the antenna length by the same *percentage* that the frequency is high or low, respectively.

The shallow null may be a more difficult problem to deal with. In this case, first examine the antenna system for poor workmanship, corroded contacts and joints, out-of-parallel open-wire lead-in, and large wire loops that might affect transmission line characteristics. Make certain that neither of the antenna elements is nearer to a large physical object than the other is.

The capacitive or inductive loading of some nearby object might make it necessary to unbalance the antenna physically to obtain an electrical balance. It's all right if one element is shorter than the other when you're finished—just so the antenna system works properly.

Finally, when your antenna system provides you with good readings, take notes on the way you performed your tests and how you set up the test conditions. Then, periodically recheck your antenna system. You'll be surprised how often you discover deterioration. —30—

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If you find this hard to believe, try the following experiment. Test the system resonance of a sealed-enclosure speaker system in a bare box and test it again after filling it with acoustical padding. You will find that the resonant frequency is lower in the latter case by as much as 10 Hz—or more.

To understand how this is possible, it is necessary to study the physics of sound propagation. Sound is produced in air as a series of "waves" which consist of an area of compression followed by an area of rarefaction or partial vacuum. Compressing air causes an increase in temperature (a fact familiar to anyone who has ever pumped up a tire). Conversely, a reduction of air pressure results in a temperature drop. A sound wave, therefore, is composed of a continuous train of compressions and rare-

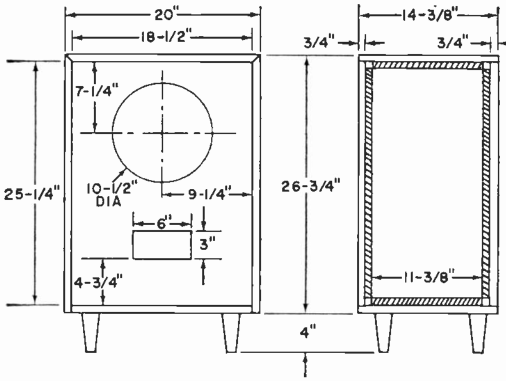


Fig. 1. Except for furniture legs, entire enclosure is made of ¾"-thick plywood and ¾"-square pine.

BILL OF MATERIALS

*1—Olson Electronics Model S-971 Deluxe three-way speaker**
*3 pkgs.—Olson Electronics No. HF-17 acoustical Fiberglass**
2—26¾" x 14⅜" pieces of ¾" plywood for enclosure sides (see text)
1—20" x 14⅜" piece of ¾" plywood for enclosure top (see text)
1—18½" x 14⅜" piece of ¾" plywood for enclosure bottom
2—25¼" x 18½" pieces of ¾" plywood for enclosure rear and speaker mounting board
4—11⅜" pieces of ¾" x ¾" pine for corner glue blocks
4—18½" pieces of ¾" x ¾" pine for cleats
4—23¾" pieces of ¾" x ¾" pine for cleats
Misc.—#8 x 1¼" flathead wood screws (7 doz); #12 x 1" panhead screws (4); 4" furniture legs (4); grille cloth; expanded aluminum (optional); decorative trim; glue; zip cord; solder; etc.
**Available from Olson Electronics, 260 S. Forge St., Akron, Ohio 44308.*

factions at slightly different temperatures.

Heat flows from a high- to a low-temperature area. But in the case of sound waves within the range of 20 to 20,000 Hz in air, the wavelength is too long and thermal conductivity of the air too small for heat transfer to take place. Hence, the waves are said to be adiabatic (constant heat) rather than isothermal (constant temperature).

Now, when the speaker enclosure is stuffed with acoustical padding, an interesting change takes place. The stuffing absorbs and gives up heat, which changes the operation of the air from adiabatic to isothermal. And when sound is isothermally propagated in air, its velocity decreases. Because the wavelength of sound is directly proportional to its velocity, reducing one also reduces the other. Or, looking at the situation from the standpoint of a loudspeaker in a box, the reduction in wavelength means that the enclosure is "larger" by comparison to wavelength.

Through the proper application of enclosure design and selection of stuffing material, the "Bigger-Than-Life Speaker System" performs as though it is actually bigger than it really is.

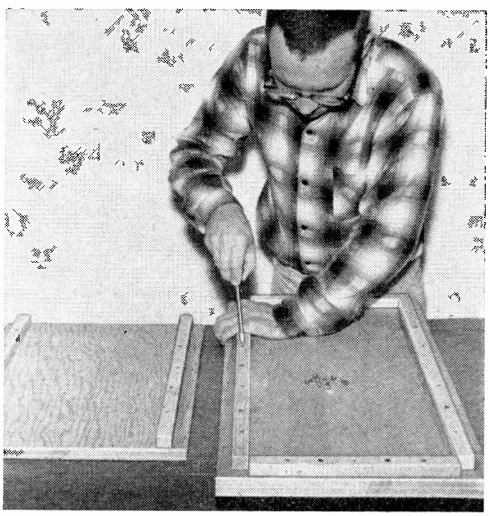


Fig. 2. Start assembly by joining cleats to bottom (left) and cleats and glue blocks to side (right).

Overall System. Now that the general principle has been described, the next step, obviously, is to apply it to a specific speaker enclosure. This is exactly what has been done in the Bigger-Than-Life Speaker System described here. The dimensions of the system enclosure are modest—a mere 6000 cu in. However, the system is designed around a high-quality three-way speaker and employs a 3" × 6" port (see Fig. 1) that tunes the fully stuffed enclosure to a 45-Hz resonance. (A port of this size would normally require an enclosure volume of about 8000 cu in. to be correctly tuned to the same frequency.)

In this speaker system, the port is tuned to a higher frequency than the speaker's free-air resonance to insure that the system will provide good performance in the 45- to 125-Hz range.

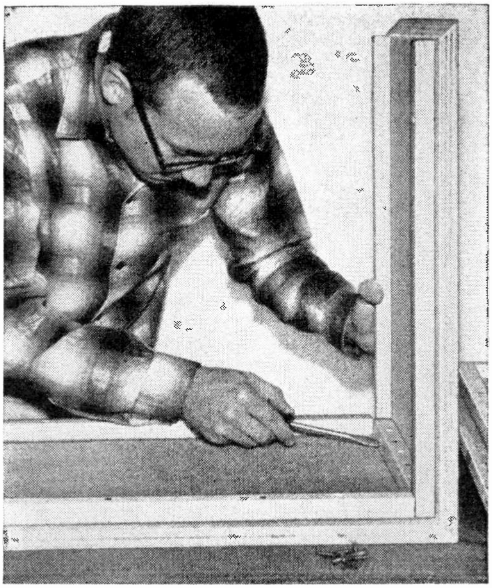


Fig. 3. Attach all cleats and glue blocks; glue and screw together top, bottom, and sides of enclosure.

[As was mentioned before in "Tune Up Your Bass Reflex" (Spring '69 EEH), many experts recommend tuning a bass reflex enclosure to a frequency above that of the speaker when the speaker's resonance is very low. Thus, the chance of "weak" bass is avoided by the simple expedient of enlarging the port.]

If this enclosure performs as though it were one-third larger than it really is, something has to give—in this case it's efficiency. After all, you can't get something for nothing. The loss in efficiency is due to the fact that a stuffed enclosure absorbs more power than a conventional bass reflex enclosure of larger volume. However, if space is a problem, you will most likely be happy to make the trade.

Construction. Assembling the system after all of the parts have been cut to the sizes illustrated in Fig. 1 and specified in the Bill of Materials is fairly simple. In effect, you just put together a box, install a speaker, and drop in the proper amount of stuffing.

The walls of the enclosure are ¾"-thick plywood, joined together with glue and screws through the corner blocks. The top edges of the sides, and the edges of the top that mate with the sides, should be miter cut to 45° angles. If you do not have the equipment for making miter cuts, you can employ butt-joint construction. However, make absolutely certain that whichever method you use you maintain the same inner dimensions shown in the illustration.

Begin construction by attaching cleats to the bottom and cleats and glue blocks to the sides of the enclosure as shown in Fig. 2. Then join the top and one side together (Fig. 3) with glue and screws, driving the screws through the corner block and into the top plate. Glue and screw the other side in place.

Invert the assembly, coat mating surfaces with glue, and attach the bottom. Note that the bottom butts against the inner walls of the sides. It can be secured in place with nails driven through the bottom into the cleats, followed by screws for greater strength. The nails will hold the parts in place while the screws are being installed.

Apply a coat or two of flat black paint to the outer surface of the speaker mounting board and the edges of the

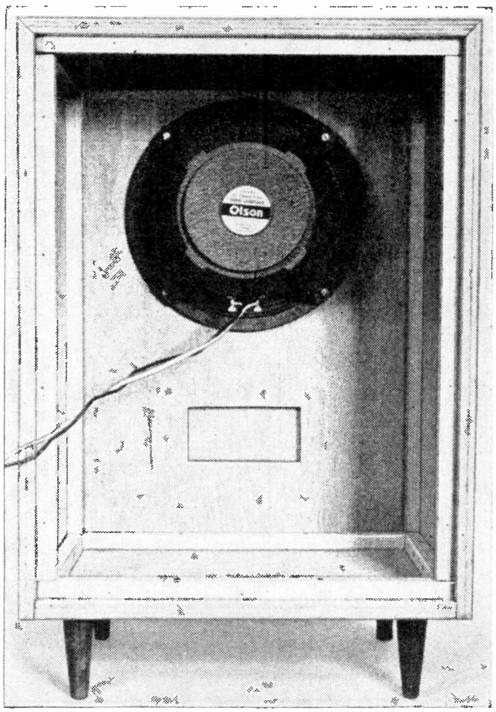
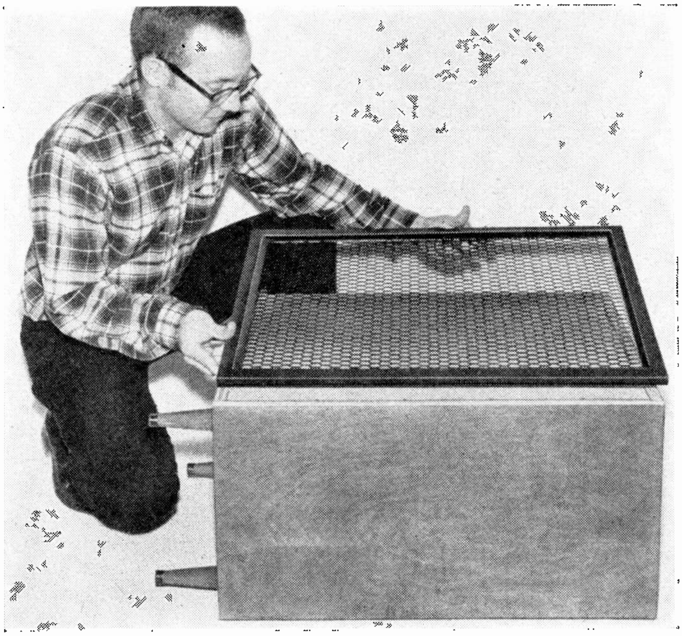


Fig. 4. After enclosure is assembled, attach furniture legs to bottom and install speaker as shown.



Expanded aluminum grille/picture-frame assembly goes into place only after grille cloth has been tacked onto speaker mounting board. You can use wire brads or ornamental screws to fasten the assembly down.

speaker and port cutouts. Then install the speaker mounting board in the enclosure with glue and screws. Affix a set of 4″ furniture legs to the bottom of the enclosure as shown in Fig. 4. Then tack your choice of grille cloth and trim in place, and sand, stain and varnish the enclosure.

If you decide to use large-pattern expanded aluminum to set off the grille cloth, plan space for it behind the front trim. An easy method of accommodating the expanded aluminum is to employ picture-frame molding with a 3/16″ rear groove. The groove is just the right depth for the job.

Now, for a striking appearance, you might want to paint the molding flat black and use a brightly colored grille cloth. Decorator burlap is attractive—and inexpensive. When installing the grille cloth, stretch it slightly before tacking it in place.

Use a thick, "hard-set" cement (such as liquid solder) to secure the expanded aluminum to the picture-frame molding. Then attach the grille assembly to the front of the enclosure with finishing nails and cement or with ornamental screws.

Set the enclosure flat on its front, install the speaker with panhead screws, and solder a length of zip cord to the speaker terminals. Now, fold each of the packages of fiberglass stuffing into three equal layers. Cut a hole through the center of all three layers of one package of fiberglass, pass the zip cord and control through the hole, and lay the fiberglass flat over the speaker in the enclosure. Do the same with the remaining two packages of fiberglass. There is no need to tack the fiberglass in place; it is stiff enough to stand unsupported when the rear wall is screwed down.

Do not substitute any other brand of fiberglass fill unless you are prepared to perform tests to determine exactly how much of the substitute to use. The reason is that fiberglass is available in various densities, and each density requires more or less fill. Also, remember that three packages of the fiberglass fill specified in the Bill of Materials must be used inside each enclosure.

Finally, mount the control and bring out the speaker leads through holes drilled through the rear wall of the enclosure. Then fill in the hole through which the speaker wire exits with cement to maintain an air-tight enclosure, and fasten it down with screws.

That's it! Connect the speaker system to your amplifier, and you're ready to enjoy room-filling sound. —30—

your own private OWL

AUTOMATIC "OUTSIDE WELCOME LIGHT" TO GREET YOU AND YOUR FRIENDS

BY JAMES A. ARCHER

PUT AN OWL in your driveway! Not an owl that goes "who" at you but an OWL (Outside Welcome Light) that turns on the front- or back-porch light when you pull the car into the driveway and turns it off again after you're safely in the house. That way you don't have to stumble over the kid's toys on the porch steps or fumble for your keys in the dark.

The OWL will also greet a visitor when he turns his car into your driveway and the system can even be hooked up to your front doorbell to turn on the light when the bell is pushed.

The system is activated when the photocell, mounted near the driveway is momentarily illuminated by the headlights of a car. It is designed to respond only to a sudden increase in light—and is not activated by daylight.

The principal components in the OWL are a resistor photocell, an SCR, two relays and a unijunction timing circuit. The device is relatively easy to construct and should cost no more than $25.

Construction. The system is in two major sections: a control circuit and a power supply. Each is housed in a 3" × 4" × 5" metal enclosure, although any other method of packaging can be used (both circuits can be placed in one large package, for instance). The control circuit is shown in Fig. 1. When wired point-to-point on a perf board, it is as shown in Fig. 2. Resistor *R4* determines the sensitivity of the overall system, and its value is selected to suit the particular installation. A good value to start with is 10,000 ohms. Once the circuit has been wired and checked for possible wiring errors, the perf board is mounted in its chassis with spacers at each corner. A seven-terminal barrier strip can be used to make connections to the external circuits.

Power relay *K2* is usually mounted close to the point where the power is actually to be switched. Put it in a small metal enclosure and connect its coil to the control circuit as shown in Fig. 1.

The schematic of the power-supply circuit is shown in Fig. 3. Also shown are the optional circuit for the doorchime system and its associated components. The two outputs are 20 volts d.c. and 15 volts a.c. The former is used by the control circuit; the latter by the chime coils. If you are not using the doorchime arrangement, do not use *D3, D4, R1,* and *C2* in the power supply. Diode *D3* can also be eliminated from the

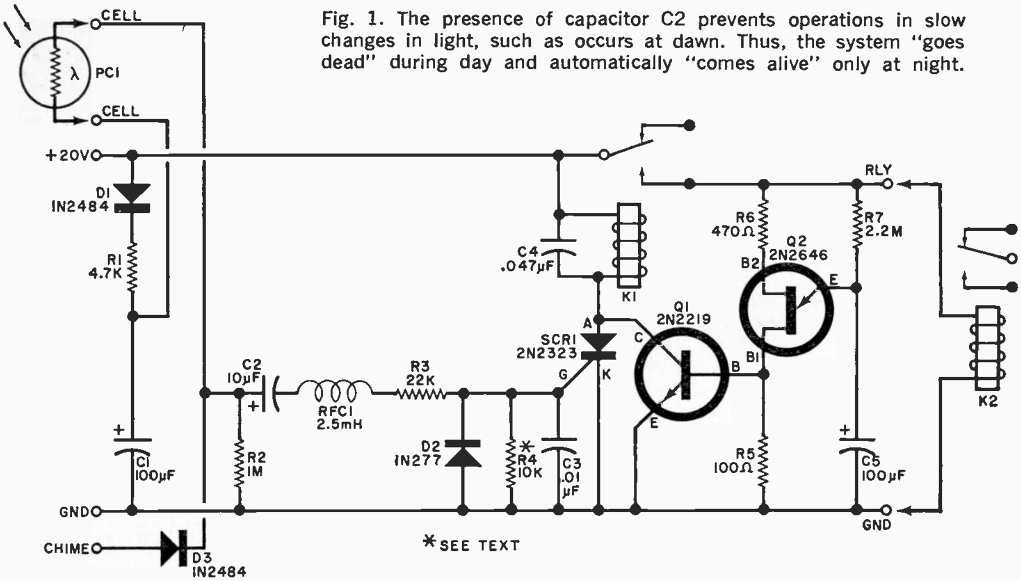


Fig. 1. The presence of capacitor C2 prevents operations in slow changes in light, such as occurs at dawn. Thus, the system "goes dead" during day and automatically "comes alive" only at night.

PARTS LIST

C1,C5—100-µF, 25-volt electrolytic capacitor
C2—10-µF, 25-volt electrolytic capacitor
C3—0.01-µF, 25-volt capacitor
C4—0.047-µF, 25-volt capacitor
D1,D3—1N2484 diode
D2—1N277 diode
K1—24-volt d.c. coil, single-pole relay
K2—10-ampere, 24-volt d.c. coil, enclosed relay (Knight KN115-1C-24D or similar)
PC1—Cadmium-sulphide photocell (Lafayette 19T2101 or similar)
Q1—2N2219 transistor
Q2—2N2646 unijunction transistor
R1—4700-ohm
R2—1-megohm
R3—22,000-ohm
R4—10,000-ohm (see text)
R5—100-ohm
R6—470-ohm
R7—2.2-megohm
(All resistors ½-watt)
RFC1—2.5-mH r.f. choke
SCR1—2N2323 silicon controlled rectifier
Misc.—3" x 4" x 5" metal enclosure; 7-terminal barrier strip (or similar); 7-pin tube socket for K1; spacers; mounting hardware; small, clear plastic medicine (pill) bottle; clear potting compound; length of weatherproof twin-conductor cable; pipe (optional); 22,000-ohm resistor (optional shunt); etc.

control circuit. Figure 4 shows the layout that the author used for the power supply.

If you are using the doorchime option, remove the existing low-voltage transformer from the chime circuit. The low-voltage for the chimes is taken from *T1* in the power supply. Mount *D3, D4, R1,* and *C2* on a terminal strip within the chime case. Use a multi-contact barrier strip to make connections to the external circuit.

The photocell can be mounted in any place where it will catch the direct beam of the car headlights. This may be indoors or outside; but if it is to be mounted outside, the photocell must be made weatherproof. To accomplish this, connect a piece of heavy-duty outdoor cable to the control-circuit chassis and cut the cable long enough to reach the mounted position of the photocell. Carefully strip and solder the outside ends of the cable to the photocell. Insulate the soldered connections with electrical tape.

To protect the photocell completely, it must be encased in a transparent mold, but this is not as difficult as it seems. Start with a small plastic pill bottle. If the bottom of the bottle is less than ¼" thick and reasonably transparent, seat the sensitive surface of the photocell on the bottom inside of the bottle. Fill the tube with epoxy glue or other transparent potting compound. Of course, any other type of mold can be used—just make sure that not more than ¼" of the transparent potting compound covers the sensitive surface of the photocell. Otherwise, light sensitivity may be hampered.

The outside of the finished mold can be painted black (or any other dark col-

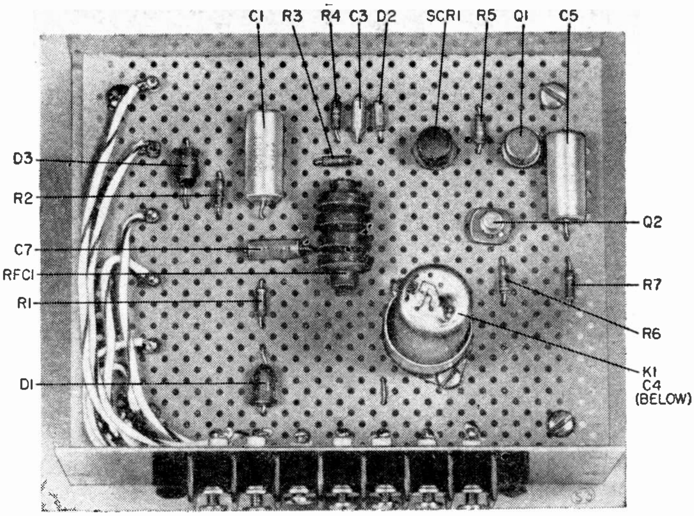


Fig. 2. Though the author used perf-board construction with layout shown, most any construction technique is sufficient.

or) to reduce light pickup from the sides. If the cell must be highly directional, the mold can be mounted at the end of an open length of pipe or tubing so that the pipe can be aimed in the desired direction. Be sure the potting compound covers an inch or two of the cable to make a good weatherproof seal.

When the entire system has been checked out for possible wiring errors, connect it together as shown in Fig. 5. This diagram also shows two ways of connecting *K2* to existing wiring for the outside light. All external electrical wiring must conform to your local electrical codes.

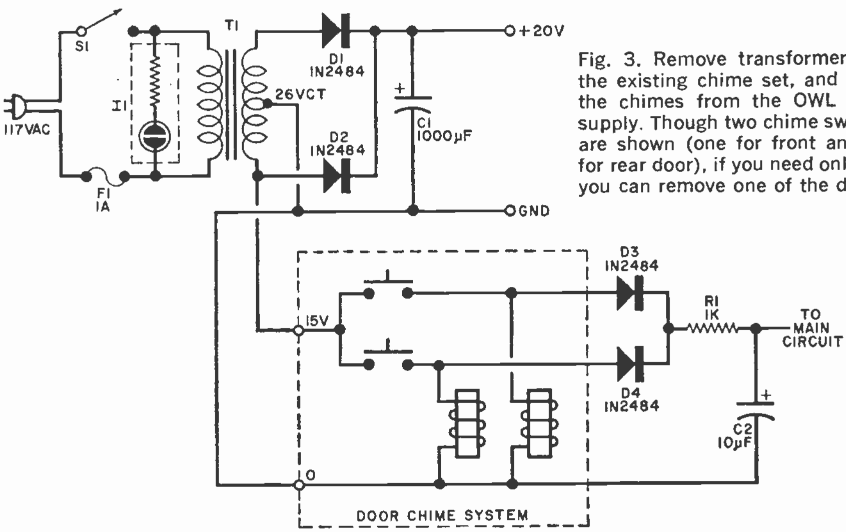


Fig. 3. Remove transformer from the existing chime set, and power the chimes from the OWL power supply. Though two chime switches are shown (one for front and one for rear door), if you need only one, you can remove one of the diodes.

PARTS LIST

C1—1000-µF, 25-volt electrolytic capacitor
C2—10-µF, 25-volt electrolytic capacitor
D1-D4—1N2484 diode
F1—1-ampere fuse and holder
I1—117-volt neon lamp assembly (optional)
R1—1000-ohm, ½-watt resistor
S1—S.p.s.t. switch
T1—Power transformer, 26.8-volt, 1-ampere secondary (Triad F-40X or similar)
Misc.—Doorchime assembly (internal low voltage transformer removed, see text); suitable metal enclosure for power supply; mounting hardware; 4-terminal barrier strip; etc.

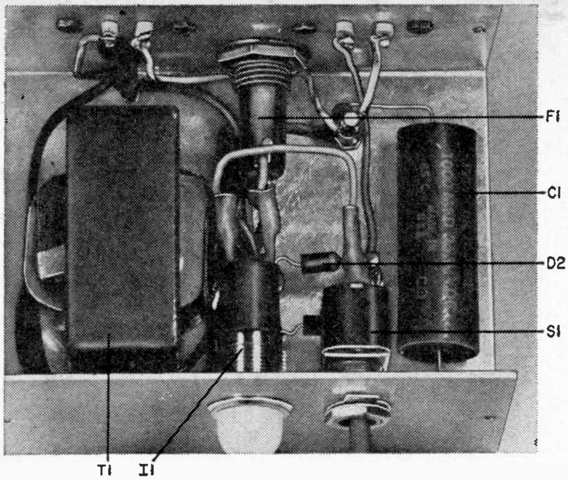


Fig. 4. The power supply can be built in one end of the chassis and made compact.

Testing and Use. Before making any tests, it is suggested that *R7* (2.2 megohms) of the control circuit be shunted by a 22,000-ohm resistor to speed up the response time of the system. This temporary modification reduces the normal 5-minute response time to a few seconds.

With the system hooked up and connected to a power source, connect a conventional lighting fixture to the contacts of *K2* as shown in Fig. 5. The light should be off. Place the palm of your hand over the sensitive surface of the photocell and aim the photocell toward a source of light. When you remove your hand, the relay should be energized and the light should come on. The light should remain on for a few seconds and then automatically turn off, even if the photocell is still exposed to the ambient light. If the circuit works properly under these conditions, remove the temporary resistor across *R7* to restore the 5-minute delay.

(*Continued on page* 106)

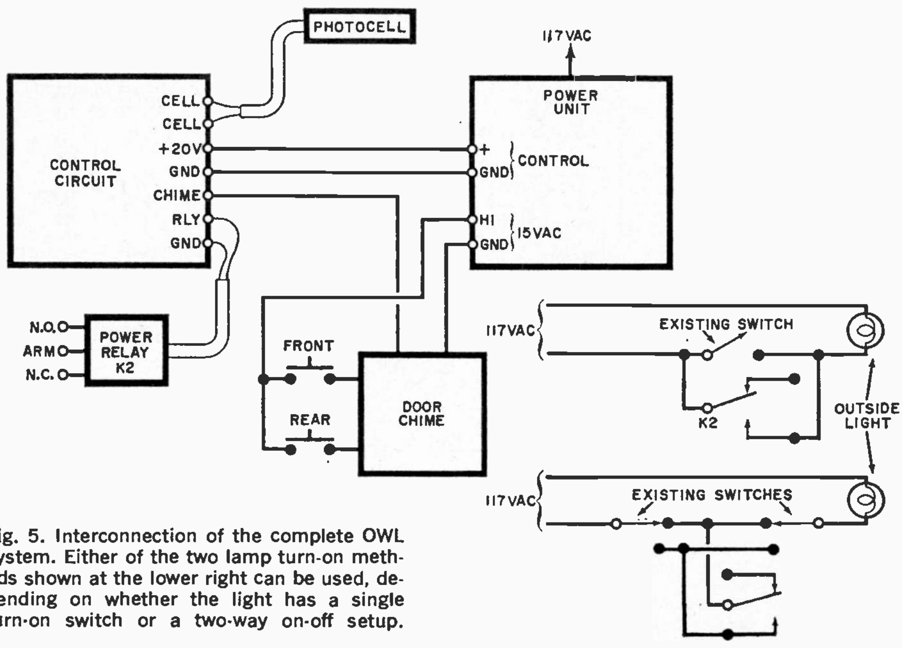


Fig. 5. Interconnection of the complete OWL system. Either of the two lamp turn-on methods shown at the lower right can be used, depending on whether the light has a single turn-on switch or a two-way on-off setup.

HOW IT WORKS

Photocell *PC1* and resistor *R2* are connected together to form a voltage divider. The photocell is a light-sensitive variable resistor whose resistance changes from about 15 megohms when it is in total darkness to less than 1000 ohms when it is exposed to a bright light. As a result, the voltage applied to *C2* ranges from 1.5 volts when *PC1* is in darkness to about 20 volts when *PC1* is in bright light. Capacitor *C2* blocks the steady-state d.c. from the rest of the circuit so that, under normal conditions, there is no gate signal on *SCR1*.

When *PC1* is abruptly illuminated, the voltage on *C2* rises sharply and is applied to the gate of *SCR1* as a positive going pulse. The SCR is turned on by the pulse and relay *K1* is energized. When *K1* is energized, power is supplied to energize *K2*, whose contacts can carry the current required by the outside light, and to the timing circuit consisting of *Q1* and *Q2*. The emitter circuit of *Q2*, a unijunction transistor, takes about five minutes to charge up to the point where *Q2* fires. Once *Q2* fires, the drop across *R5* turns on *Q1*. With *Q1* conducting, the drop across the SCR is lowered and the SCR is turned off and relay *K1* is de-energized.

Diode *D1*, resistor *R1*, and capacitor *C1* form a decoupling network to prevent accidental triggering from power line transients. R.f. choke *RFC1* and capacitor *C3* prevent false triggering by r.f. interference. Diode *D2* shunts negative-going pulses, while *R3* and *R4* determine circuit sensitivity.

Activation of the doorchime system is essentially similar, in that a voltage pulse is applied to *C2* from the chime circuit rather than from the photocell circuit. When the doorchime circuit is activated during the daytime, the voltage at *C2* is already high due to the low resistance of the photocell so no voltage pulse can occur and the system remains off.

Retest the system. Now the light should remain on for five minutes or so before switching off.

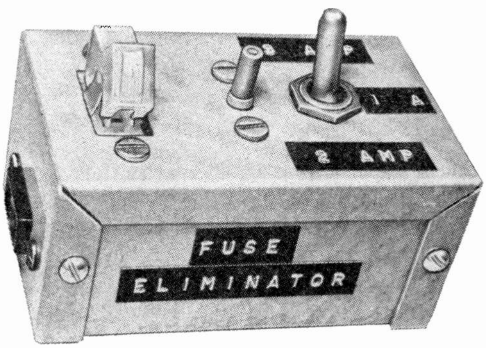
Install the photocell where it can "see" an automobile headlight as the car comes up your driveway. Make sure that it cannot see any random headlights due to traffic in the street. Install the electronics in a protected area where they won't get wet and connect the photo cell to the circuit using the weatherproof cable.

If you find that the system needs more sensitivity (depending on your car's headlights and the location) increase the value of *R4* in the control circuit. If the system is too sensitive, decrease *R4*. –30–

NO MORE FUSES

BY NEIL JOHNSON

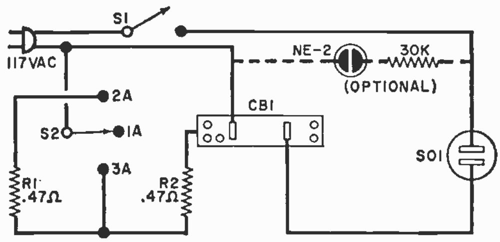
ONE CIRCUIT BREAKER, THREE CURRENT RANGES



TO SAVE TIME and trouble, most electronics experimenters are turning to circuit breakers as substitutes for fuses. When a fuse blows, you have to hunt around for the correct replacement—it's easy to make a mistake, too, since different current ratings come in the same physical size. With a circuit breaker, all you have to do is push the reset button when the cause of trouble has been eliminated.

Circuit breakers do have one drawback. When you install one in your bench wiring, it has one definite current rating. In working with instruments and equipment of different wattage ratings, you may be too far over or under the breaker rating. By adding a couple of low-cost resistors and a switch, you can now make a multi-current circuit breaker that can be preset for several ratings.

Construction. The heart of the circuit, as shown in Fig. 1, is the breaker, in this case a conventional 1-ampere thermal type used in many TV sets. The resis-



PARTS LIST

CB1—1-ampere thermal circuit breaker (Workman FA1 modified as described in text)
R1, R2—0.47-ohm, 5-watt resistor (see text)
S1—S.p.s.t. switch to carry 360 watts
S2—S.p.d.t. switch, center off, to carry 3 amperes
SO1—117-volt outlet
Misc.—Suitable enclosure, 117-volt line cord with plug, NE-2 neon lamp with 30,000-ohm resistor (optional), mounting hardware.

Fig. 1. One circuit breaker can be made to trip at three different ratings by using it as is, or adding low-value resistors in parallel with internal resistance.

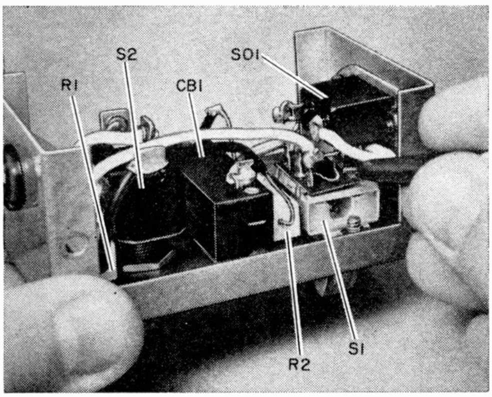
tance of the thermal portion of the breaker is 0.96 ohm. To increase its current carrying capability, a one-ohm resistor can be connected across the resistor part of the breaker. To increase the current rating even farther, a ½-ohm resistor can be connected across this portion.

To make the necessary modifications to the circuit breaker, observe that on its back side, one end has two rivets and a soldering lug while the other end has only one rivet and a soldering lug. The modification is made at the end with two rivets. Looking at the end of the breaker adjacent to the two rivets, you will see a U-shaped cutout in the plastic. At the top of this channel is the end of a piece of metal (not to be confused with the metal front cover).

Using a large needle or the end of a small scribe, carefully clean the surface of this metal. Then tilt this end of the breaker down and tin the clean metal area, being careful not to overheat the breaker (use a 40- to 60-watt iron or gun). Prepare a small piece of wire by stripping off ¼" of insulation and tinning the exposed wire. Form the tinned end of the wire into a small loop and sweat solder it to the previously prepared metal piece on the breaker. Do not apply too much solder to this joint since it could act as a thermal sink.

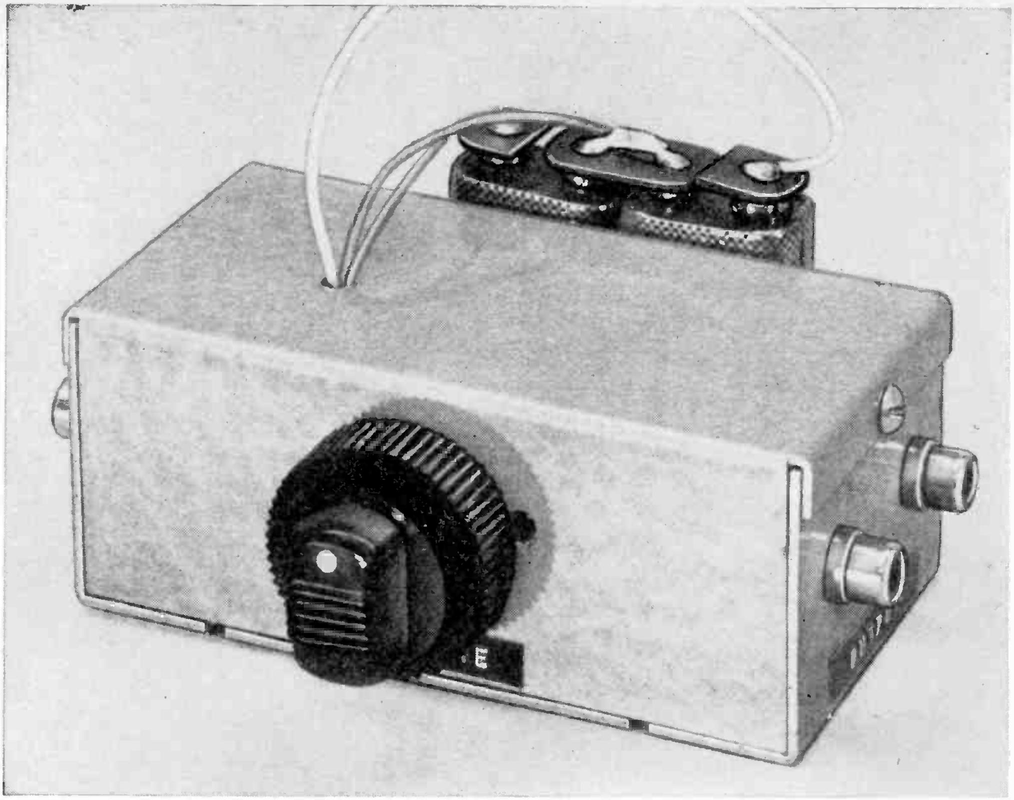
As shown in the photographs, the author mounted the circuit breaker in a small metal enclosure, though any other mounting method can be used. Mount the on-off switch *S1*, circuit breaker *CB1*, current-selector switch *S2*, and power outlet socket *SO1* as desired. If you want a "power on" indicator, connect an NE-2 neon lamp and a 30,000-ohm resistor in series across the terminals of *SO1*.

The author used a pair of Workman model WT47 current limiting resistors for *R1* and *R2*. However, a pair of 1-ohm, 2-watt conventional resistors in parallel can be substituted for either one. Leave at least a 1/16" space around the resistors to avoid heat transfer to the breaker.



Inside view of the author's prototype. Make sure air can circulate between the power resistors (R1 and R2) and heat-sensitive thermal circuit breaker.

Operation. In use, the modified breaker will open at either 1, 2, or 3 amperes, depending on the setting of the selector switch. These current ratings are roughly equivalent to 120, 240 and 360 watts, respectively and are suitable for most applications. The "carrying" capacity is approximately 65% of the break rating—or 75, 150, and 225 watts, respectively, on 117 volts a.c. If reactive loads are applied, don't be surprised if the breaker opens sooner than expected. This is due to high instantaneous currents—which, incidentally, will cause a fuse of the same rating to blow. —30—



IC Stereo Preamplifier

PROVIDES HIGH-QUALITY AMPLIFICATION FOR NAB TAPE, RIAA PHONO, AND BROADBAND AUDIO

BY PAUL B. JARRETT, M.D.

DO YOU need a good, new stereo preamplifier with all kinds of "extras"? Here is an IC Stereo Preamp that has provisions for NAB tape-head equalization (for both 3¾ and 7½ in./s) and RIAA magnetic phono inputs. It can also be used as a general-purpose broadband preamplifier.

Built around a recently developed integrated circuit, the preamplifier has very low input noise (half a microvolt, typically), an output of 4.5 volts r.m.s., and a channel separation of 60 dB minimum at 10 kHz. The design is also short-circuit proof. The preamp is small enough to fit under the chassis of a small power amplifier. Power requirements are so modest that the preamp can be driven by a pair of transistor radio batteries if desired.

The integrated circuit used here (Motorola MC1303L) actually contains a matched pair of preamp circuits with identical characteristics.

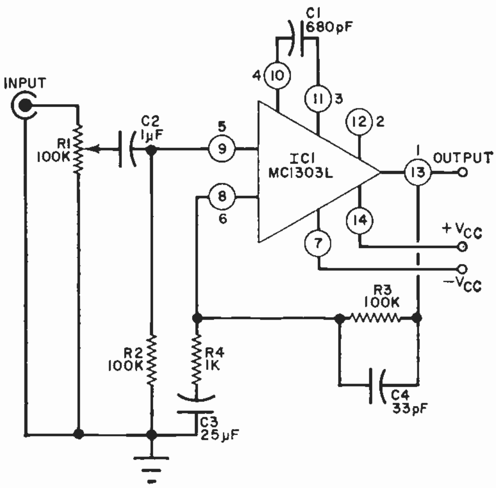


Fig. 1. The general-purpose broadband preamplifier is useful for microphone and tuner inputs. Only half of stereo system is shown in all diagrams.

PARTS LIST

*C1—680-pF capacitor**
*C2—1-μF, 3-volt electrolytic capacitor**
*C3—25-μF, 3-volt electrolytic capacitor**
C4—33-pF capacitor
IC1—Dual stereo preamplifier integrated circuit (Motorola MC1303L)
R1—Dual (concentric), audio-taper, 100,000-ohm potentiometer
*R2,R3—100,000-ohm, ½-watt resistor**
*R4—1000-ohm, ½-watt resistor**
Misc.—RCA phono jacks (4), 14-contact, in-line IC socket (Augat 314-A61D or similar), metal chassis, perf board, set of concentric knobs, wire, etc.
**Two required—one for each channel.*

Circuits. For a broadband, general-purpose preamplifier, use the circuit shown in Fig. 1. Only half of the circuit is shown with the terminal connections to the IC shown in the circles. For the second channel, duplicate the circuit, but use the IC pin numbers that are outside the circles in Fig. 1. Note that pins 2 and 12 are not used and that the volume controls for the halves are concentric.

For an NAB tape-head equalized preamp, use the circuit shown in Fig. 2. Again, only half of the circuit is shown, connected to the circled pin numbers of the IC. The duplicate half of the circuit uses the uncircled pin numbers. The value of *C4* depends on the tape speed. Both values are given in the Parts List and you can use both, with a switch, if necessary.

To make a magnetic phono playback preamp with RIAA equalization, use the circuit in Fig. 3. If you have trouble obtaining the 750,000-ohm resistor used in this circuit, use one of 820,000 ohms.

Construction. The author used perf board construction in a small aluminum case. With a little care, you could also build your own printed circuit board and mount the complete preamp in any type of chassis. You can even mount it on standoffs in the power amplifier and probably obtain operating power from the amplifier power supply.

To prevent possible damage to the IC, you may find it advantageous to use a 14-contact, in-line IC socket (see Parts List for Fig. 1). You can then complete the wiring of the circuit and examine it for possible errors without subjecting the IC to the possibility of heat damage or accidental voltage reversal. Note that the IC has a standard orientation mark on one end. Looking down at the top of the IC, the pins are numbered from 1 to 14

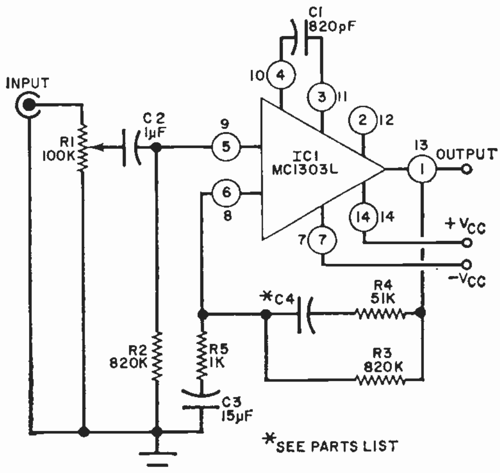
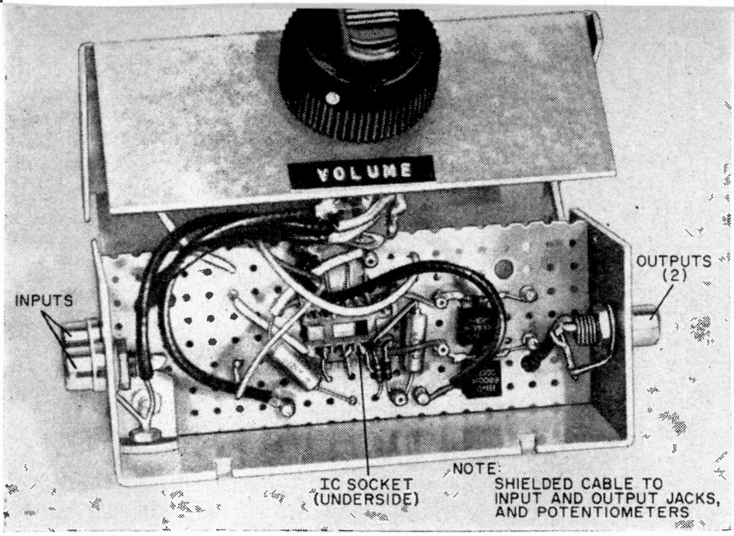


Fig. 2. This NAB tape-head equalized preamp can be preset for either 3¾ in./s or 7½ in./s depending on value selected for C4 (can be switch selected).

PARTS LIST

*C1—820-pF capacitor**
*C2—1-μF, 3-volt electrolytic capacitor**
*C3—15-μF, 3-volt electrolytic capacitor**
C4—1500-pF capacitor (3¾ in./s, see text)*
C4—910-pF capacitor (7½ in./s, see text)*
IC1—Dual stereo preamplifier integrated circuit (Motorola MC1303L)
R1—Dual (concentric), audio-taper, 100,000-ohm potentiometer
*R2,R3—820,000-ohm, ½-watt resistor**
*R4—51,000-ohm, ½-watt resistor**
*R5—1000-ohm, ½-watt resistor**
Misc.—See Fig. 1.
**Two required—one for each channel*



The IC preamplifier can be fabricated on perf board. A 14-lead in-line socket may be used to save possible damage to IC while soldering it into the circuit. Use shielded leads for the input and output, and to (coaxial) potentiometers.

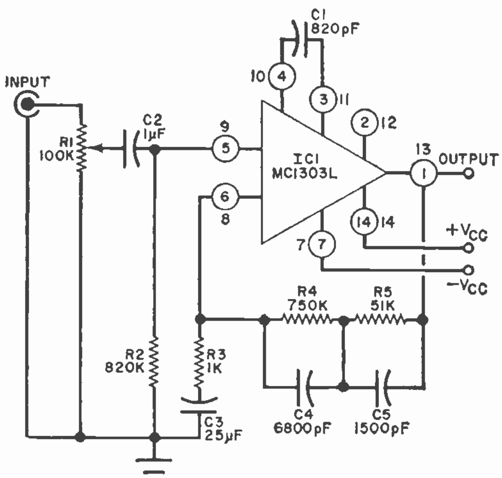


Fig. 3. This circuit is used for RIAA equalization for magnetic phono playback. A slight change in R4 value can be made (see text) without doing harm.

PARTS LIST

*C1—820-pF capacitor**
*C2—1-μF, 3-volt electrolytic capacitor**
*C3—25-μF, 3-volt electrolytic capacitor**
*C4—6800-pF capacitor**
*C5—1500-pF capacitor**
IC1—Dual stereo preamplifier integrated circuit (Motorola MC1303L)
R1—Dual (concentric), audio-taper, 100,000-ohm potentiometer
*R2—820,000-ohm, ½-watt resistor**
*R3—1000-ohm, ½-watt resistor**
*R4—750,000-ohm, ½-watt resistor**
*R5—51,000-ohm, ½-watt resistor**
Misc.—See Fig. 1.
**Two required—one for each channel.*

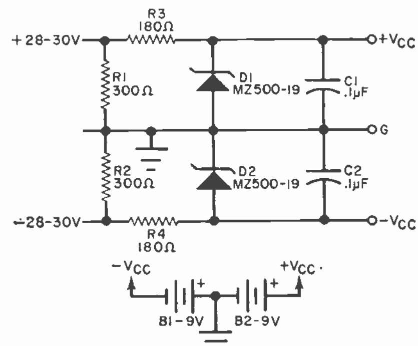


Fig. 4. The preamplifier can be powered either by a zener-regulated circuit (top) or a pair of nine-volt conventional transistor radio batteries (lower).

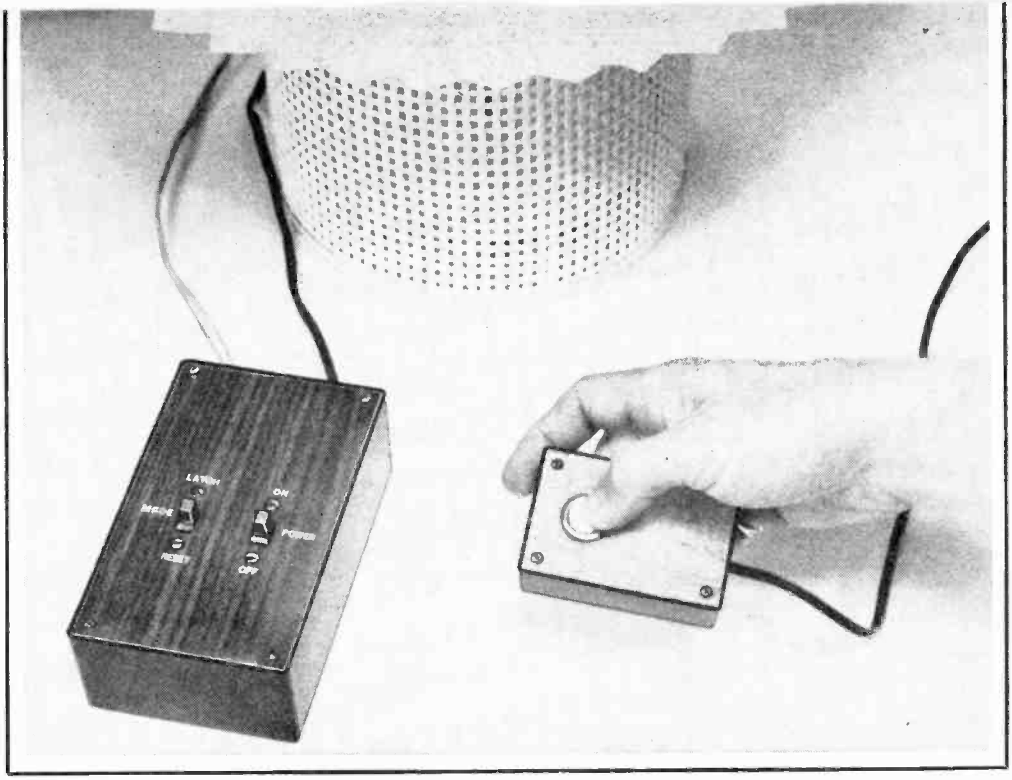
PARTS LIST

B1,B2—9-volt transistor radio battery (optional)
C1,C2—0.1-μF capacitor
D1,D2—Zener diode, 13-volt (Motorola MZ-500-19 or similar)
R1,R2—300-ohm, 3-watt resistor
R3,R4—180-ohm, 2-watt resistor

counterclockwise from the identifying mark.

The entire circuit, with the exception of the input and output jacks and the concentric volume control, is constructed on the perf (or PC) board. Use shielded leads between the input and output connectors and the potentiometer, and between the potentiometer and the first component in the circuit.

For a power supply, the author used a pair of 9-volt transistor batteries. The two batteries were connected in series, with the common center connected to ground. The $+V_{CC}$ was then +9 volts and $-V_{CC}$ was −9 volts. If you are using a conventional power amplifier with a power supply of 28 to 30 volts, use the reduction circuit shown in Fig. 4. —30—



BUILD WWRC

SUPER-SENSITIVE "WIRED WIRELESS REMOTE CONTROL" IS ALL SOLID STATE

BY JOHN S. SIMONTON, JR.

HOW DO YOU install a burglar alarm when the area to be protected (garage, storage building, etc.) is at some distance from where the alarm is to be located? The obvious answer is to install wiring between the two points. That's fine, as long as you can do it. Sometimes, however, it is a physical impossibility or is not permitted by regulations or laws.

The Wired Wireless is a communications system which takes advantage of the fact that in the majority of cases, good, concealed wiring does in fact exist between any two points in a building complex. These are the commercial power lines used to carry electricity. Although these lines are designed for 60-Hz power,, it is possible to pass somewhat higher frequencies through them for a reasonable distance. (Note that the Wired Wireless cannot be used between two points if there is a transformer anywhere in the power line between them.)

There are two sections to the Wired Wireless. One is a small, self-powered transmitter which is coupled to the power line. When it is turned on by a triggering signal, it generates another signal which activates a remote receiver also coupled to the same power line. The second section is the receiver. When it gets the signal from the transmitter, an internal relay is energized. The action of the relay can be used to set off an alarm or any other type of signal device.

The Wired Wireless can also be used

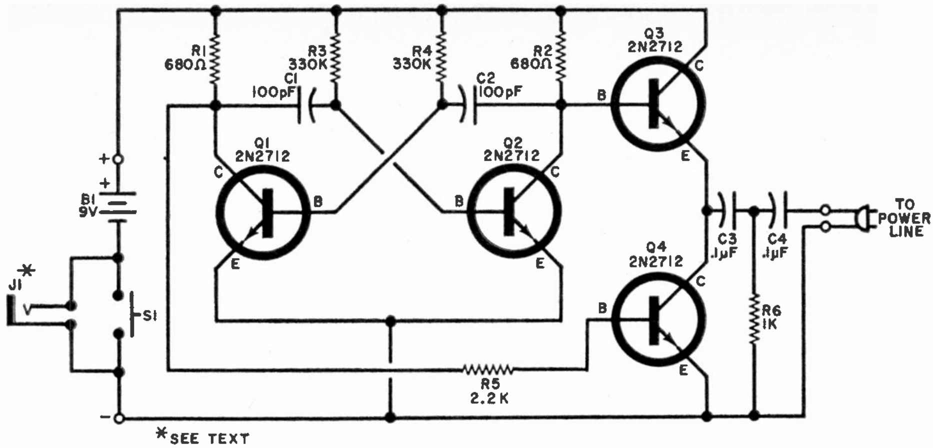


Fig. 1. Power is applied only when S1 (or J1) is closed. The multivibrator then generates a high-frequency audio signal which is passed down the power line to the receiver.

PARTS LIST

B1—9-volt battery
C1,C2—100-pF disc capacitor
C3,C4—0.1-μF disc capacitor
J1—Open-circuit miniature jack (optional)
Q1-Q4—2N2712 transistor
R1,R2—680-ohm, ¼-watt resistor
R3,R4—330,000-ohm, ¼-watt resistor
R5—2200-ohm, ¼-watt resistor
R6—1000-ohm, ¼-watt resistor
S1—Normally open pushbutton switch
Misc.—Plastic case approximately 3" x 2" x 1", case cover, battery clip and leads, line cord with plug, wood-grain contact paper (optional), mounting plastic, cement, etc.
Note—An etched and drilled PC board for 95¢ or a complete kit of parts including circuit board and case and either jack input (WW-2JO) or pushbutton input (WWT-2S) for $5.95 is available from PAIA Electronics, P.O. Box 14359, Oklahoma City, Okla. 73114. Postpaid in continental U.S. Oklahoma residents add 3% sales tax.

for non-alarm purposes to turn on appliances or lights from remote locations or as a signalling device such as those used by a sick person confined to bed.

Transmitter Construction. The circuit for the transmitter is shown in Fig. 1. The components are small in size and number and are best assembled on a printed circuit board. A foil pattern for such a board is shown in Fig. 2. Note that, because of their small size, ¼-watt resistors are used rather than the more common ½-watt units, though the latter may be used if desired. Component mounting is shown in Fig. 3. Because of the small size of the assembly, be careful not to damage the components with heat when soldering.

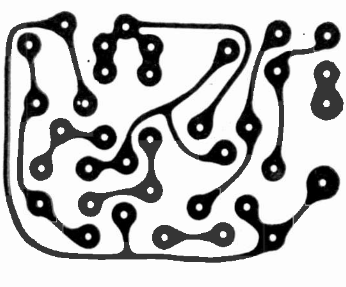


Fig. 2. Actual-size printed circuit foil pattern used for the receiver.

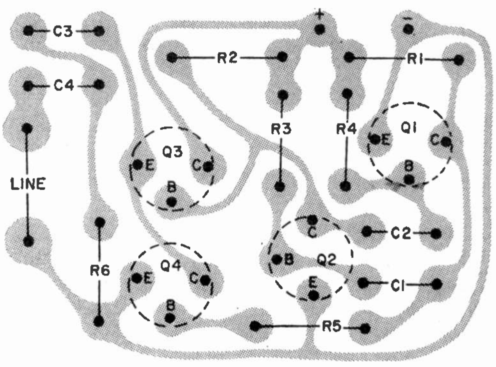
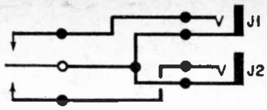


Fig. 3. Install components as shown here. The use of miniature parts helps make for a small package.



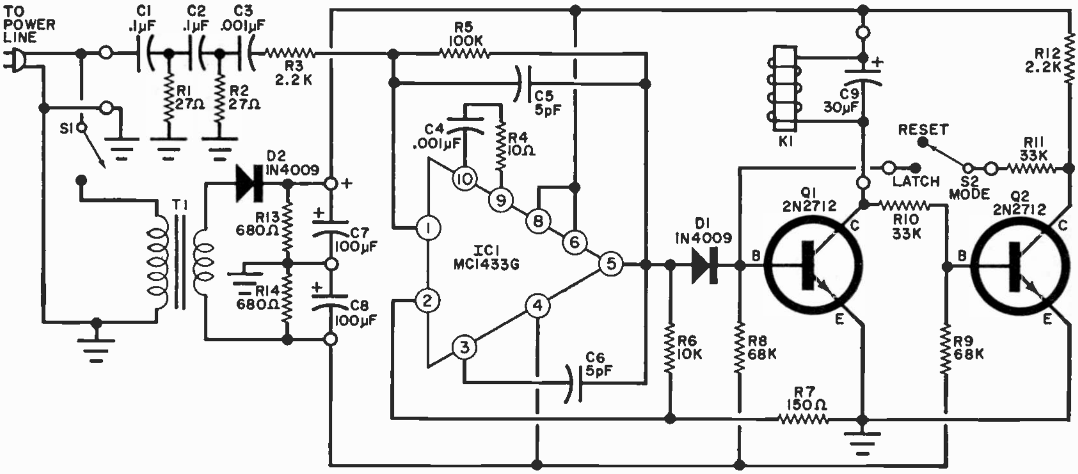


Fig. 4. The receiver is built around a new IC driving a latching circuit. To avoid switching transients, only the power transformer is switched in and out of the circuit. The relay contacts can operate an alarm, low-power light, or a power relay.

In the author's prototype, the PC board was glued to a thin piece of plastic foam material which, in turn, was glued into a small plastic case. Use either a silicon rubber cement or epoxy rather than a plastic cement as the latter may damage the plastic foam. Make sure that you leave enough room for the battery and its connector and for pushbutton switch *S1*. Carefully drill a small hole in one end of the case to pass the line cord through. Mount the pushbutton switch in the cover and, if you desire, use a wood-grain contact paper to trim the cover. For some applications an optional open-circuit jack can be installed across *S1*.

To test the transmitter, connect an oscilloscope to the prongs of the power-line cord (either side ground) and depress the pushbutton, *S1*. A burst of high-frequency square waves will be seen as long as the switch is depressed.

Receiver Construction. Construction of the receiver is straightforward (see Fig.

HOW IT WORKS TRANSMITTER

There are actually three sections in the transmitter. The first is an astable multivibrator, consisting of *Q1* and *Q2*, which generates a signal of approximately 500 kHz. The second section (*Q3* and *Q4*) is a buffer stage that matches the output of the multivibrator to the low impedance of the power-line output. Section three is a high-pass filter composed of *C3*, *R6* and *C4*, which prevents the output transistors from being affected by the 60-Hz power-line frequency but allows the high-frequency signal from the multivibrator to pass.

The transmitter is powered by an internal battery controlled by normally open pushbutton *S1*. When the pushbutton is depressed, a burst of 500 kHz is passed into the power line; when the pushbutton is released, the output ceases.

PARTS LIST

C1,C2—0.1-µF disc capacitor
C3,C4—0.001-µF disc capacitor
C5,C6—5-pF disc capacitor
C7,C8—100-µF, 10-volt electrolytic capacitor
C9—30-µF 25-volt electrolytic capacitor
D1,D2—1N4009 diode
IC1—Operational amplifier (Motorola MC-1433G)
J1,J2—Miniature open-circuit phone jacks
K1—Relay, 1750-ohm coil (Sigma 65F1A-12DC or similar)
Q1,Q2—2N2712 transistor
R1,R2—27-ohm
R3,R12—2200-ohm
R4—10-ohm
R5—100,000-ohm
R6—10,000-ohm
R7—150-ohm
R8,R9—68,000-ohm
R10,R11—33,000-ohm
R13,R14—680-ohm
(*All resistors ¼-watt*)
S1,S2—S.p.s.t. switch
T1—Filament transformer, secondary 12.6 volts, 300 mA.
Misc.—Plastic case approximately 6" x 3½" x 2" with cover, line cord, wood-grain contact paper (optional), terminal strips, mounting hardware, etc.
Note—An etched and drilled PC board for $1.75 or a complete kit of parts for $15.95 is available from PAIA Electronics, P.O. Box 14359, Oklahoma City, Okla. 73114. Postpaid in continental U.S. Oklahoma residents add 3% tax.

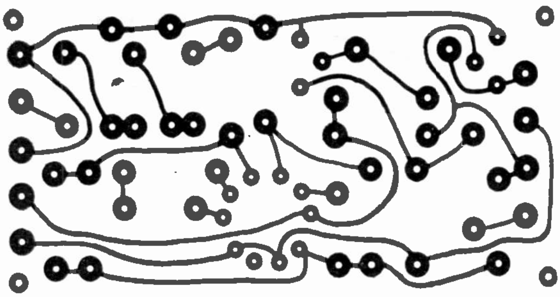
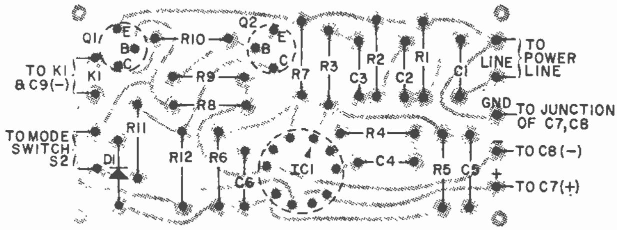


Fig. 5. (Left) Actual-size PC foil pattern for the receiver.

Fig. 6. Install the components as shown below. This diagram also shows connections to the external circuitry. Make sure that IC1 is properly oriented.

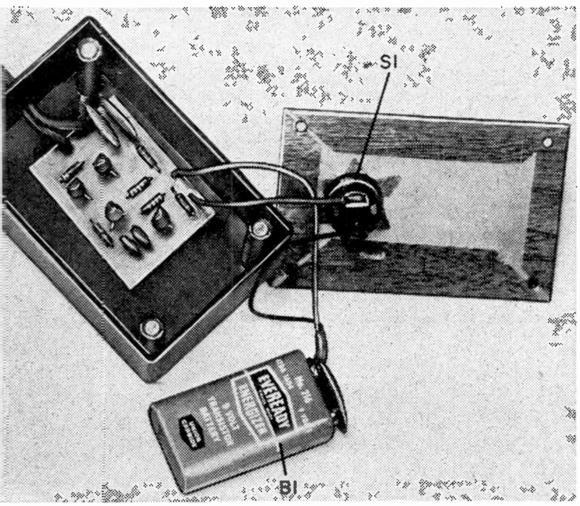


4). However, the use of a printed circuit board is highly recommended since the circuit uses an IC—also because the circuit has a tendency to oscillate if proper component layout is not followed. A foil pattern for the board is shown in Fig. 5 and component mounting in Fig. 6. Be sure the IC is properly oriented before installing it.

Physical placement of the PC board in the case, with relation to the other circuit components, is not critical. In the author's prototype, shown in the photo, the relay, with *C9* attached, is at one end and the power supply components are at the other end with the PC board in the middle. Both the POWER switch, *S1*, and the MODE switch, *S2*, are mounted on the cover with 6″ to 8″ leads connected to them.

Drill a small hole at one end of the case for the power-line cord. Also mount *J1* and *J2* on the end. These two jacks are used to connect external circuits and devices to the relay contacts.

The receiver fits very nicely in the



By using this method of packaging, the transmitter, battery B1, and switch S1 can fit in a small box.

HOW IT WORKS
RECEIVER

The heart of the receiver is an operational amplifier in an integrated circuit, *IC1*. Because of the high-pass filter between the amplifier input and the power-line connection (*C1, R1, C2, R2, C3,* and *R3*) and the negative feedback around the amplifier (*C5* and *R5*), the IC amplifies over a very narrow frequency range, which is chosen to match that of the transmitter.

The circuit gain is increased by positive feedback from *R6* and *R7*. Capacitor *C6* and the combination of *C4* and *R4* are used for frequency compensation and to prevent undesirable circuit oscillation.

After it is amplified by *IC1*, the signal is detected by *Q1*, which also acts as a relay driver. When *S2* is in the LATCH position, the output of *Q1* drives *Q2*, forming a bistable flip-flop. When a signal is received, the flip-flop changes state to keep the relay energized even if the input signal is removed. Diode *D1* isolates the relay driver circuit from the IC circuit.

specified plastic case. As with the transmitter, you can cover the top of the receiver with wood-grain contact paper.

The power transformer is fastened down to the case and the remainder of the power supply components are wired point-to-point on a pair of terminal strips suitably located near the transformer. When wiring to the terminal strips, make sure that you do not use the lugs connected to the mounting strap (the ground lug) as this might make the mounting screw on the underside of the case "hot" to ground and cause a shock.

To prevent voltage surges across the amplifier input each time line power is applied, *S1* is arranged so that it turns on the power supply without changing the amplifier input circuit.

To check the receiver operation, connect it and the transmitter to the same a.c. power circuit. Turn the receiver on, place the MODE switch on LATCH, and depress the transmitter pushbutton. The receiver relay should pick up. Turn the MODE switch to RESET. The relay should drop out when the transmitter pushbutton is released. Once the relay is picked up and the MODE switch is on LATCH, the relay should not drop out when the pushbutton is released.

Applications. The list of uses for the Wired Wireless is practically endless. Signalling systems represent probably the simplest application. In most systems of this type, you will want to use the normally open contacts of the receiver relay to activate a bell, buzzer or electronic alarm such as a Mallory "Sonalert." Power for an alarm with a current drain of 20 mA or less may be tapped from the receiver's internal 18-volt power supply but for devices requiring more current you will need an external power source.

The receiver can be used in the latch mode if the external circuit is to operate continuously once a signal is received. If the receiver is to operate only when the transmitter is activated, use the reset mode. If you are sure that only the reset mode is desired, you can eliminate *S2, R9, R10, R11, R12,* and *Q2* from the receiver circuit. With this modification, the latch mode is entirely eliminated.

The Wired Wireless also makes an ideal general-purpose remote control unit for house or farm. A coffee pot in the kitchen or lights and machinery in an outbuilding may be controlled by a suitable power relay energized through the receiver's relay contacts. If you want a push-on/push-off type of operation, the receiver may be used in the reset mode with *K1*'s contacts activating an impulse relay. For sequencing operations, a stepping relay can be controlled.

Because of the low cost of the transmitter and the elimination of connecting wires, the Wired Wireless is perfect for burglar or fire alarm applications when it is desired to have a number of sensors in different locations.

Sensors. A wide variety of sensors—

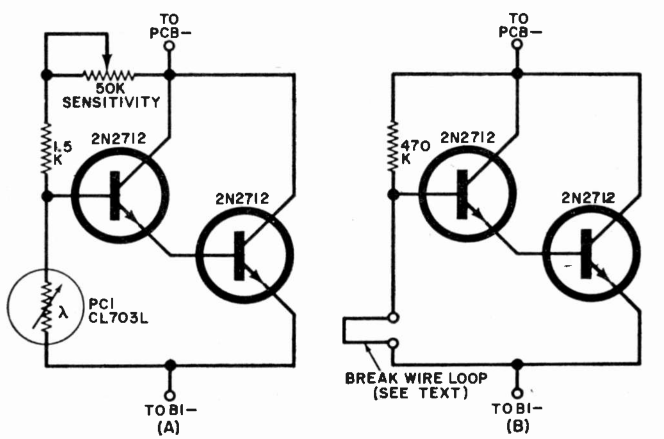
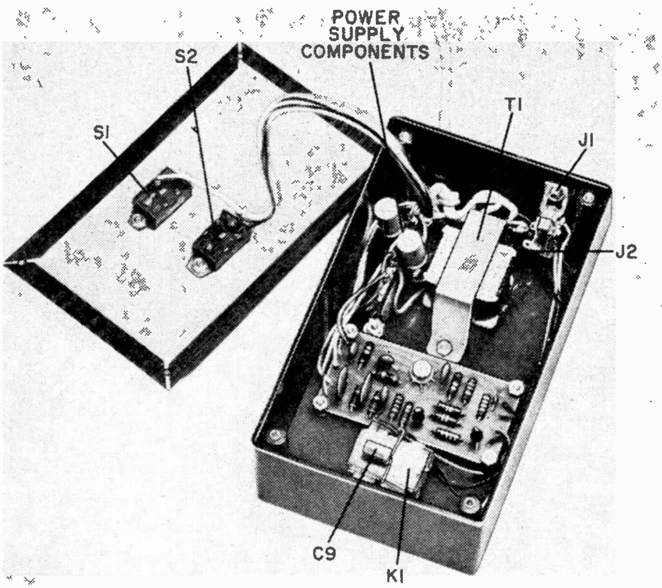


Fig. 7. Here are a couple of suggested sensors. The photoelectric system (A) can be used to protect an opening such as a door or window, while the system shown in (B) is the classic break-wire approach.



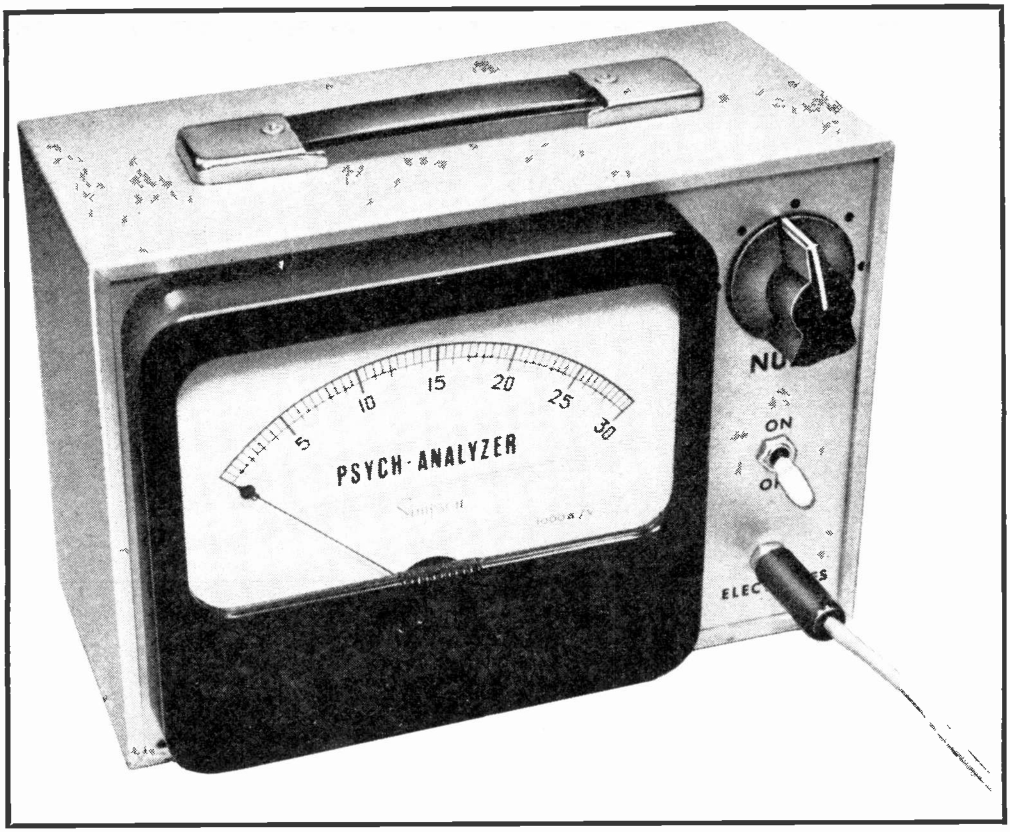
The receiver is larger than the transmitter and contains a power supply. The relay outputs are terminated by J1 and J2 at rear.

other than the simple pushbutton—may be used to trigger the transmitter. For instance, for a burglar alarm, a normally closed pressure-sensitive switch can be placed so that its contacts are held open by the pressure of a door or window. Then, when the door is opened, the switch closes and turns on the transmitter. You will want to use an input jack on the transmitter (in parallel with *S1*) so that the switch can be plugged in. Since the door may be closed again after entry, the latch mode of operation is the logical choice for the receiver. Additional switches may be wired in parallel to guard more than one door or window and additional transmitters may be placed in other rooms or buildings.

If you want to guard an entry that has no door, you can use a photoelectric sensor such as that shown in Fig. 7A. Place a light source so that it shines on the photocell and so that the beam is broken by an intruder. Enclose the photocell in a 5-dram pill bottle which has been painted flat black on the inside to protect it from ambient light.

To adjust this type of system, block the light from the photocell and place the sensitivity control at its high-resistance end. Then slowly decrease the resistance until the alarm sounds. To increase battery life, use the brightest light source practical and the highest setting of the sensitivity potentiometer that will give proper operation. Red filters may be used with the light source if desired. Since the photosensor will cause the transmitter to send a signal only while the light beam is actually interrupted, the latch mode of receiver operation should be used.

It is difficult to set up a light beam to cover a large area such as a field or an oddly shaped room. For this purpose, a break-wire type of sensor can often be used to advantage. A simple sensor of this type which may be built into the transmitter or plugged into it through an optional jack is shown in Fig. 7B. The breakable loop may be a piece of thin wire (#30 or smaller) suspended a few inches above the ground or it can consist of conducting foil on a window pane. Large pieces of electronic or similar equipment may be protected using this scheme if the wire loop is replaced by a shorting bar on the bottom of the equipment. The bar completes a circuit between two contacts on the workbench. As soon as the equipment is moved, the circuit is broken and the alarm is activated. Any number of loops may be used but make sure that they are all in series with one another. —30—



Build a PSYCH-ANALYZER

CHECK EMOTIONS AND SENSIBILITIES BY GALVANIC SKIN RESISTANCE

BY ROBERT E. DEVINE

AFTER SEEING the latest adventures of your favorite TV detective, have you ever wished you had a lie detector of your own? You could check your friends' psyches—determine their likes, dislikes, phobias, and idiosyncrasies! You can do it with the "Psych-Analyzer"—a device that's easy to construct and will provide you and your friends with many entertaining (and maybe revealing) hours.

The term "lie detector" is actually a misnomer. The Psych-Analyzer can only detect and display variations in the electrical resistance of the subject's skin. Such variations are directly related to physiological fluctuations caused by emotional stress and are beyond the control of the subject; hence, psychologists call them "autonomous." It is the examiner's job to observe and interpret the responses. Detecting a lie requires skill in the interpretation.

The professional lie detector (best known in the Keeler polygraph) simultaneously measures and records several parameters of physiological response that are known to fluctuate under emotional stress. These include blood pressure, depth and rate of breathing, pulse rate, and skin resistance. Of these, the most easily observed and the most dramatic in its dependability is the skin resistance in the palm of the hand. It is this meandering value of resistance that the Psych-Analyzer detects and displays—the significance is complex. Only a professional psychologist could determine

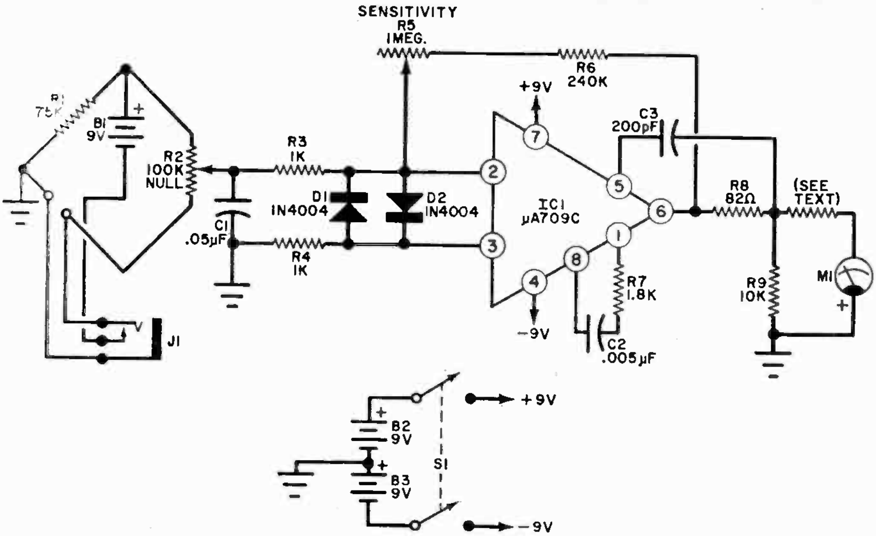


Fig. 1. The low-level d.c. error signal generated in the bridge is amplified by the high-gain IC amplifier and displayed on the meter.

PARTS LIST

B1-B3—9-volt battery
C1—0.05-μF capacitor
C2—0.005-μF capacitor
C3—200-pF capacitor
D1,D2—1N4004 (or any silicon diode)
IC1—Integrated circuit (Fairchild μA709C). See text.
J1—Modified closed-circuit jack. See text.
M1—0-1-mA meter with series resistor (2500 to 3000 ohms) to measure 3 volts.
R1—75,000-ohm, ½-watt resistor
R2—100,000-ohm potentiometer
R3,R4—1000-ohm, ½-watt resistor
R5—1-megohm potentiometer (miniature preferred)
R6—240,000-ohm, ½-watt resistor
R7—1800-ohm, ½-watt resistor
R8—82-ohm, ½-watt resistor
R9—10,000-ohm, ½-watt resistor
S1—D.p.s.t. switch
Misc.—Eight-pin TO-5 socket (for IC1), two 1"-square pieces of heavy copper or two large foreign coins, pair of bicycle clips, length of insulated wire, battery clips (3), case as desired, mounting hardware, etc.

the true meaning—in the meantime, have some fun!

Construction. The complete schematic of the Psych-Analyzer is shown in Fig. 1. Since it is basically a d.c. amplifier and problems due to lead length or placement are not likely to occur, the project lends itself to breadboard-type construction. Interfering high frequencies, caused by r.f. pickup, are bypassed to ground at the output of the bridge. Before final packaging, a conventional VOM, VTVM, or TVM switched to its 2.5- or 3-volt range can be used to test the circuit instead of the regular output meter.

To insure a neat finished product, however, and to avoid inadvertent wiring errors, it is preferable to use an etched circuit board (shown actual size in Fig. 2). Once the board is complete, all components except *IC1* can be installed as shown in Fig. 3. The IC is mounted in an 8-pin, TO-5 socket that fits into the hole drilled in the circuit board. Notch out a small indentation in the board for the socket locating projection, noting that this projection is at pin 8 of the IC. The tab on the IC is also located at pin 8. Push-fit the IC socket into the hole and solder the leads to the adjacent solder pads of the foil. When soldering the components, take care not to use excessive heat as this can damage diodes *D1* and *D2*.

Before installing *IC1* in its socket, its leads should be trimmed down to approximately ¼" in length. Do not use a conventional side cutter for this purpose since the cutting force of typical side cutters can damage the IC. Common wire strippers, hinged like a pair of scissors

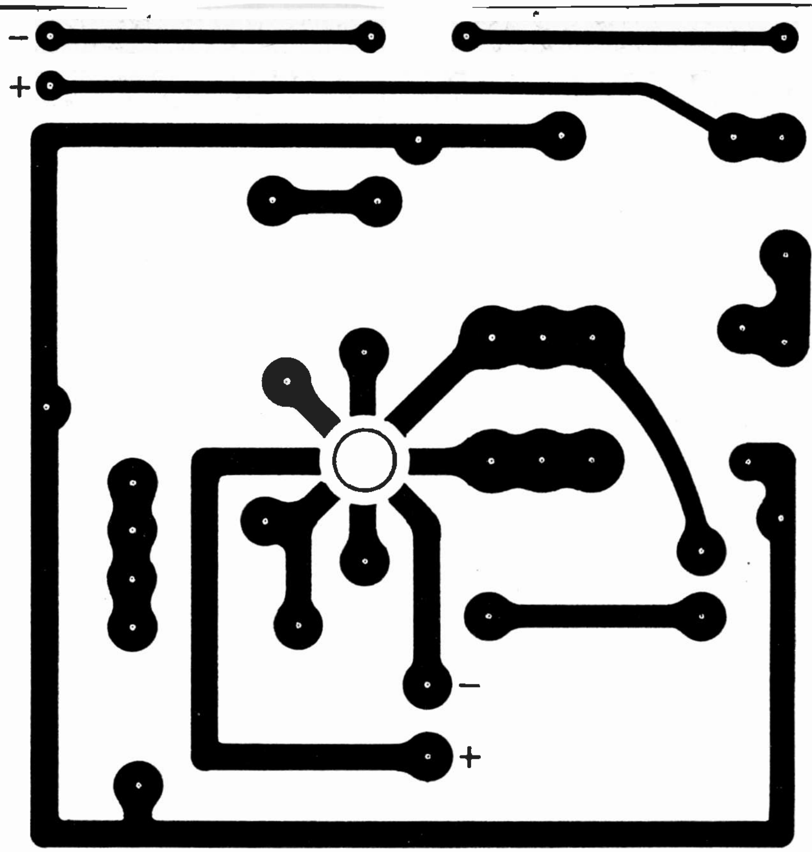


Fig. 2. Actual-size printed board foil layout. You can create this circuit on perf board if desired.

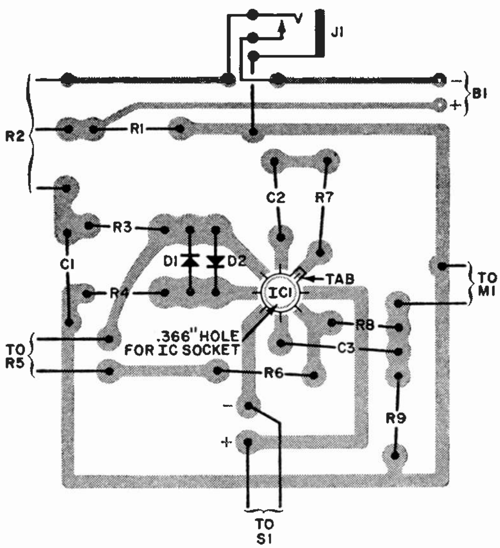


Fig. 3. Install the components as shown here. Note that J1 is arranged to close when plug is inserted.

and having a relatively gentle cutting action, should be used.

A jack, for *J1*, that has one contact that closes when the mating plug is inserted may be difficult to find. You can use a jack that has a normally closed circuit and modify it so that it fits the circuit as shown in Fig. 1. Just be sure before you buy the jack that it is a type that can be modified (by bending the top contact so that it is on the bottom).

Any type of d.c. voltmeter capable of indicating to 2.5 or 3 volts can be used for *M1*. If you use a 1-mA ammeter, insert a 2500-3000-ohm resistor in series with the meter to convert it to a suitable voltmeter.

At the time of the writing of this article, the price of the μA709C varied over wide limits. If you buy this from an electronics distributor selling either Fairchild or ITT versions, you may expect to pay up to $10.00. However, it is our understanding that low-cost 709C Op Amps are available from PolyPaks, P.O. Box 942, South Lynnfield, MA 01940.

Just be sure to get a TO-5 packaged version.

Any type of case can be used to house the analyzer. Mount meter *M1*, NULL control *R2*, power switch *S1*, and jack *J1* on the front panel. Although the author mounted SENSITIVITY control *R5* on the back panel, it also can be mounted on the front if desired. Control *R5* should be marked LO when its rotor is away from *R6*, HI with its rotor adjacent to *R6*, and MED in the middle.

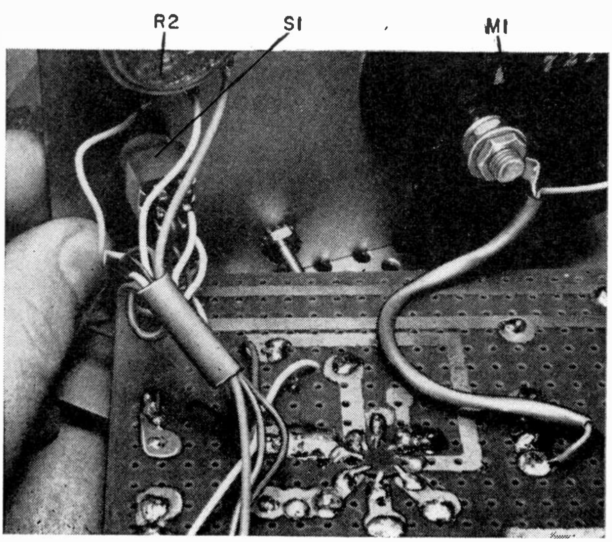
The batteries can be mounted on one wall of the chassis, using strips of aluminum to secure them in place. Mount the PC board using standoffs.

Electrodes. The electrodes are made from pieces of 1"-square, 1/8"-thick copper slightly rounded with a ball-peen hammer so that they are convex to fit the palm of the hand. You can also use two large foreign coins (such as Mexican 20-centavo pieces). Although copper is preferred for the electrodes, the large coins will work. (Note that the electrodes must be kept clean during use. Polish them occasionally with a piece of fine sandpaper, especially if the copper or other metal gets to be dark or oxidized.

Solder a small U-shaped bracket to the concave side of the electrode to hold one end of the clamp. The clamps hold the electrodes snugly in the palms of the hand and are made from a pair of bicycle pants clips, available at bike supply shops. The spring tempering at one end of each clip must be removed through heat treatment. Using any form of heat (gas stove, blowtorch, etc.) heat one end (for an inch or less) of each clip until it is cherry red, then allow it to cool slowly. After it has cooled, insert this end under the U-shaped bracket allowing about 1/4" to protrude. Make a sharp bend on this small tip so that the clip cannot come out of the bracket. When this is done, the electrode should be able to pivot freely on the end of the clip and position itself automatically in the palm of the hand. The remainder of each clip can be bent so that the electrodes fit snugly in the hands. For comfort and to insulate the back of the hand, cover the clips with cambric tubing.

To connect the electrodes to the detector, use a 2-to-4-ft. piece of two-wire cable and separate the two leads at one end for about 1 foot. Solder one wire to each electrode and put a male plug on the other end to mate with *J1*. No wiring polarity need be observed. At the electrode end, secure the wire to the cambric-covered clip to prevent its being accidentally torn loose from the electrode.

Testing. Even if power switch *S1* is in the ON position, the amplifier section does not have an output if the bridge circuit is not energized. This is done by inserting the electrode plug into *J1*. Never leave the electrodes plugged in even if *S1* is turned off, since the bridge circuit power is automatically applied whenever the plug is inserted. To shut off the de-



Lengths of insulated tubing can be used to create neat-looking cabling between the PC board and front-panel components. Use wires of different colors for each lead to facilitate signal tracing.

tector completely, place *S1* in the OFF position and remove the electrode plug.

To check system performance, temporarily clip a fixed resistor of 50,000 or 100,000 ohms between the electrodes. Insert the electrode plug in *J1*. Place the SENSITIVITY control on LO and the NULL control near its mid-scale position. When you turn *S1* on, rotating *R2* should cause the meter needle to swing smoothly from zero to full scale. A 75,000-ohm resistor will cause the meter to indicate zero with the NULL control near its center of travel.

If the system works all right so far, pinch both sides of the temporary resistor with the thumb and forefinger of each hand. This reduces the effective resistance and should make the meter indicate up scale. If the indication is down scale, check the polarity of the meter connections or the battery connections to the bridge circuit.

Rotating *R5* to MED or HI increases the sensitivity proportionately. In actual practice, it is seldom necessary to use high sensitivity unless the subject has extremely high skin resistance or abnormally low emotional activity.

Unplug the electrodes and turn *S1* off. Always do this if the detector is to be left off for any period of time.

Using the Psych-Analyzer. To protect the meter from unnecessary overload, before using the analyzer, set the NULL control (*R2*) near its center of rotation, set the SENSITIVITY control at MED, and place the electrodes on the subject's palms.

With the subject seated comfortably, an electrode on each palm, insert the plug into jack *J1* and turn on the power switch. Bring the meter needle to a point just above zero by use of the NULL control. Hereafter, aside from "noise" due to a change in the pressure of the electrodes against the subject's skin or any slight motion of the subject's muscles, all meter movements represent bona fide changes in skin resistance. From time to time you will have to re-zero the meter as the absolute level of skin resistance changes slightly. Generally speaking, the absolute level represents the subject's state of arousal.

There are innumerable stimuli that will cause a subject to react and start an internal chain reaction beyond his control. The end result is an upward swing of the meter signifying a decrease in skin resistance. The stimulus can be conveyed through touch or sound or any of the other senses, but the most dramatic reaction—particularly for aural stimuli—will result from a stimulus that has strong emotional attachments (the names of loved ones, for instance) or that is distasteful (taboo words).

The *expectation* of stimulus can also cause an indication on the analyzer. For instance, clang two pieces of metal together, and the subject will almost invariably exhibit a large response. After things have returned to normal (30 to 60 seconds) pretend to make the same noise again but stop just short of doing so. The response will be almost as great as before.

A point of interest is the latency or delay between the occurrence of a stimulus and the meter response. One authority in the field claims that the latency is 1.7 seconds for an aural stimulus and 2.1 seconds for a visual stimulus. If you have a stopwatch, you can check this.

Another authority has a theory about

HOW IT WORKS—ELECTRONICALLY

The circuit of the Psych-Analyzer is divided into three sections: a measurement bridge, a d.c. amplifier, and an output indicator.

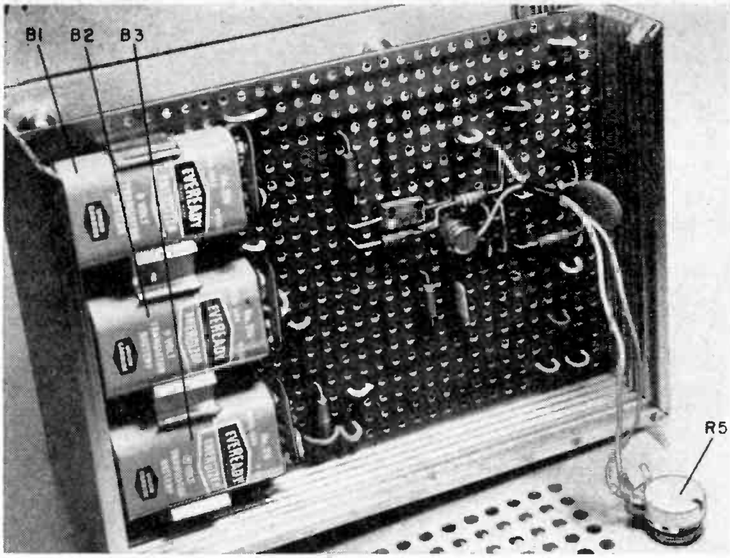
The bridge is made up of *R1*, *R2*, and the subject's skin resistance. Resistor *R1* corresponds to the known resistor of a Wheatstone bridge, while the skin resistance is the unknown. The output voltage of the bridge is nulled by rotation of *R2* to balance the bridge. If, after the bridge is balanced, the resistance of the subject's skin varies, the bridge is unbalanced, and a d.c. voltage appears on the arm of *R2*. This low-level d.c. signal is amplified by the operational amplifier *IC1*. Capacitor *C1* is used to bypass unwanted a.c. signals that may be induced into the circuit from stray power-line pickup or r.f. from nearby radio stations.

To protect the IC from excessive input, series resistors *R3* and *R4* limit the current flow and diodes *D1* and *D2* reduce transients by limiting the input level to 0.6 volts. (Incidentally, there are 15 transistors in the *IC1*, TO-5-size case.)

The operational amplifier is used to perform certain mathematical operations in computer applications. The amplifier gain can be controlled by varying the amount of feedback from output to input (pin 6 to pin 2). This is done by varying the setting of *R5*.

The resistor-capacitor circuit (*C2-R7*) between pins 1 and 8 and capacitor *C3* between the output and pin 5 are used for frequency compensation. Resistor *R8* protects the IC against overload damage if the output is accidentally shortened.

The voltmeter has a 1000-ohm-per-volt movement with a 0-to-3-volt scale.



The three 9-volt batteries are supported by clips at one end of the oversize perf board. Although the author mounted R5 (sensitivity control) on rear, it could just as well be mounted on the front panel.

HOW IT WORKS—PHYSIOLOGICALLY

In 1888, a scientist named Féré found that if he attached an electrode to each forearm of a human subject and connected these electrodes in series with a weak source of d.c. and a galvanometer, the galvanometer needle would have rapid. upscale deflections when the subject was emotionally stimulated. The phenomenon is still sometimes referred to as the Féré effect, but is now more commonly called GSR, galvanic skin response (or resistance). Most electronics experimenters have noted this effect when they hold the leads of an ohmmeter in their hands.

Tests have shown that the GSR effect is actually strongest in the palms of the hands and soles of the feet, the back of the hand and wrist being less responsive. In 1929, another scientist (Richter) noted that the GSR effect disappears when the electrodes pierce the skin.

It would be natural to assume that the GSR effect is a function of the amount of perspiration on the skin, a common indication of emotional stress. Although this might play a small part, it is not the whole answer. Experiments have shown that, if two small pieces of toweling are soaked in warm salt water (to simulate heavy perspiration) and placed between the skin and the electrode, the GSR effect does not disappear.

Since there is still no absolute explanation of the GSR effect, feel free to form your own opinion.

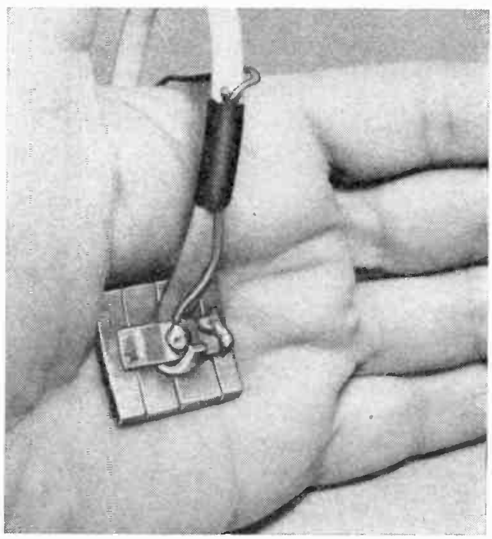
latency when taboo words are used. By mixing pleasing words with unpleasant ones he discovered that the latency was much greater with the unpleasant ones. He attributes this to "fear of punishment." Although his subjects were college students, he felt that they unconsciously put up a defense (inbred from childhood) against these forbidden words and therefore took longer to recognize them. You will also find that a subject's response declines with repeated stimuli of the same nature—a matter of adaptation on his part. A period of rest will restore the subject to his previous state of reaction.

As mentioned previously, the absolute level of skin resistance at any particular time represents a measure of general activation or arousal. This is sometimes referred to as Base Line Conductance. (Conductance is the inverse of resistance.) The base is high (high conductance and low resistance) when the subject is wide awake and alert and low when he is drowsy or asleep.

An easy way to determine the validity of the Psych-Analyzer as a lie detector

(*Continued on page* 153)

Each electrode should fit snugly in the palm of the hand. The modified bicycle-clip clamp should be insulated with tubing to provide electrical isolation.



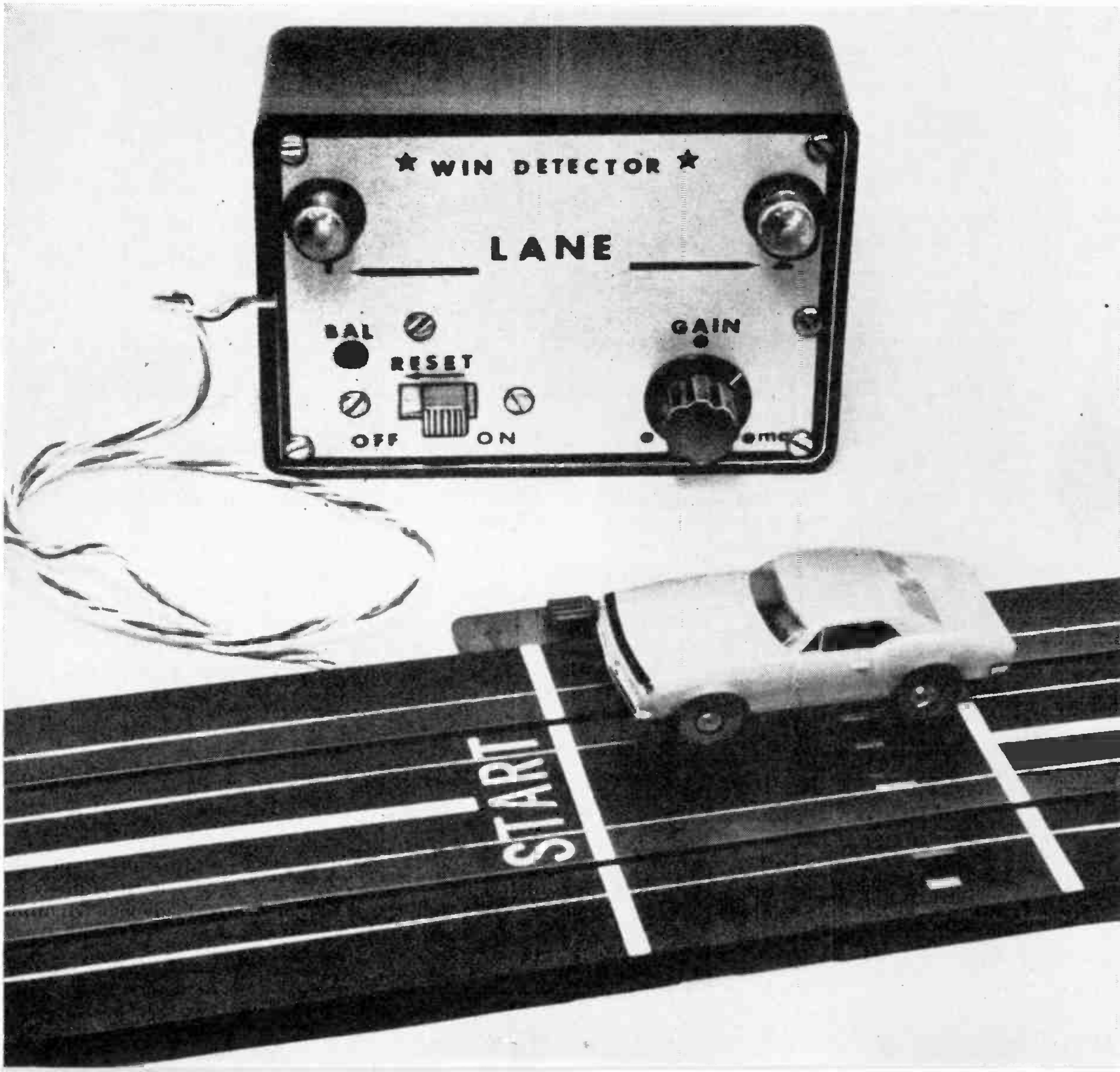
BUILD SLOT-CAR WIN DETECTOR

A FINISH-LINE JUDGE THAT CAN'T BE TRICKED

BY W. T. LEMEN

VISUAL determination of the winner in a close, fast slot-car race is almost impossible—the usual result is a heated discussion between the two participants. What you need is a photoelectric "Win Detector" that will end all the arguments by detecting the winner even if the two cars are separated by only 1/32 of an inch. You can build one from an integrated circuit (IC) and two fast-acting photo pickups mounted under the track at the finish line.

The Win Detector uses its own battery and works in normal room lighting—the winner is indicated by a glowing lamp. Because only a single switch controls the operation, the Win Detector can be used by small fry easily and safely.



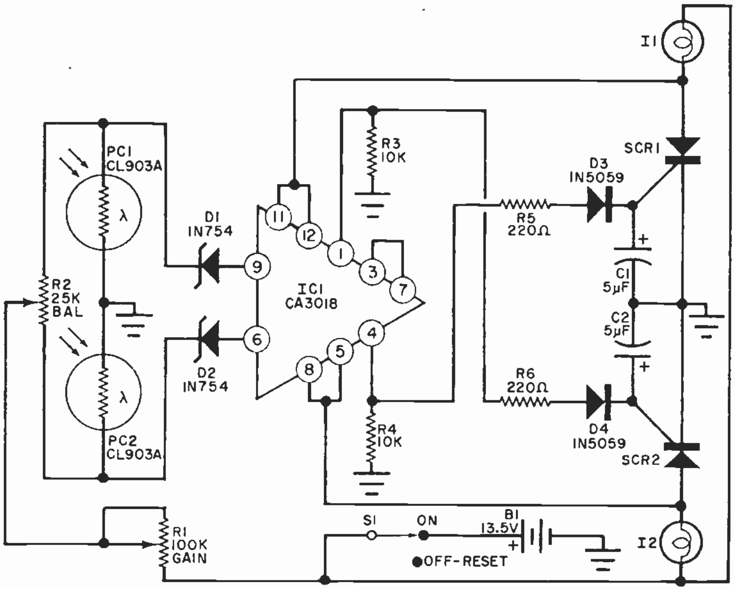


Fig. 1. The IC contains two independent circuits whose external components are arranged so that, when one of the two circuits operates, the other is automatically deactivated. This insures that only one track is winner.

PARTS LIST

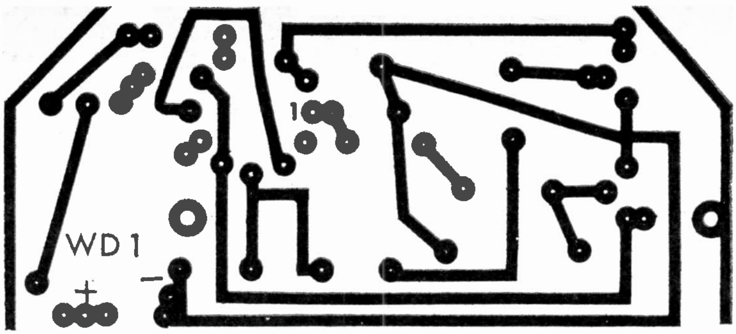
B1—13.5-volt battery (Burgess XX9 or similar)
C1,C2—5-μF, 15-volt electrolytic capacitor
D1,D2—1N754 zener diode
D3,D4—1N5059 diode
I1,I2—14-volt lamp (#330) with suitable holder (Dialco 0931-502)
IC1—Integrated circuit (RCA CA-3018 or KD 2114)
PC1,PC2—Photoresistor (Clairex CL903A or similar)
R1—100,000-ohm potentiometer
R2—25,000-ohm printed-circuit potentiometer (Mallory MTC)
R3,R4—10,000-ohm, ¼-watt resistor
R5,R6—220-ohm, ¼-watt resistor
S1—S.p.s.t. slide switch
SCR1, SCR2—Silicon controlled rectifier (Texas Instruments TIC-47)
Misc.—Plastic case 4" x 2⅞" x 1 9/16" (Harry Davies #220); 1/16" aluminum panel 3¾" x 2⅝"; length of three-conductor cable; ¾" fiber spacers (2); battery connector; ¼" diameter fiber tubes 7/16" long (2) and wood block for photo pickups; knob; mounting hardware; etc.

Construction. The circuit for the Win Detector is shown in Fig. 1. Most of the components are mounted on the printed circuit board whose foil pattern is shown in Fig. 2. Figure 3 shows how the components are located. Observe the polarities on diodes and capacitors. To install the IC, make a "spider" formation of its leads, bending them about 1/16" below the case so that they go out radially. Then about 3/16" out from the case bend them down again so that they fit in the holes of the circuit board. Note that leads 2 and 10 of *IC1* are not used and that a mounting hole is provided for pin 2 to keep the IC properly located. Lead 10 can be cut short at the case. The tab on the IC is located at lead 12 and the other leads are numbered clockwise from there looking at the case from the bottom.

After forming the leads of the IC into a spider, insert it on the board, making sure that the orientation is correct. Also be sure that the SCR's are properly oriented. Connections to the panel-mounted components are also shown in Fig. 3.

The Win Detector can be mounted in any type of chassis. Parts placement and circuit layout are not critical. If you want to duplicate the author's prototype, make the metal front plate according to the diagram in Fig. 4. It can be fabricated from a piece of 1/16" aluminum. Conventional dry transfer lettering can be used to make an attractive panel. Mount *S1*, *R1*, *I1*, and *I2* on the metal panel and wire them to the circuit board

Fig. 2. Printed circuit board can be made from this actual-size pattern. The number "one" on the IC pattern is for pin 1.



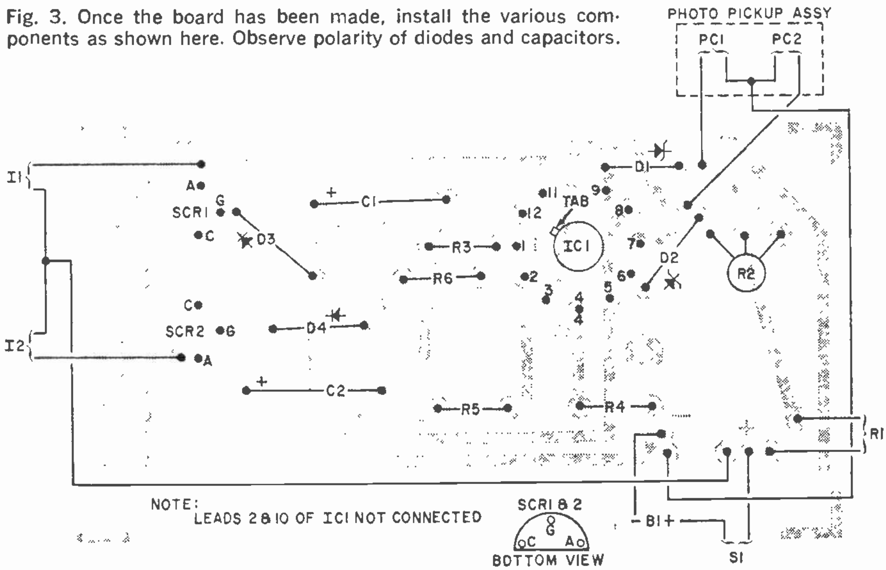
allowing enough wire to mount the board about ¾" below the panel. Cut a small hole in the side of the plastic box to accommodate the three leads to the photo pickups. The three-conductor cable between the chassis and the photo-pickup assembly can be any reasonable length.

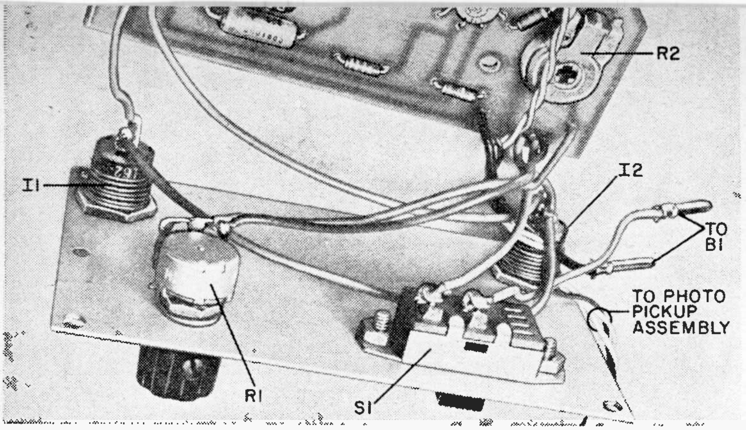
Attach the circuit board to the front panel using a pair of ¾" insulated (fiber) spacers and appropriate hardware. The battery should fit inside the plastic case between the board and one long wall of the case.

The design of the photo-pickup assembly is contingent on the physical layout of the track you are using. If your finish line can be made to be at a raised portion of the track, you can use the layout shown in Fig. 5. In this case, the only two dimensions not given in the diagram are the width of the overall wooden block and the center-to-center distance between the two ¼" holes. The block should be cut to fit snugly under and between the track edges at the finish line and the ¼" holes should be spaced so that they are directly under the centers of the lanes. Press fit the photo pickups into the fiber tubes; then fit the fiber tubes into the ¼" holes in the wooden block.

Connect the three leads from the electronic assembly to the photo pickups as shown in Fig. 1 and Fig. 3. Solder and insulate these leads to prevent accidental loosening or shorting. The photo-pickup assembly can be attached to the track now. A three-terminal disconnect plug may be used between the detector and pickups to permit the track to be

Fig. 3. Once the board has been made, install the various components as shown here. Observe polarity of diodes and capacitors.





Interior of the author's prototype. Access to R2 is through a small hole in the metal front panel.

disconnected from the detector for storage.

For the more common plastic tracks, drill ¼"-diameter holes adjacent to each track pin slot so that the car must pass over the hole to block the ambient light. Mount the two photo pickups, one at each track, and secure them in place with cement. Wire the pickups to the electronic assembly as described above.

Operation. With the slot-car track in position, be sure that the photo-pickup assembly is in unobstructed light. Place the RESET switch, S1, in the ON position and set GAIN control R1 to its maximum. One of the lights should come on. With *R1* at maximum, flip *S1* between the OFF and ON positions, simultaneously adjusting *R2* (through the hole in the cover) until one light or the

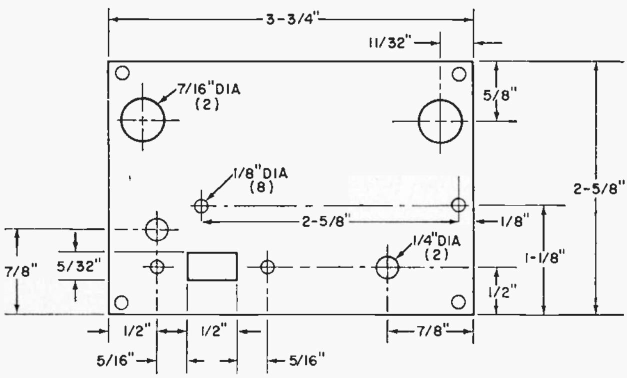
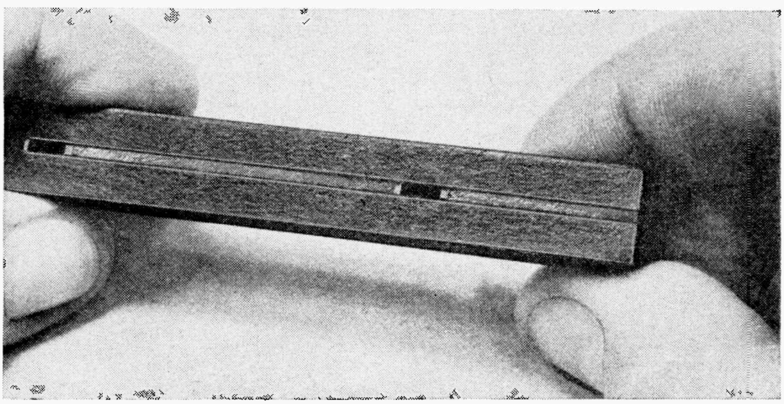


Fig. 4. Although any mechanical layout can be used, you can duplicate the author's front panel with these details.


Lengths of opaque tape are used to narrow the field of view of the two cells for more accuracy.

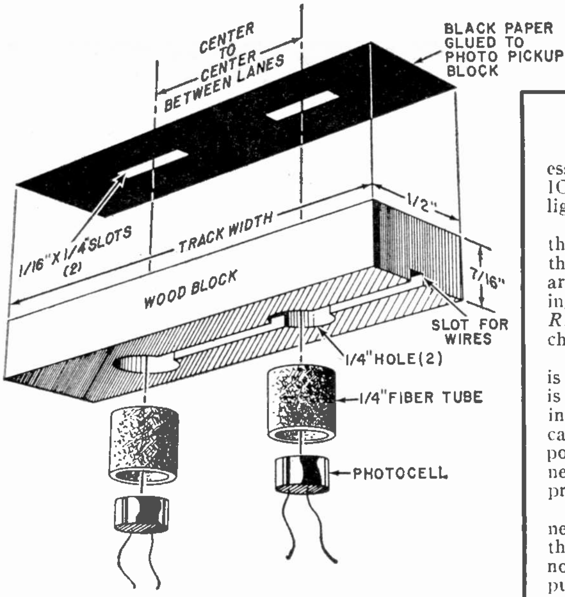


Fig. 5. If you have a raised track, make the photo-pickup assembly as shown here. If you have a plastic track, mount the photocells in drilled holes.

other comes on when *S1* is on. It is possible to balance the system so accurately that both lights come on. Back off on *R1* until operation of *S1* does not cause either light to come on.

Test the system by passing your hand across the photo pickups in one direction (causing one light to come on). Then reset the system and pass your hand over the block in the other direction to turn the other light on. You may have to adjust the setting of the GAIN control for best operation. Once a light comes on, it will remain on regardless of any other pass of the hand (or slot car) until the RESET switch is operated.

If you are using undersized slot cars or if you want faster triggering, reduce the values of capacitors *C1* and *C2*. –30–

HOW IT WORKS

The electronic portion of the Win Detector is essentially two balanced amplifiers (within one IC) with photo pickups as sensors and indicator lights driven by SCR's.

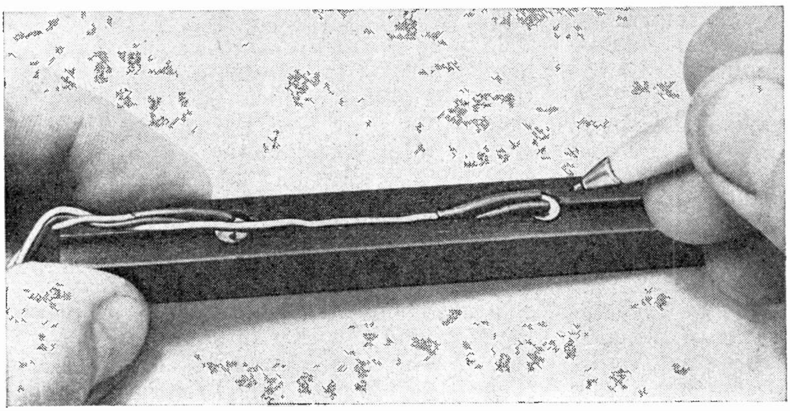
Photo pickups *PC1* and *PC2* are connected to the bases of the two input transistors of *IC1* through zener diodes *D1* and *D2*. The pickups are connected to battery *B1* through the balancing potentiometer *R2* and the gain potentiometer *R1*. The balance control adjusts for lighting changes and circuit differences.

In operation, *R1* is adjusted (after the circuit is balanced) so that the potential at either zener is just slightly below its firing level. A reduction in the amount of light reaching either pickup causes an increase in its resistance and raises the potential on the zener diode to which it is connected. This causes the zener to break down and provide a signal at the input to the IC.

The outputs of the IC (pins 1 and 4) are connected as emitter followers with *R3* and *R4* as their loads. The voltages at pins 1 and 4 are normally zero. When either amplifier has an input from its photo pickup, its output fires the associated SCR and turns on the indicator light. The IC outputs are connected to the SCR's through current-limiting resistors *R5* and *R6* and blocking diodes *D3* and *D4*.

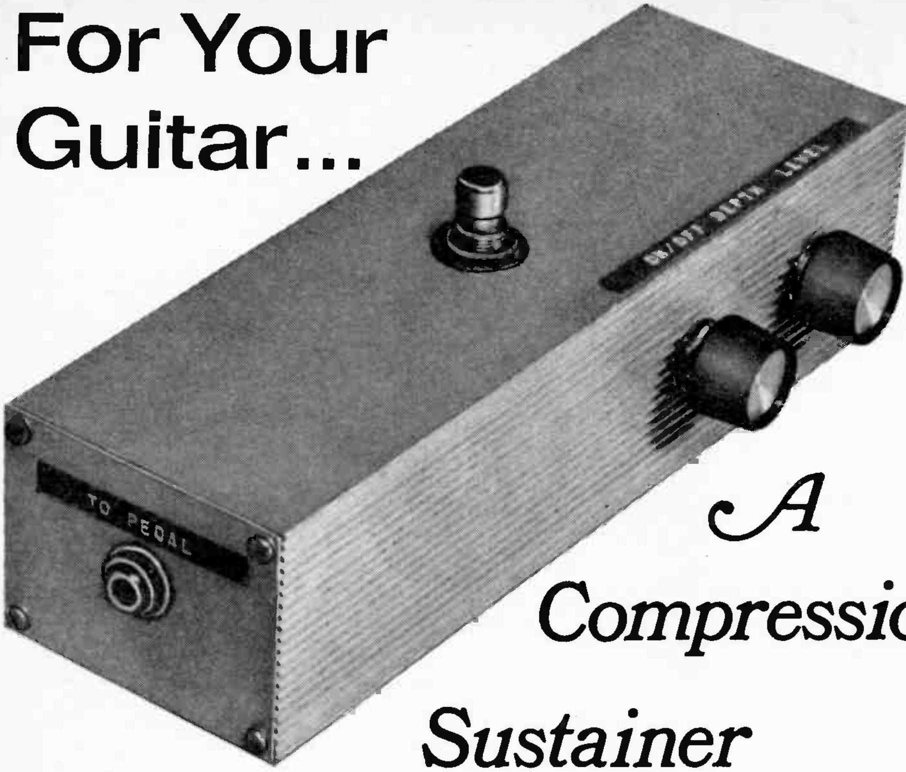
Note that the positive supply for each half of the IC is taken from the junction of each lamp and its associated SCR and not from the battery. These points are normally positive when the lamps are off, but the potential drops to zero when the SCR conducts. In this way, when either lamp turns on, the power to the opposite channel is cut off so that it cannot be energized. Therefore, the first channel to operate shuts down the other one, providing a definite indication of the winner.

Capacitors *C1* and *C2* are transient filters which assure turn off of the SCR's when the RESET switch is operated.



After photocells are wired together, they are friction fitted into the two holes drilled into a wooden block. The slot accommodates 3 wires.

For Your Guitar...



A Compression Sustainer

BY CRAIG ANDERTON

MAKE MUSIC LIKE THE GREATEST

Having trouble competing with the top guitarists and bassists? The chances are your instrument doesn't have the lazy, sustained sound that is mandatory these days. Fuzztone doesn't always help since it is unsuitable for chording and, quite often, the distortion it produces on a solo isn't wanted.

How do the stars do it? For one thing, they use plenty of volume; but volume is expensive (even counting only the ruptured speakers and eardrums). A much better way to get all the sound you want is to build a compression sustainer.

The sustainer brings up the level of the soft, low-level passages; the softer you play, the more it amplifies. All the little instrument nuances feed into the amplifier at the same volume as the loudest chords you play. Because of the compressing action, when a note starts to decay, the amplification goes up. This characteristic is what produces sustain. Best of all, the unit is physically small, self-powered, and can be built for around $20 if you don't have a suitable compressor or for less than $5 for extra parts if you do.

The compressor the author used was featured in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK, in the article "Add Comply to Your Tape Recorder." Of all the compressors the author tried, the Comply unit is the most practical in terms of size, noise figure, and smooth compressing action. But a few modifications must be made before it can be used for a musical instrument.

It is doubtful that you would require compression all the time (although, after using this device for a while, you may) so a means must be included for switching it in and out. A foot-switch is preferable. The packaging must be exceptionally sturdy, not only to survive the

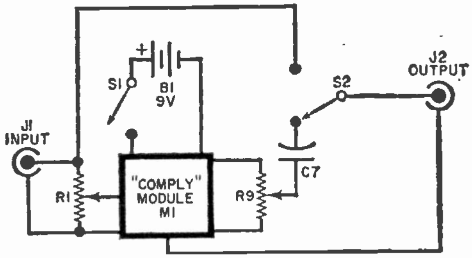


Fig. 1. Compressor circuit is built around Comply module, and aside from foot-operated switch, uses same components. One position of S2 bypasses the Comply, and the other position introduces sustain.

PARTS LIST

B1—9-volt battery
C7—On Comply module
J1,J2—Open-circuit phone jack
M1—Comply module (see EXPERIMENTER'S HANDBOOK, *Winter '69)**
R1,R9—On Comply module
S1—On Comply module with R1
S2—Heavy-duty s.p.d.t. foot-operated switch
Misc.—Heavy-duty metal enclosure approximately 8" x 2½" x 2" (optional, see text) or simple metal enclosure and small, but strong metal box for footswitch (see text), connecting cable, battery holder, mounting hardware.
**A complete kit of parts for the original Comply module including circuit board, pre-punched cabinet, all components, hardware, wire and solder, but less battery is available for $19.50, postpaid from Caringella Electronics, Inc., P.O. Box 327, Upland, CA 91786.*

rigors of road travel but also to withstand the pressure from the footswitch.

The switching circuit used with the Comply unit is shown in Fig. 1. This arrangement produces no annoying clicks in the amplifier output.

Construction. Packaging the compressor can be accomplished in one of two ways. The first is to mount the entire subsystem in a very strong metal box with the footswitch (*S2*) on the top and the other controls and input-output jacks on either the sides or ends. Since this scheme requires an exceptionally strong metal box, you may prefer the second

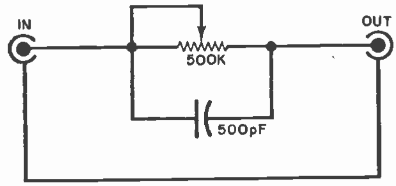
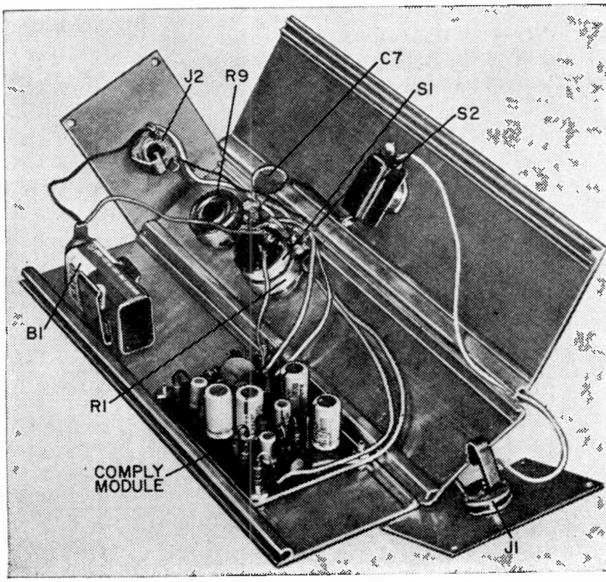


Fig. 2. If you feel that the guitar bass is a little too pronounced, add this simple adjustable bass-cut filter to the circuit. The pot determines bass level.

method. In this approach, the compressor is built in a conventional aluminum or sheet metal enclosure and the footswitch is mounted in a small, strong metal box that can take the punishment. A cable is then used to connect the footswitch to the electronics package.

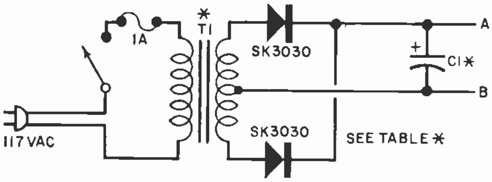
Assemble the compressor as described in the previous article (see Parts List). Mount the input jack (*J1*), the input level control (*R1* with attached power on-

(*Continued on page* 152)

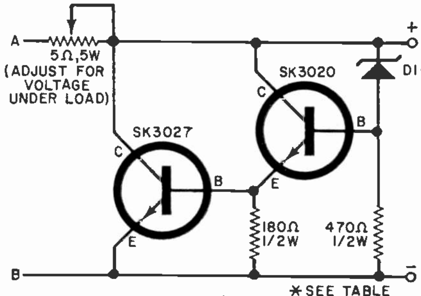


The author built his version in a metal box, strong enough to take foot-switch punishment. You can build the sustainer in a lighter weight box and use a smaller, stronger box to house the foot-switch.

BUILD YOUR OWN POWER SUPPLY



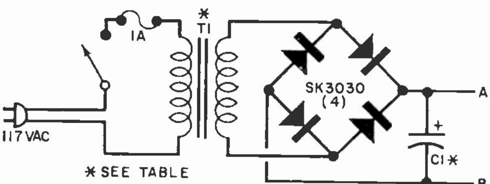
(A)



(D)

MANY READERS have asked us to print a circuit design for a power supply that would be simple yet would provide the unusual d.c. voltages that may be required in experiments and project constructions involving semiconductors. In answer to these requests, we suggest a circuit given in the *RCA Solid-State Hobby Circuits Manual.* (The handbook is available at most electronics parts distributors for $1.75.)

Four building-block circuits are described—two transformer-rectifier units, a series regulator, and a shunt regulator. By using the proper transformer voltage and regulator, you can build a supply for any one of eleven voltages



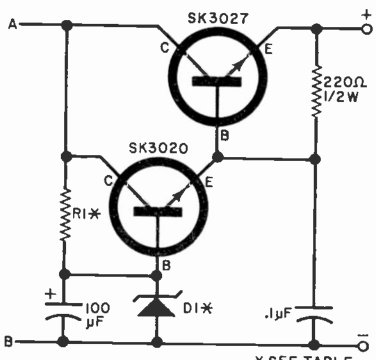
(B)

as shown in the table. The manual also describes circuit refinements and elaborations for building continuously variable supplies for the same voltage ranges.

The transformer-rectifier circuit shown at *A* can be used for power supplies delivering 15 volts or less, while that at *B* is for 3- to 35-volt outputs. Below 15 volts, take your pick—two less rectifier diodes are required for circuit A.

The series regulator shown at *C* is for supplies delivering at least 6 volts; below 6 volts, use the shunt regulator, circuit *D*.

In any case, use a one-ampere fuse in the transformer primary. The transformer should have a 117-volt primary and a 1-ampere secondary rating at the voltage given in the table. A check of your electronics catalogs will show a number of transformers that fill the bill. —30—



(C)

FIXED POWER SUPPLY DESIGN TABLE

D. C. OUTPUT VOLTAGE	TRANSFORMER SECONDARY VOLTAGE (A)	(B)	C1 µF/VOLTS MINIMUM	REGU-LATOR CIRCUIT	D1 VOLTAGE RATING	R1 OHMS/ WATTS
3	12.6	6.3	2500/10	D	*	5/5
4.5	12.6	6.3	2500/10	D	3.3	5/5
6	20	10	4000/15	D	4.7	5/5
6	20	10	4000/15	C	7.5	390/½
9	30	15	4000/15	C	10	820/½
10	30	15	4000/25	C	11	680/½
12	30	15	4000/25	C	13	330/½
15	40	20	2500/50	C	16	680/½
18	–	22.5	2500/50	C	9.1 and 10 in series	1000/½
20	–	28.5	2500/50	C	11 and 11 in series	470/½
29	–	38	2500/50	C	15 and 15 in series	1200/½
35	–	40	2500/75	C	36	680/½

*Use 3 forward-biased SK3020 in series

BUILD A

POWER INVERTER

117 volts a.c. from your car battery

BY JON COLT

ALTHOUGH most of us live in a 117-volt 60-Hz world, there are many—campers, boat owners, long-distance truck drivers, and trailer dwellers, for example—whose only source of power is 12 volts d.c. One of the biggest drawbacks in the use of low-voltage d.c. power is the cost of appliances and equipment which operate on such power. Equipment that uses 117 volts a.c. is much lower in cost and more readily available.

With the Power Inverter described here, you can change your world from d.c. to a.c. and, if you like, shave in your car using an ordinary electric shaver.

The Power Inverter, whose schematic is shown in Fig. 1, takes 12-volt d.c. from a battery and delivers approximately 117 volts at nearly 60 Hz. (Actual voltage and frequency depend on the load.) Its 100-watt load capability can handle most common appliances.

Construction. Although almost any reasonably strong case can be used (transformer *T2* weighs slightly more than 6 pounds), the author used a 6" × 5" metal enclosure, with four rubber feet on the bottom.

If you want to duplicate this unit, use the photo above as a guide for the front panel. The pilot light is used to indicate when the inverter is running, and is optional. The two power-input binding posts are also optional—a pair of heavy leads capable of carrying 10 or 11 amperes from the battery to the inverter could be used (14 gauge minimum recommended). The holes immediately above the two power outlets (*S01* and *SO2*) are for the use of devices with three-prong plugs.

One transistor is mounted on each side of the U-shaped case. Use a shoulder insulator and a solder lug at one collector (case) terminal on each transistor and make sure that the base and emitter holes provide plenty of clearance. Each transistor must be insulated from the metal case by a mica washer, with silicone grease on both sides. Mount the various components and install the two transformers with the heavier *T2* on the bottom of the chassis and *T1* on the top. Wire the inverter in accordance with Fig. 1. The wires going to the transistor emitters and collectors should be at least 18 gauge and should be flexible since they go to a demountable portion of the case. Clip the transistor base and emitter leads to about ¼". In soldering to the transistor leads use a heat sink (such as long-nose pliers) to keep the body of the transistor from overheating and being severely damaged.

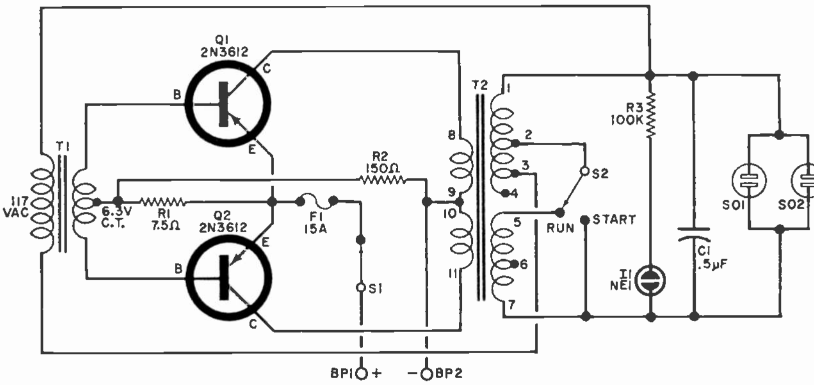


Fig. 1. A basic low-frequency (approximately 60 Hz), 100-watt power oscillator, the inverter also has dual power position to save drain on the battery.

PARTS LIST

BP1,BP2—5-way binding post (optional, see text)
C1—0.5-μF, 400-volt capacitor
F1—15-ampere fuse and fuseholder
I1—Neon lamp (optional)
Q1,Q2—2N3612 transistor
R1—7.5-ohm, 5-watt resistor
R2—150-ohms, 2-watt resistor
R3—100,000-ohm, ½-watt resistor (optional)
S1—D.p.d.t. 10-ampere switch
S2—S.p.d.t. switch
SO1,SO2—117-volt power receptacle, chassis mounting (one is optional)
T1—Filament transformer, 117-volt primary, 6.3-volt, 1.2-ampere secondary
T2—Rectifier transformer (Knight 54A2333)*
Misc.—6" x 5" x 4" metal case, rubber feet (4) three-lug terminal strip, silicone grease (Dow #4 or similar), power transistor mica washer insulating kit (2), shoulder insulators (2), solder lugs (2), mounting hardware, length of 18-gauge insulated flexible wire, length of 14-gauge insulated wire pair, automobile cigarette plug (optional), heavy-duty crocodile clips (2, optional)
*Available from Allied Electronics, 100 N. Western Ave., Chicago, Ill. 60680, part number 54A2333, $10.24.

Check-out. If the inverter is to operate properly (oscillate), the two transformers must be phased. To do this, apply 12 volts d.c. from a 10- to 11-ampere source, making sure the polarity is correct; and connect an incandescent lamp of 60 watts or so (be sure it is switched on) to either *SO1* or *SO2*. Place *S2* in the START position and turn on *S1*. If the lamp does not light immediately, turn the power off. Reverse the connections of *T1* to the bases of the transistors and try again. The lamp should come on. Place *S2* on RUN to obtain full output. If the lamp still does not come on, check fuse *F1* and then the rest of the circuit for faulty

HOW IT WORKS

The operation of the power-oscillator inverter depends on *T2*, a conventional power transformer with many taps and a tendency to oscillate near line frequency (60Hz) when connected in the circuit. Transformer *T1* is a filament transformer used to provide feedback for the two-transistor oscillator. The oscillator starting network is made up of resistors *R1* and *R2*. Capacitor *C1* absorbs the damaging high-energy spikes which can occur at the transistor collectors under light or no-load conditions.

The taps on the secondary of *T2* (and the switching between them) are used in two different ways. The first use is to improve the efficiency of the circuit. If a filamentary load (conventional lamp) is used, the starting network has to be much heftier than is necessary to drive a pure resistive load of the same wattage. This would normally produce an attendant increase in constant power loss. A filament has a much lower resistance when cold than when hot (measured cold resistance of a 100-watt bulb is about 10 ohms—calculated hot resistance is about 137 ohms). With *S2* in the START position, a heavy load is reflected back to the primary of *T2* as a much lighter load, giving the inverter a chance to start. Once these types of loads have started, *S2* is switched to RUN for normal operation. In this way, *S2* permits the use of a much lighter starting network than would be possible if the taps on *T2* were not available.

The taps on *T2* and the switching provided by *S2* also provide a means of reducing the drain on the battery. With *S2* on START, the drain on the battery is low and any lamp connected to the load receives lower current than when the switch is on RUN. Thus, any lamp used with the inverter can be considered to be a "two-way" type and can be operated on "low" when battery conservation is important.

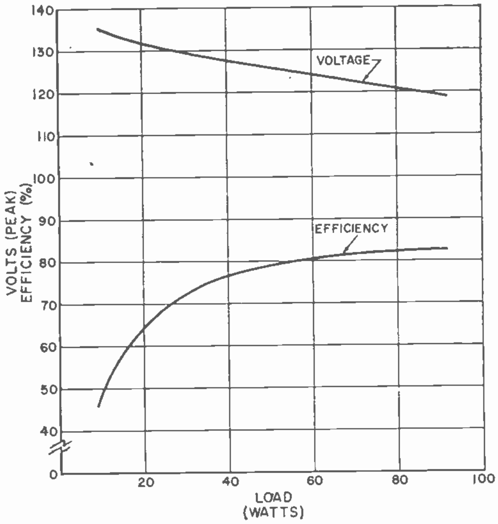
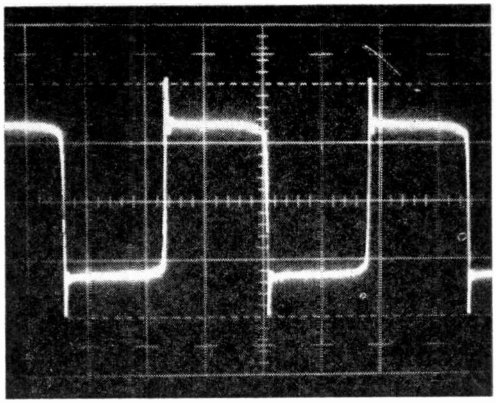


Fig. 2. Output voltage decreases slightly as the inverter is loaded while the efficiency improves.



Although output waveform is far from being a sine wave, it is useful for a number of applications.

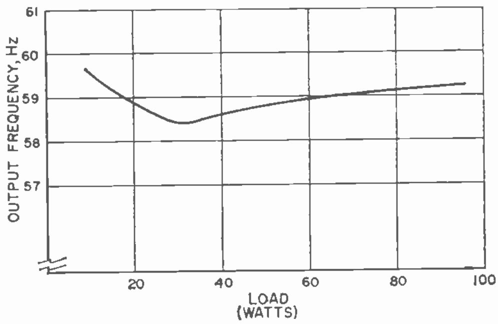


Fig. 3. The output frequency remains reasonably constant as the load varies from minimum to maximum.

components or poor solder connections. The fuse protects only the vehicle's battery system because transistors short out much faster than the fuse can blow. Therefore, you can't count on the fuse to protect the transistors if you overload the inverter.

There are a few precautions that must be observed to avoid damaging the inverter. First, always provide adequate wiring to the inverter input (capable of carrying 11 amperes). Second, never turn on the inverter without a load connected to it. Third, always make sure that the switch on the load is on and avoid a moderate overload. The inverter can take a very heavy overload such as a short

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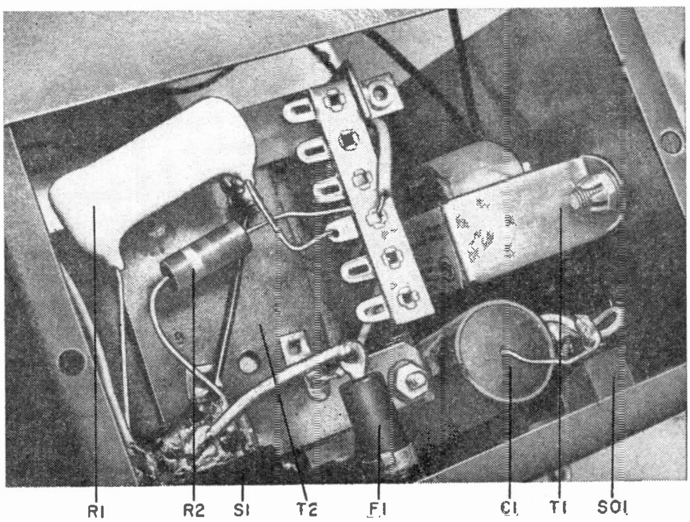
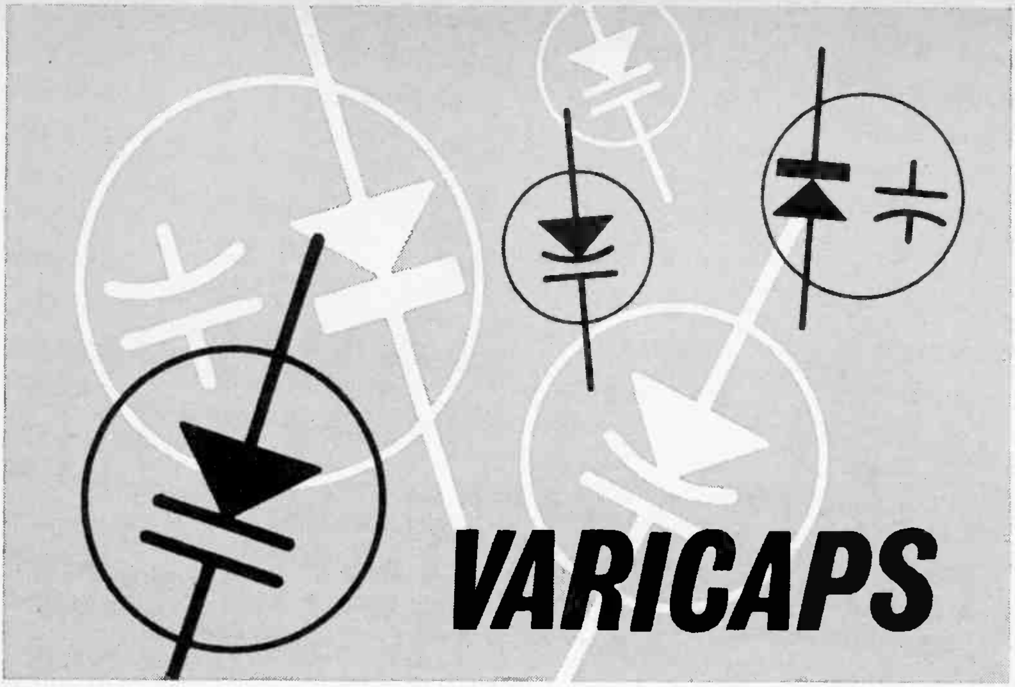


Interior of author's prototype. Any method of construction can be used as long as you remember that T2 weighs six pounds, therefore should be mounted on the bottom. Locate R1 and R2 so that they are air cooled.



VARICAPS

THE WHY'S AND WHEREFORE'S OF VOLTAGE-VARIABLE CAPACITANCE DIODES

BY A. A. MANGIERI

SOME OF the most significant and important devices in the history of electronics have been developed in the past few years. One of these devices is the voltage-variable capacitance diode; also referred to as the "varicap" or "varactor" diode.

The varicap (to settle on one convenient name) is the solid-state equivalent of the conventional tuning (variable) capacitor commonly used in radio receivers. In the consumer market, the varicap is found in the tuning circuits of r.f. receiver sections, in a.f.c. circuits, and as frequency multipliers. (Several of the top-quality FM receiver manufacturers are employing varicap tuning, usually providing multi-station pushbutton tuning, and at least one varicap TV tuner is available.)

A varicap-potentiometer tuning circuit has several important advantages. It is more compact, lighter in weight, and more rugged than the conventional tuning capacitor. In addition, fabrication of the varicap is less critical (to provide a predetermined capacitance range) than the capacitor.

The varicap is actually a semiconductor diode. But it differs from the ordinary diode in that it is specifically designed to function as a capacitor under the right conditions. To see how this is accomplished, a brief review of capacitor fundamentals and *p-n* junction semiconductor physics is in order.

In its simplest form, a conventional fixed capacitor consists of two conductive plates separated by an insulator (dielectric) as shown in Fig. 1. When a d.c. voltage is applied to the plates, current flows until the capacitor charges up to the applied voltage level. A change in the amplitude, or a reversal of the polarity, of the applied voltage does not affect the value of the capacitor.

To change the value of a capacitor, you must change the area of the plates, the distance between the plates (dielectric thickness), or the dielectric material. For example, as illustrated in Fig. 2,

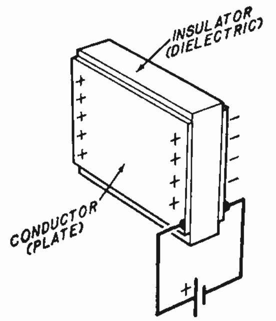


Fig. 1. Simplest capacitor consists of two conductive plates separated by an insulating dielectric.

doubling the dielectric thickness reduces the value by half, and reducing the dielectric thickness by half doubles the capacitance value. A ganged tuning capacitor employs the change-of-plate-area technique; physical rotation of the shaft meshes and unmeshes the plates, thereby increasing and decreasing capacitance. (Changing the dielectric material is generally not considered as a practical means of varying capacitance value because of the obvious problems involved.)

The varicap accomplishes capacitance changes through a system of variable reverse biasing instead of through a physical change. This phenomenon is directly related to the physics of the *p-n* junction in semiconductors.

All materials are classified as conductors, semiconductors, or insulators according to the quantity of "free" electrons available in them. (An electron that can easily be freed from its atom or molecule through the application of a voltage is termed a "free" electron. Obviously, these free electrons must be in the outermost, or valence, rings where they are least tightly bound.)

Consequently, for a good conductor there are a great many free electrons available. (Copper, for example, has one free electron for every 13 atoms.) A good insulator may have only one free electron for several billion atoms or molecules. The semiconductor has an intermediate number of free electrons, more than an insulator but less than a conductor.

Semiconductor materials like germanium and silicon are basically poor conductors because of their lack of a large quantity of free electrons. However, during the manufacture of a *p-n* junction, small measured amounts of impurity elements can be added to the semiconductor crystal by a process known as "doping" to form positive (*p*-type) and negative (*n*-type) materials. (The impurities introduce mobile electric charges into the semiconductor crystal to step up conductivity. The doping also adds an equal number of stationary charges, fixed by the immovability of atoms in the crystal.)

Now consider a 9-volt reverse bias applied to the *p-n* junction illustrated in the drawing at left in Fig. 3. Current flows as the mobile charges become rearranged, with the positive and negative mobile charges both moving toward the junction. At the junction, the opposite-polarity charges pair up and neutralize each other (all within specific zones on both sides of the junction) leaving a depletion region of fixed charges.

Recall now that an insulator (dielectric) lacks movable charges, just as does the depletion region. The depletion region thus acts as the dielectric of the diode capacitor.

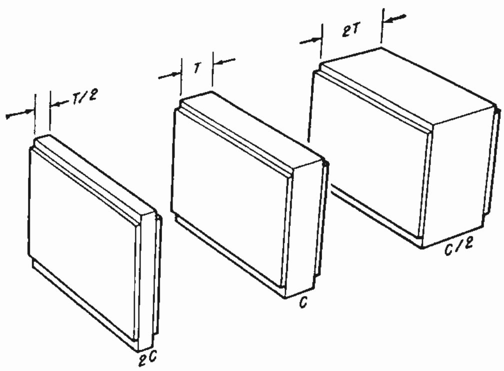


Fig. 2. Changing dielectric thickness (plate separation) causes inverse change in capacitance value.

The uncovered fixed charges in the depletion region, negative in the *p* material and positive in the *n* material, set up a space charge or internal voltage that is opposite in polarity to the applied voltage. This zone widens sufficiently to uncover enough fixed charges to build up a barrier voltage equal to but of opposite polarity to the applied voltage. Notice now that the fixed charges and battery polarity in Fig. 3 match those of the charged fixed capacitor shown in Fig. 1.

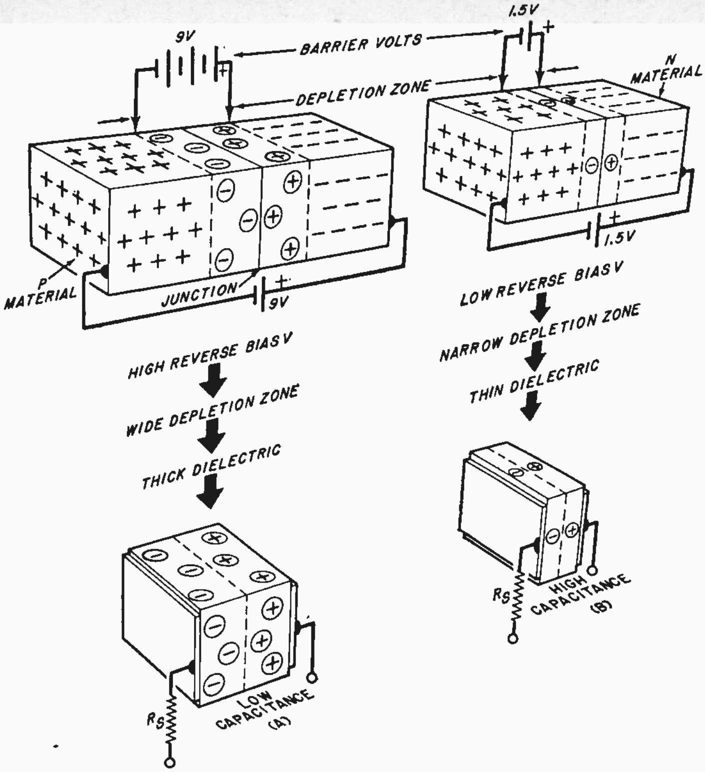


Fig. 3. When reverse bias is applied, p-n junction exhibits capacitance effects. Large amplitude bias voltage (left) causes low-value capacitance, while low amplitude voltage (right) produces proportionally higher capacitance value.

It is this set of conditions that provides the *p-n* junction with a capacitive effect.

With 1.5 volts of reverse bias on the junction as shown at right in Fig. 3, a smaller number of fixed charges need be uncovered in the depletion region to build up the bucking barrier voltage of 1.5 volts. As a result, the region width is narrower than if the reverse bias were 9 volts. The narrower depletion region corresponds to a thinner dielectric and a higher capacitance value (similar to Fig. 2 where dielectric thickness was reduced by half to double capacitance). It is now obvious that reverse-bias voltage can be varied from a high to a low amplitude to cause corresponding changes in junction capacitance.

With no bias voltage applied to the junction, some of the movable positive and negative charges nearest the junction manage to attract each other to produce an even narrower depletion region. This results in a built-in barrier voltage of about 0.25 volts for germanium and 0.6 volts for silicon diodes.

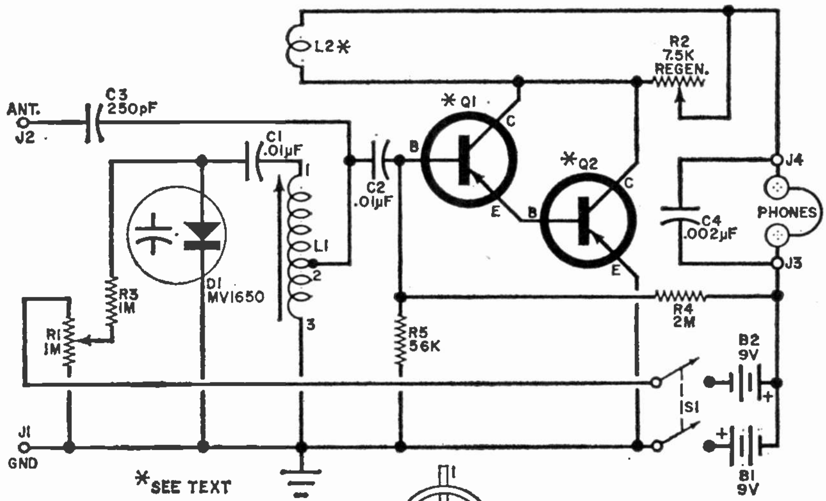
Next, those portions of the *p* and *n* materials outside the depletion region still have both movable and fixed charges. These portions have the ability to conduct but also have some resistance. This resistance is shown as *Rs* in Fig. 3. What distinguishes the varicap from other types of diodes is that *Rs* is maintained as low as possible to reduce losses in the "capacitor."

Because all semiconductor devices include at least one *p-n* junction, all also exhibit some degree of voltage-variable capacitance. The group includes all bipolar transistors, FET's, all semi-conductor diodes, and SCR's and other solid-state switching devices. Junction capacitance which hampers high-frequency operation in many semiconductor devices can be put to good use in voltage-variable capacitance diode applications.

On pages 138 and 139 you will find a practical hobby application of the varicap. The project is a one-transistor super-regenerative AM broadcast band tuner, using the varicap as the tuning capacitor in conjunction with a potentiometer. -30-

A Varicap Front End AM Tuner

BY A.A. MANGIERI



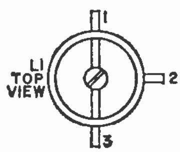


Fig. 1. Tuning circuit consists of L1 and D1; reverse bias supplied by B1 and B2 can be varied with R1.

PARTS LIST

B1,B2—9-volt battery
C1,C2—0.01-μF disc capacitor
C3—250-pF mica capacitor
C4—0.002-μF disc capacitor
D1—Motorola tuning diode (Allied Electronics 49D26 MV 1650, see text)
L1—Tapped antenna loopstick (Superex VLT 240)
L2—Feedback coil (see text)
Q1,Q2—General-purpose pnp germanium r.f. transistor (see text)
R1—Log taper potentiometer (see text)
R2—7500-ohm potentiometer
R3—1-megohm, R4—2-megohm, R5—56,000-ohm — all resistors ½-watt
S1—D.p.s.t. switch
Misc.—Magnetic headphones; perforated phenolic board; solderless terminals; #28-#32 magnet wire for L2; audio power module (optional); loudspeaker (optional); etc.

THE REGENERATIVE AM broadcast band tuner described here employs a varicap diode in place of the common ganged capacitor. Tuning, as mentioned earlier, is accomplished by adjusting a potentiometer.

Although only one tuned circuit is used, regeneration is sufficient to provide remarkable sensitivity and selectivity. A simple 3′-long test-lead "antenna" will suffice for reception of most local stations. The author tried a 20′-long antenna and obtained excellent results, pulling in a station known to be some 1400 miles distant.

The tuner (shown schematically in Fig. 1) consists of a single tuned regenerative amplifier/detector arrangement. Varicap diode *D1* is connected in parallel with *L1* with *C1* serving as a d.c. blocking device for *L1*. Batteries *B1* and *B2* provide the reverse-bias source for *D1*, while potentiometer *R1*—the tuning control—facilitates continuously variable bias. Also, resistor *R3* in the wiper circuit of *R1* prevents the r.f. signal voltage from shorting out through the bias supply.

Transistors *Q1* and *Q2* are connected in a complementary arrangement to simulate a single very-high-gain transistor. And to maintain the required high Q in the *L1* circuit, the base of *Q1* is connected to the low-impedance tap on *L1*.

Feedback winding *L2* serves as a regeneration link that feeds back some of the amplified signal voltage to *L1* for reamplification. The amount of feedback, or regeneration, is controlled by potentiometer *R2*.

Construction. During construction of the tuner, neither component placement nor orientation is critical. The breadboard arrangement shown in Fig. 2 is provided only as a guide. You can make the project more compact—small enough to fit into a shirt pocket—if you desire.

A word of advice: before installing *R1* and *R2* in the circuit, use an ohmmeter to check these pots while slowly rotating the shafts from stop to stop several times. If there are any abrupt resistance changes or indications of erratic operation, try a new pot. Potentiometer *R1* must have an audio taper, but it can have a value anywhere between 50,000 ohms and 2 megohms.

Then, when installing the *R1* control, connect the left terminal to ground and the right terminal to the negative lead of *B2* (pot viewed with shaft pointing toward you). Now, connect *R2* into the circuit so that resistance increases with a clockwise rotation of the shaft. It is a good idea to use an ohmmeter to double check for proper shaft rotation.

Close-wind *L2* centered over *L1*, winding clockwise (as viewed from the end of the coil opposite the slug screw). Start winding from the lug end of *L1*. Then connect the starter lead to *J4* and the other lead to the transistor collectors.

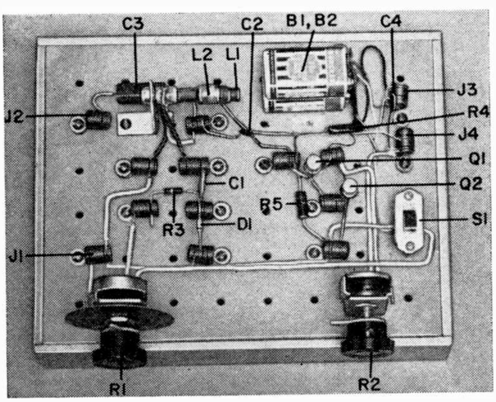


Fig. 2. Breadboard assembly is provided as component layout guide; if you prefer, you can assemble your project in a substantially smaller volume space.

Any of various types of germanium r.f. amplifier transistors will perform well for *Q1* and *Q2*. Do NOT use nonlinear converter/mixer transistors. If you have specification sheets for your transistors or a transistor beta tester, select transistors with betas between 40 and 100. If you use a very-high-gain transistor—say one with a beta of 200—pair it with a low-gain unit.

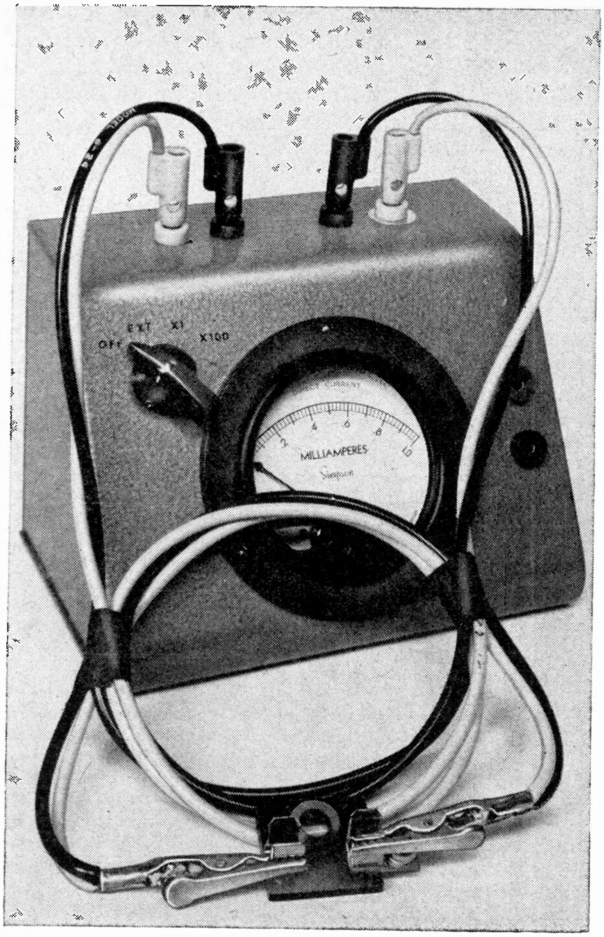
Connect the cathode (banded end) of *D1* directly to ground; the other lead to the junction of *C1* and *R3*. (If you have some surplus high-current, low-leakage silicon power diodes, you might want to try substituting one of these for the varicap. Many such rectifiers will perform satisfactorily, though with a lesser tuning range, if the r.f. losses and d.c. leakage are sufficiently low. Diodes in the greater-than-five-ampere range may even possess sufficient junction capacitance to cover the entire AM broadcast band with the coil specified.)

Alignment. Tuning and adjustment of the tuner will have to be by trial and error. However, once accomplished, the tuner should provide stable performance over a considerable length of time.

First, back out the coil slug about ⅝", connect an antenna and earth ground to *J1* and *J2*, and connect a pair of headphones to *J3* and *J4*. Set *R2* fully counterclockwise, and close *S1*. Now, slowly rock *R1* back and forth while advancing *R2* clockwise until you hear a whistle or beat note. Tune in a station. Then back off *R2* to eliminate the whistle while readjusting *R1* to bring in the station clearly and at maximum volume.

If you are unable to hear a station, or if you hear a loud distorted audio tone, you may have to experiment with the values of *R4* and *R5* to compensate for transistor gain and leakage current variations. Then, when you obtain the proper results, connect a d.c. milliammeter in series with the headphone lead at *J3* and observe the indication; it should lie between 1 and 2.5 mA when *R2* is fully counterclockwise.

(*Continued on page* 150)



Constant-Current Ohmmeter

BY ALVIN B. KAUFMAN

Build unusual test equipment project

THE UBIQUITOUS VOM is one of the handiest pieces of test equipment available to the electronics experimenter. Although useful in a thousand different ways, there are times when a VOM can be the cause of damage to the equipment being tested—by applying excessive current to low-resistance devices, for instance. This means that you can't use a conventional VOM to test D'Arsonval meter movements, meter fuses, or transistors, to name a few items that are current sensitive.

Another limitation on the use of the VOM, is the poor accuracy obtainable on the lowest resistance range (usually R×1). The VOM range selector switch, battery clips, and test lead terminations often become slightly resistive with time and use and interfere with the readings for very low resistances. Of course you can clean clips and lead ends but it's a little difficult to get at the contacts on the selector switch.

The constant-current ohmmeter described here eliminates these problems and, in addition, does not require a zero adjustment for resistance measurements. Although this new ohmmeter has its own meter, an external d.c. voltmeter can be used if desired.

Construction. The author built his meter in a conventional 4¼" × 4" × 4" metal case with a sloping front, although any other approach can be used. The two external meter jacks (*J1* and *J2*), switch *S1*, and meter *M1* are mounted on the front panel. The two pairs of testlead jacks (*J3-J4* and *J5-J6*) are mounted on the top. The battery is secured in the case by a mounting clip.

The circuit, shown in Fig. 1, is wired point-to-point. When making the connec-

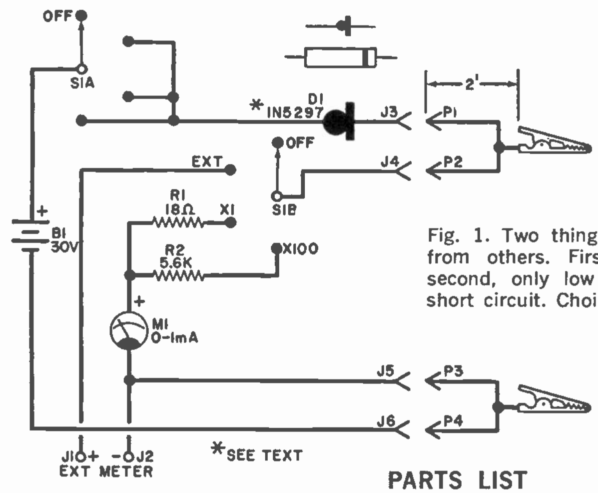


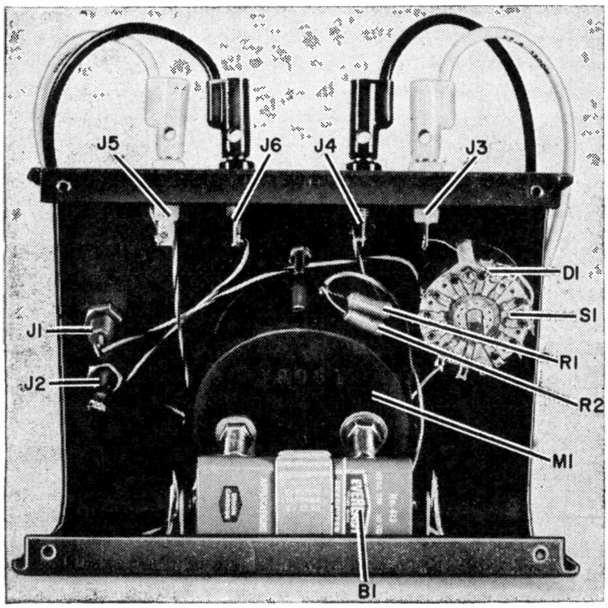
Fig. 1. Two things make this ohmmeter different from others. First it requires no zero control; second, only low current can flow, even with a short circuit. Choice of D1 determines the current.

PARTS LIST

B1—30-volt battery (Eveready 413 or similar)
D1—1N5297 constant-current diode (Allied Electronics #49D261N5297-MOT-$4.45. See How It Works for diode selection.)
J1-J6—Banana jacks (E.F. Johnson 108 series)
M1—0-1-mA meter (Simpson Model 25 or similar)
P1-P4—Plugs to mate with banana jacks
R1—18-ohm, 1-watt, wire-wound 1% resistor
R2—5600-ohm, 1-watt, wire-wound 1% resistor
S1—Two-pole, four-position rotary switch
Misc.—Metal enclosure, battery holder (Keystone 183 or similar), four 2-foot heavy-duty test leads, 2 alligator clips, knobs.

tions to *S1*, be sure that the correct terminals are used on each section. Also be sure that *D1* is wired in correctly. If you use the Motorola diode called for in the parts list, the black band should be toward *J3*. Unlike a conventional diode, if the constant-current diode is installed with the wrong polarity, it will conduct heavily and ruin both itself and the meter.

Operation. With switch *S1* on OFF, connect the test clips to an unknown resistance. If the unknown is 900 ohms or



The circuit and assembly are very simple. The bulk of the components are mounted on the front panel with only the battery on chassis bottom.

CALIBRATION OF OHMMETER			
X1 SCALE		X100 SCALE	
Resistance	Meter Reading	Resistance	Meter Reading
10Ω	.16	500Ω	.095
20	.275	1000	.165
30	.365	2000	.29
40	.44	3000	.38
50	.50	4000	.45
60	.54	5000	.51
70	.58	6000	.56
80	.62	7000	.60
90	.65	8000	.64
100	.68	10,000	.695
200	.83	20,000	.84
300	.90	30,000	.91
400	.93	40,000	.95
900	1.00	50,000	.97

less, place *S1* in the ×1 position and determine the resistance by using the calibration table. If the unknown is above 900 ohms, use the ×100 position of *S1*.

To use an external d.c. meter, be sure that it has at least 20,000 ohms per volt and connect it to *J1* and *J2* with *S1* in the EXT position. Using a 1-mA constant-current diode for *D1*, divide the meter reading by 0.001 to get the value of the unknown resistance in ohms. For example, a 0.1-volt indication means 100 ohms, a 1-volt indication, 1000 ohms, etc.

Almost any 0-1-mA meter can be used for *M1*, provided both range resistors (*R1* and *R2*) are adjusted for correct dial reading. You can use an accurate resistor decade box for the unknown resistor and adjust the range resistors to get the proper indications. For maximum accuracy, use 1% resistors and a meter with a comparable tolerance.

In any case, unless the internal one-milliampere meter is used, do not turn the constant current ohmmeter *on* without the test leads being connected to a resistor. With an open circuit, the full current from the constant current diode is applied to the meter. The internal meter is rated for this current, but a high-sensitivity (low current/voltage) external meter may be damaged.

For very high accuracy, an oscilloscope or a low-range sensitive d.c. voltmeter can be used for the meter. —30—

HOW IT WORKS

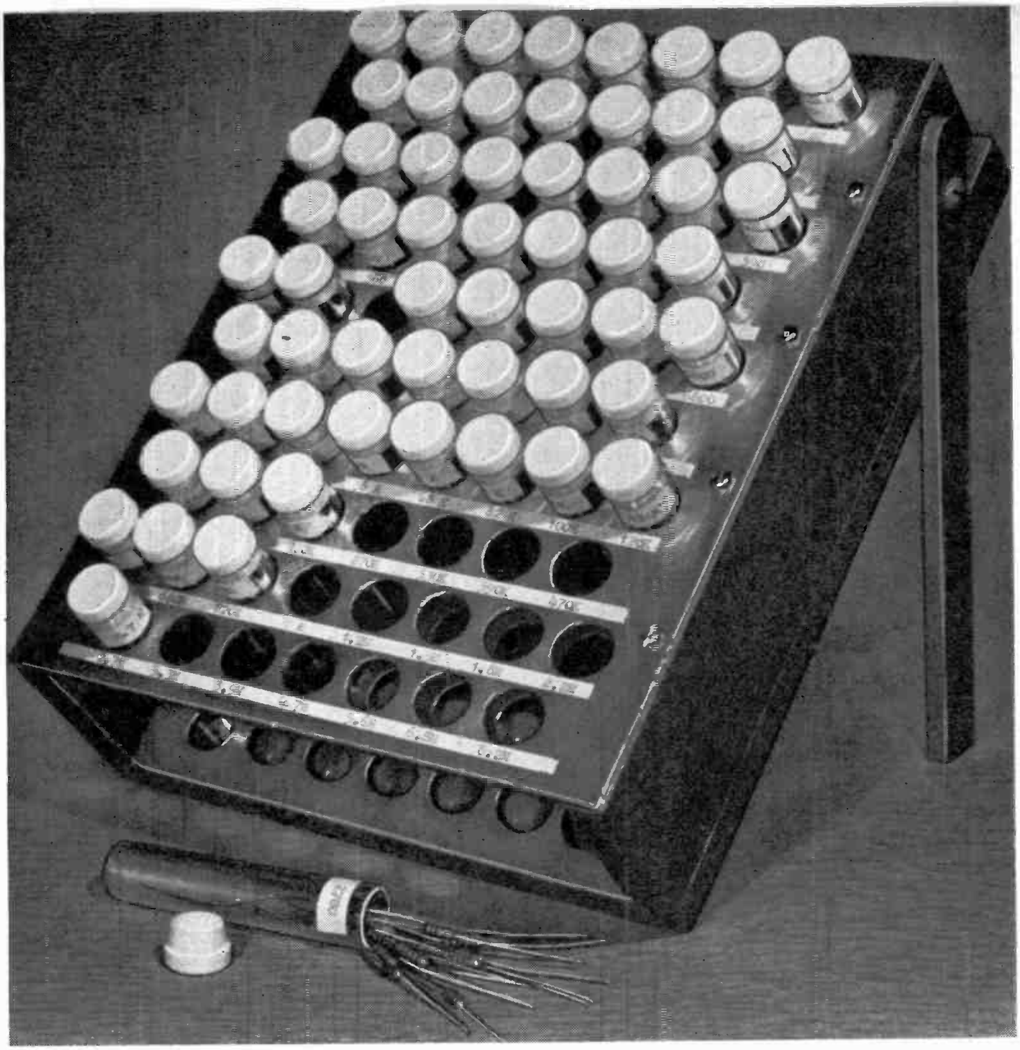
The circuit uses a new semiconductor device—the constant-current diode. This diode maintains a constant current through an unknown resistance regardless of the ohmic value, up to some specified resistance. Since the voltage developed across the unknown resistance is being measured, no balancing or current adjustment controls are required.

The constant-current diode is basically a junction field-effect transistor (JFET) with its gate and source electrodes connected together inside the case. The constant current is accurate provided the applied voltage is between 1 and 100 volts (depending on the diode selected).

There are 32 diode types available with constant currents ranging from 220 microamperes to 4.7 milliamperes (1N5283 through 1N5314). The current value selected determines three other measurement parameters. These are the ohms/volt value, the voltage sensitivity required of the meter, and the high resistance range of the test set.

In the circuit shown in Fig. 1, *D1* is a 1-mA constant-current diode. The ohmmeter range could not exceed 29,000 ohms if the diode pinch-off rating was one volt, because the drop across the unknown resistor would then be 29 volts. If the unknown resistor were zero ohms, the full supply voltage would be placed across the diode. Thus the diode must be selected to withstand the voltage and power dissipation encountered in the operational condition.

If the readout meter is to indicate ohms on a linear scale, it should (for the range selected), have a resistance twenty or more times the value it is to indicate.



A Home For Ohms

BY A. J. LOWE

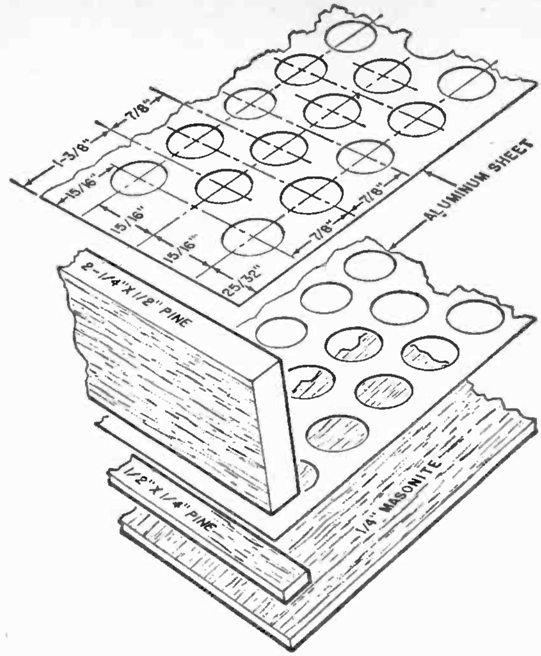
A PLACE FOR EVERYTHING AND EVERYTHING IN ITS PLACE

UNLIKE most other electronic components, the physical size of a resistor does not vary from value to value of resistance in a given power rating. This "sameness" can cause you to waste a great deal of time if you have to locate a specific resistance value in a well-stocked but haphazardly arranged spare parts supply. Ideally each value of resistance should have its own bin—not an easy thing to arrange if space is limited, but the rack shown in the photo is perfect for compact, easy-access storage of resistors and other small parts.

Called a "Home for Ohms" because of its obvious value for resistor storage, the facility consists of 75 individual bins (actually pill containers) and a perforated rack. At most, the rack, with all bins in place, occupies only about 80 square inches of space and can accommodate 1200 or more resistors.

The pill containers used for the bins should measure about 3½″ long by ⅝″ diameter. The best source of supply for the pill containers is your local drug store. If you can't get them, however, try substituting stoppered test tubes.

The rack is made of two 10″ × 8″ sheets of 1/16″ aluminum, pine spacers,



To maintain maximum strength, stagger the holes in the aluminum sheets as illustrated in this drawing.

and a Masonite bottom plate. Use an 11/16" chassis punch to make the holes according to the dimensions provided in the drawing. The rows of holes should be staggered to retain maximum strength in the aluminum sheets. And for accurate hole alignment, it is a good idea to clamp the aluminum sheets together while drilling the pilot holes for the chassis punch; then separate the sheets and punch each hole separately.

When assembling the rack (see drawing), use flat-head wood screws on the bottom and oval-head wood screws on the top. The optional 8" legs shown in the photo should be allowed to swivel flush with the sides of the rack so that it can lie flat for storage.

Each container—not cap—and each hole should finally be labeled with the value of the resistor (or other component) it contains to provide a quick locator system. If you don't wish to stock 75 different values of resistors, you can utilize the extra containers for signal diodes, tubular capacitors, or other small components. —30—

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Build a Pos-Neg Pulse Generator

INDISPENSABLE TRIGGER SOURCE FOR DIGITAL CIRCUITS

BY FRANK H. TOOKER

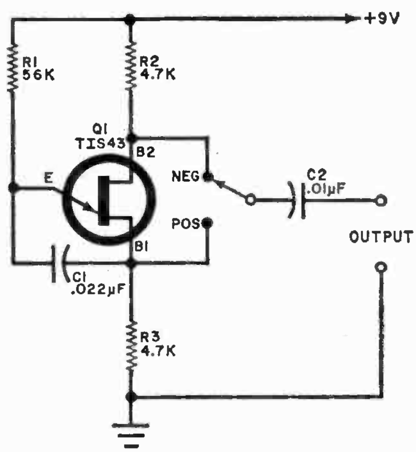


Fig. 1. Simple unijunction transistor circuit generates positive or negative pulses of relatively wide durations.

IN THE COURSE of experimenting with, developing, and testing computer logic and counter circuits, it is useful, if not essential, to have an available source of pulses to supply triggers or actuating signals. Such a source should provide pulses that are quite narrow, of adequate amplitude, and either positive or negative in polarity, selectable at the flick of a switch.

The circuit shown in Fig. 1 is satisfactory for a number of applications. Output amplitude is good, and the setup is quick and easy to breadboard in an emergency. Pulse duration is wide, however.

In the circuit shown in Fig. 2, an inductor, *L1*, with a fairly high Q is used in the B2 circuit of *Q1*, rather than a resistor. Both *B1* and the low end of timing capacitor *C1* are grounded. Each time the UJT fires, a negative pulse and a positive pulse are produced consecutive-

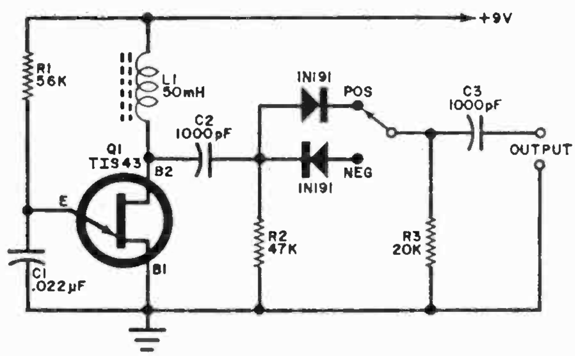


Fig. 2. This circuit generates positive and negative pulses simultaneously with the shape of the pulse sharpened by the inductor in the base 2 circuit.

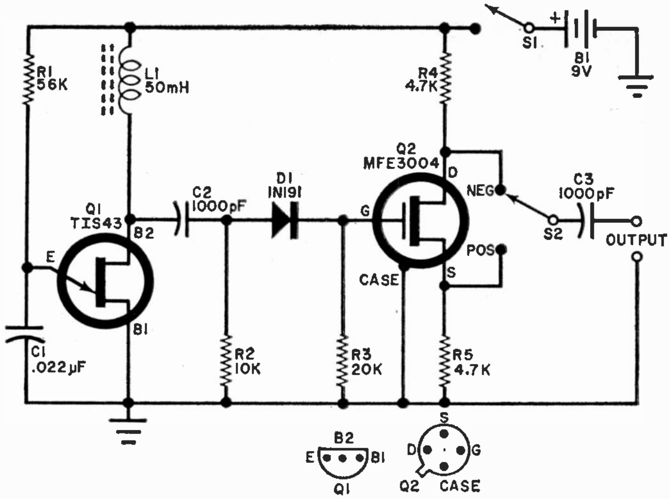


Fig. 3. With the addition of a MOSFET, only positive-going pulses from Q1 are used. Phase splitting then provides a repetition rate of 400 pps of either polarity.

PARTS LIST

B1—9-volt transistor battery
C1—0.022-µF, 100-volt Mylar capacitor
C2, C3—1000-pF silver-mica or polystyrene capacitor
D1—1N191 diode
L1—50mH, high-Q inductor, powdered-iron core
Q1—Unijunction transistor (Texas Instruments type TIS43)
Q2—MOSFET transistor (Motorola type MFE3004
R1—56,000-ohm
R2—10,000-ohm
R3—20,000-ohm
R4, R5—4700-ohm } *All resistors ½-watt*
S1—s.p.s.t. switch
S2—s.p.d.t. switch

ly at *B2*. Other than this, ringing is negligible. For the component values given, pulse amplitudes are approximately equal. Because the inductor is effectively in parallel with the output, differentiation occurs, with the result that both of the output pulses are quite narrow. The simple arrangement of two diodes and a s.p.d.t. switch makes it possible to have either positive or negative pulses at the output.

Performance with this circuit is quite good provided it is not too heavily loaded. (That is, it should preferably be used with a fairly high-impedance load.) If resistors *R2* and *R3* are sufficiently high in value, and loading is very light, the amplitude of the output pulse can approach the level of the power-supply potential.

In the circuit shown in Fig. 3, only the positive-going pulses from B2 of *Q1* are used since MOSFET *Q2* is an *n*-channel type. Negative pulses are suppressed by diode *D1*. The type MFE3004 MOSFET was chosen for the phase splitter because of its ability to handle the signal level and its excellent high-frequency response, rather than because of its high input impedance. The latter does permit loading of the UJT almost entirely with resistors, however.

With this circuit, differentiation occurs in the *C2-R2* circuit as well as in *L1*. Repetition rate is about 400 pulses per second, while pulse duration is about 12 µsec and output amplitude is 3 volts. Amplitudes of the positive and negative pulses are equal.

When working with any MOSFET, take care that you do not touch the isolated gate lead since any static charge can destroy the fine gate insulation within the semiconductor. Keep the three leads in direct electrical contact until the MOSFET is soldered into the circuit.

If a slower pulse rate is desired, increase the value of either *R1* or *C1*, in small steps, until the desired rate is obtained. —30—

UJT Frequency Standard

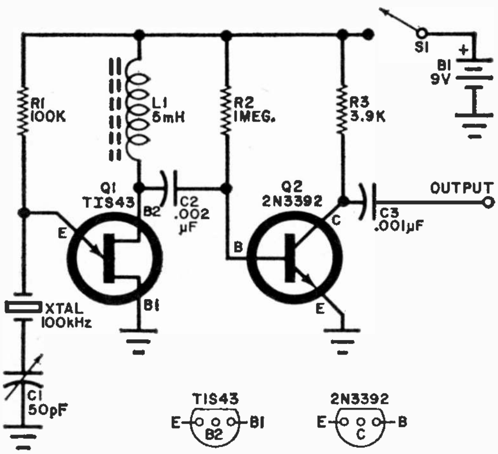
SIMPLE LOW-COST CIRCUIT RICH IN HARMONICS

BY FRANK H. TOOKER

HERE IS a 100-kHz frequency standard that uses only two transistors and consumes only 35 milliwatts of power, but puts out a signal of rectangular waveform which has an overall swing approximately equal to the value of the supply voltage! Although the circuit is simple and easy to put together, the finished instrument can be set quite accurately by zero beating its signal against the Bureau of Standards station, WWV.

The secret of the standard's excellent performance can be understood by examining the schematic shown here. A unijunction transistor, *Q1*, is used as the crystal oscillator. The UJT, with its excellent temperature characteristics and built-in feedback (in the form of negative resistance), takes the place of a number of components that would otherwise be needed to make a circuit that would perform as well as this one does.

The UJT operates somewhat in the manner of a relaxation oscillator except that the 100-kHz crystal is connected in the emitter circuit instead of the usual timing capacitor. The crystal rings the emitter circuit, causing the UJT to oscillate at the crystal's frequency. In this circuit, the crystal operates in its series-resonant mode. Thus adjusting variable capacitor *C1*, in series with the crystal, alters the crystal's resonant frequency slightly so that the standard can be matched to WWV.



Although simple, this oscillator is very stable and will remain on the frequency for a long time.

Output from the crystal oscillator appears across inductor *L1* in the base-2 circuit of *Q1*. The signal level here is high enough to drive *Q2* alternately between cutoff and saturation. The resulting signal across the load resistor *R3* is of rectangular waveform and has an overall swing very nearly equal to the value of the supply voltage The output of the standard is taken from the collector of *Q2* through capacitor *C3*.

To calibrate the standard, connect one end of a convenient length of wire to the output terminal and lay the other end near the antenna terminal of your short-wave receiver. Tune in WWV on the receiver and adjust capacitor *C1* in the direction which makes the sound coming from the speaker become lower and lower in frequency until it finally becomes inaudible. This point is called the "zero beat." The standard is now adjusted to the WWV frequency with a very high degree of accuracy.

Because the crystal operates in its series-resonant mode and because components are few, layout and construction of the standard are not especially critical. Just follow good wiring practices and you'll have a frequency standard that will serve your needs well for a number of years! -30-

PARTS LIST

B1—9-volt alkaline transistor battery (Mallory Duracell MN1604B)
C1—50-pF variable capacitor, ceramic insulation
C2—0.002-µF silver-mica capacitor
C3—0.001-µF silver-mica capacitor
L1—5.0-mH inductor, ferrite core (J.W. Miller 6304)
Q1—Unijunction transistor (Texas Instruments TIS43)
Q2—Transistor (General Electric 2N3392)
R1—100,000-ohms, ½-watt, 2% metal-glaze resistor (IRC RG20)
R2—1-megohm, ½-watt, 5% composition resistor
R3—3900-ohm, 2% metal-glaze resistor (IRC RG20)
S1—S.p.s.t. slide or toggle switch
XTAL—100-kHz series-resonant crystal (32-pF)

VARICAPS

(*Continued from page* 139)

In the event that the meter reading is greater than 2.5 mA, interchange *Q1* and *Q2* and/or adjust the value of *R4* to bring it into line. However, if the problem still persists—even when *R4* is removed—one or both of the transistors is leaking too much current and must be replaced.

Conversely, if the meter reading is too low, try increasing the value of *R5* or decreasing the value of *R4*, or both. Then, when the reading is within the 1 to 2.5 mA range, check tuning and regeneration as described above. If you still cannot tune in a station, or separate one station from another, reverse the connections of and/or add more turns to *L2*. If all else fails, you can assume that the *Q1-Q2* combination has insufficient gain, and one or both must be replaced.

After proper operation is obtained, for smoothest control or regeneration, reduce the number of turns on *L2*, one at a time, enough to produce the beat note or whistle on all stations before *R2* is advanced to its maximum clockwise position.

Operation. This tuner will cover about half of the AM broadcast band since the capacitance range of the varicap diode is rather limited. However, you can tune *L1* to cover the portion of the band you desire. If you find that very strong signals "swamp" the tuner, simply reduce the value of *C3* to 100 or 50 pF.

Finally, if the tuner tends to either "motorboat" or "plop" into or out of critical regeneration, try shifting the operating current as described earlier and reduce the number of turns on *L2*.

For speaker operation, the tuner will have to be converted to a receiver. The easiest way to accomplish this is to connect the output to any one of the various low-cost audio amplifier modules available. To do this, disconnect the headphones and replace them with a 3000 to 6000-ohm, ½-watt resistor. The signal can then be tapped from *J4* via a d.c. blocking capacitor and ground. —30—

POWER INVERTER

(*Continued from page* 133)

because it simply won't oscillate. A moderate overload permits the transistors to switch but the operation is in their linear region resulting in excessive heat generation and subsequent destruction.

For non-permanent use in a car, trailer, or truck, use a length of at least #14 wire and a cigarette lighter plug for the power input. For semi-permanent use, substitute a pair of heavy-duty crocodile clips for the lighter plug. In this case, connection can be made directly to the battery. In both cases, observe the polarity!

If the inverter produces "hash" on the vehicle's power system and interferes with radio operation, connect a 250- to 500-μF, 25-volt electrolytic capacitor across the inverter input terminals. Be sure to get the polarities correct on the capacitor.

Finally, remember that the inverter is not a substitute for the commercial 117-volt supply under all circumstances. For example, the voltage output is peak output, not r.m.s. Peak voltage of the commercial 117-volt line is about 161 volts. Hence, if you are using a device containing a peak rectifier, you can expect some reduced performance.

The output voltage is a function of the applied load as shown in Fig. 2. The frequency of the output varies with load as shown in Fig. 3. Bear this in mind when using devices whose operation depends on power-line frequency (synchronous motors, for example). —30—

COMPRESSION SUSTAINER

(*Continued from page* 129)

off switch *S1*), the output level control (*R9*), and the output jack (*J2*) on the selected cabinet. (All of these controls and jacks are called out in the EEH, Winter '69 article.) Mount the footswitch either on top of the circuit box or in its own box.

Some people may find that the compressor brings the bass level up too high. In this case, add the bass-cut control circuit shown in Fig. 2. This simple filter may be used either in the compressor electronics package or at the guitar.

Operation. Set the footswitch so that the compressor is not in the circuit. With the guitar (or other electronic instrument) attached to the compressor input, strike a chord and note the approximate level of the volume peaks. Hit the footswitch to introduce the compressor, and adjust *R1* approximately one-quarter turn clockwise (volume up). Then adjust the output control (*R9*) until the level of the music peaks is slightly higher than the level previously noted when the compressor was out of the circuit.

When using the compressor, you will notice instrument sounds that were barely audible before. If the thump sound at the attack of a note is disturbing, simply lower the gain with *R1*. If you set *R1* at slightly more than halfway, you may get spurious feedback because of the high system gain.

The compressor may be used in conjunction with any guitar accessory, such as wa-wa or fuzz. In both cases, the effect is magnified, and you must practice using the compressor to learn how to get the most from it. Also, the guitar volume control has a decreased effect since, as you turn it down, the compressor amplifies more. Because of this, the guitar volume control can be used as a vernier for the compression.

The modified compressor has been used by a number of well-known rhythm groups with great success and should provide the user with a "new sound" for his guitar. —30—

PSYCH-ANALYZER

(*Continued from page* 122)

is through the use of playing cards. Show a subject five playing cards and ask him to select mentally one of them. Instruct him to say, loudly and with real conviction, "No! That is NOT my card!" every time you show him one of the cards and ask, "Is *this* your card?" Four times he will be telling the truth, the other he will be lying. Don't let the subject watch the meter, but keep your eyes on it all the time.

Sometimes the subject will show a marked response to two cards, and you will have to work a bit longer to discover which of the two he picked. Female subjects are sometimes so responsive that you can perform this test without words, merely showing the cards to the subject. Just the sight of the card causes the meter to jump.

Experience has shown that long-time poker players sometimes respond to an ace or a joker even though it is not the card chosen. Likewise, players experienced in the game of Hearts will react to the sight of the queen of spades without having chosen it. The experiment will be easier, therefore, if you leave out cards with specific connotations.

The Psych-Analyzer should be a natural for parties. It has great possibilities as a "passion meter"—if you keep things under control! You might discover that some person who is very blasé on the surface is actually a bit prudish underneath. You might find out who sent you that unsigned Valentine card that was supposed to be funny but didn't strike you that way. Or you might try a game where someone commits a "crime" while the lights are out. Then you try to find the guilty party. *However,* don't "hang" anyone just on the basis of the skin resistivity of his palms.

As a quick check of whether or not your Psych-Analyzer is functioning, connect it to a subject's palms—or even to your own—and have him take a deep breath. The meter should give a definite indication after the relaxation of the deep breath has passed and the air has been exhaled. There may be some latency in this indication also. —30—

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ELECTRONIC EXPERIMENTER'S HANDBOOK SPRING 1970

How to get into one of today's hottest money-making fields—*servicing 2-way radios!*

He's flying high. Before he got his CIE training and FCC License, Ed Dulaney's only professional skill was as a commercial pilot engaged in crop dusting. Today he has his own two-way radio company, with seven full-time employees. "I am much better off financially, and really enjoy my work," he says. "I found my electronics lessons thorough and easy to understand. The CIE course was the best investment I ever made."

Business is booming. August Gibbemeyer was in radio-TV repair work before studying with CIE. Now, he says, "we are in the marine and two-way radio business. Our trade has grown by leaps and bounds."

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Two-way radio is booming. Today there are more than *five million* two-way transmitters for police cars, fire trucks, taxis, planes, etc. and Citizen's Band uses—and the number is growing at the rate of 80,000 per month.

This wildfire boom presents a solid gold opportunity for trained two-way radio service experts. Most of them are earning between $5,000 and $10,000 a year *more* than the average radio-TV repair man.

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The reason is that the U.S. doesn't permit anyone to service two-way radio systems unless he is *licensed* by the FCC (Federal Communications Commission). And there aren't enough licensed experts to go around.

This means that the available licensed expert can "write his own ticket" when it comes to earnings. Some work by the hour and usually charge at least $5.00 per hour, $7.50 on evenings and Sundays, plus travel expenses. Others charge each customer a monthly retainer fee, such as $20 a month for a base station and $7.50 for each mobile station. A survey showed that one man can easily maintain at least 15 base stations and 85 mobiles. This would add up to at least $12,000 a year.

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2. As soon as you've earned a reputation as an expert, there are several ways you can go. You can move out, and start signing up your own customers. You might become a franchised service representative of a big manufacturer and then start getting into two-way radio sales, where one sales contract might net you $5,000. Or you may be invited to move *up* into a high-prestige salaried job with one of the same manufacturers.

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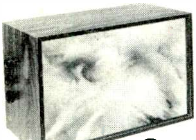

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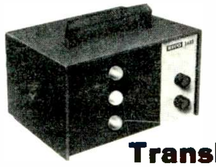

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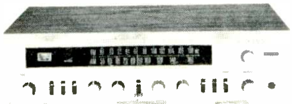

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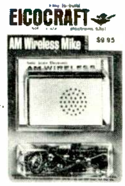

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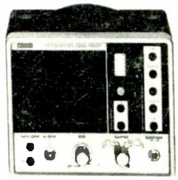

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