FALL EDITION $1.25

1965

POPULAR ELECTRONICS

ELECTRONIC EXPERIMENTER'S HANDBOOK

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HI-FI
FISHING
HAM RADIO
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PLUS: SPECIAL SECTION "THE FABULOUS DIODES"

NEW

MORE POWERFUL TESLA COIL

(page 91)

FALL EDITION
1965 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

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The Fall Edition of the ELECTRONIC EXPERIMENTER'S HANDBOOK is the tenth in a series that began in 1957. Due to the increasing popularity of electronics project building and experimentation, two editions of the EXPERIMENTER'S HANDBOOK are now being printed every year. In February we publish a Spring Edition, in October a Fall Edition. As in the preceding nine editions, this one contains construction projects and feature articles especially selected by the Editors of POPULAR ELECTRONICS.

We are particularly pleased with the projects in this Fall Edition and direct our readers' attention to the new chapter category of Science Fair Projects. It is anticipated that this chapter will be enlarged in future issues.

In the center of this Edition you will find a special 16-page article by Louis Garner on solid-state technology as it particularly applies to diodes. This is a state-of-the-art report and is comparable to feature articles of a similar nature that appear from time to time in POPULAR ELECTRONICS. Also in this Edition are several projects that first saw the light of day in our next-door-neighbor publication, ELECTRONICS WORLD. These articles have been completely revised for use in the EXPERIMENTER'S HANDBOOK.

If you have suggestions for future content, please don't hesitate to write to us.

THE EDITORS

FALL EDITION

1965 POPULAR ELECTRONICS **ELECTRONIC EXPERIMENTER'S HANDBOOK**

CONTENTS

CHAPTER

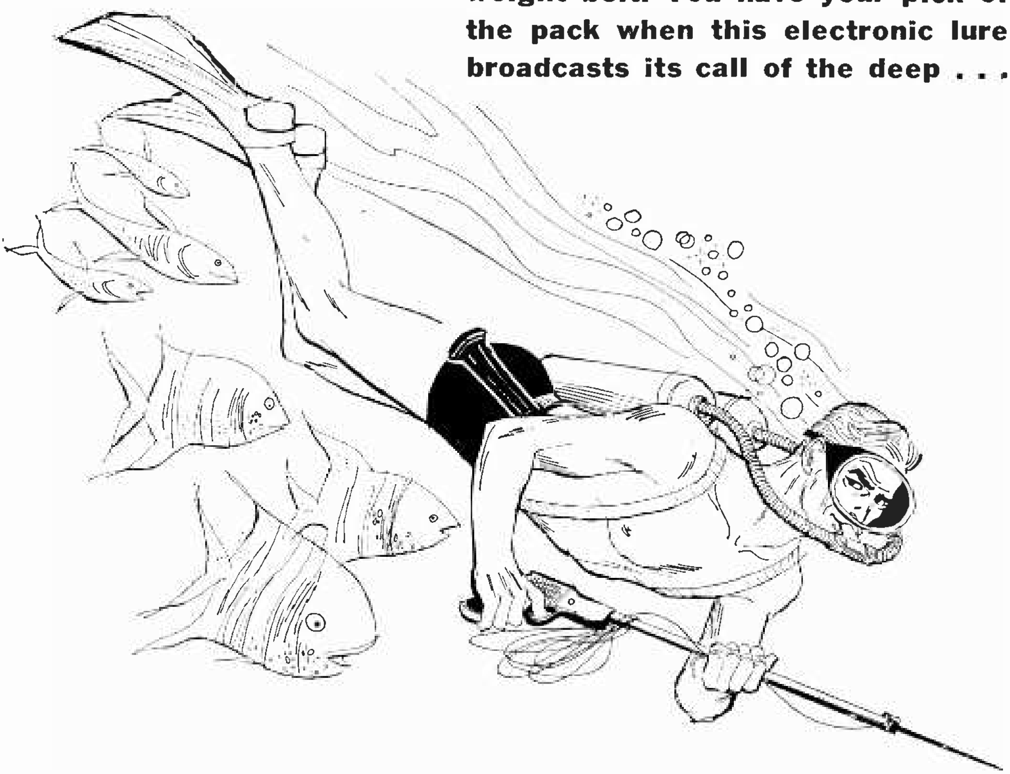
1
USEFUL HOUSEHOLD PROJECTS

Construction projects to be used around the house are generally of great interest to readers of the ELECTRONIC EXPERIMENTER'S HANDBOOK, since such projects can be displayed and operated by the "non-electronically minded" members of the family. They "prove" that the hobbyist-experimenter is not just fooling around and wasting his time. The projects in this chapter have been selected to appeal to the entire family—even though the first project ("CQ Fish" on page 8) is for the OM himself.

The "Panic Alarm" (page 11) and "Nonsense Box" (page 36) are wonderful electronic "gags." Both of these projects appear in the stores at Christmas time—selling for 5 to 10 times the cost of building one with brand-new parts. The metronome (page 14), safety flasher (page 15), and "Multi-trol" (page 28) are all handy household items. And, speaking of Christmas, take a look at the electronic device to make your tree lights twinkle (page 17). The d.c. restorer project (page 22) is one you should consider if you have a TV set that could use some improvement in black and white picture reproduction.

"CQ FISH"

Fish can't resist this CQ from a weight belt. You have your pick of the pack when this electronic lure broadcasts its call of the deep . . .

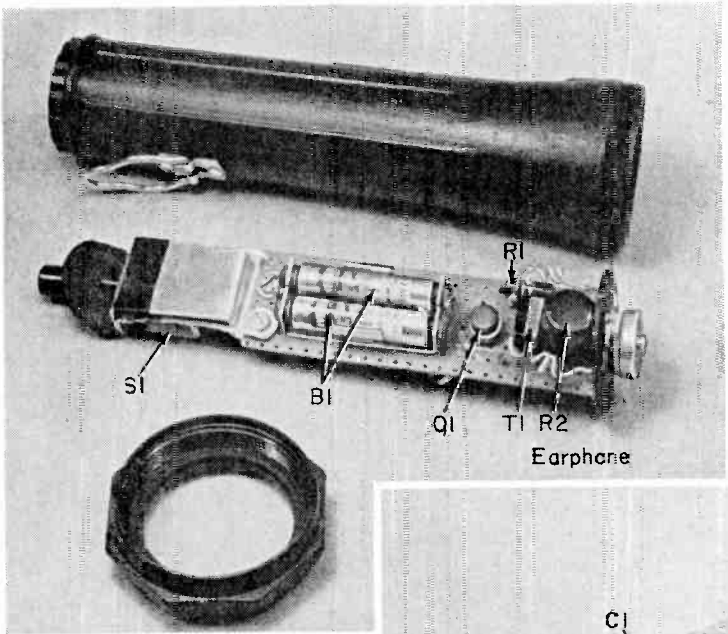


By BILL BILLICK

ELECTRONIC FISH LURES have been used for years by "stick" fishermen. Such lures depend on the low intelligence level of the fish, and have actually worked well. While it is dubious that anybody ever psychoanalyzed a fish, the great attraction would seem to be that the noise emanating from the lure sounds like food. Another theory is that all fish do not dine in the same fashion, and what might sound like food to one would just arouse the curiosity of another. In either case, the fish is lured to his ultimate destruction!

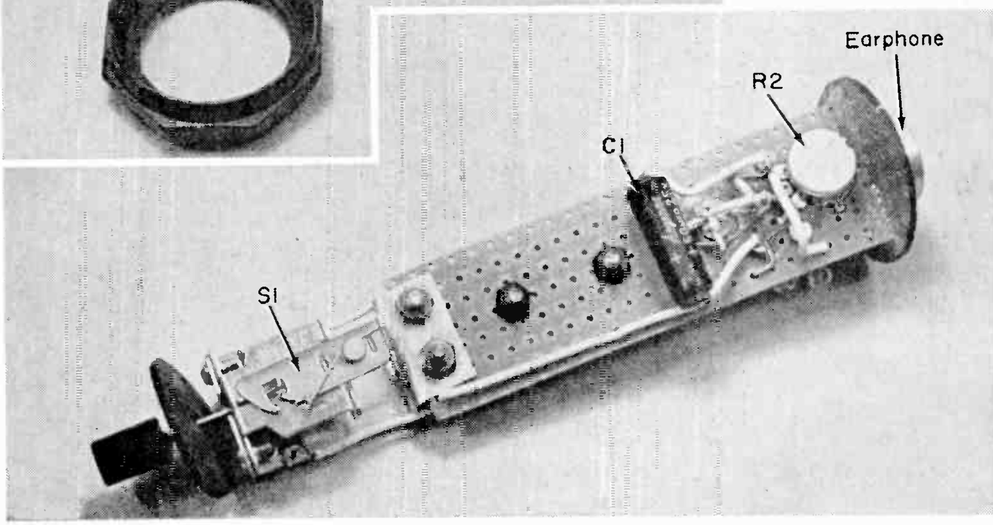
Double-Duty Lure. The fish lure described here can be employed with a fishing rod or by a skin diver. The housing of a pressure-proof skin-diving flashlight permits its use at depths up to 200 feet. To use the lure with a rod, you lower it into the water after turning it on and replacing the end-cap. A skin diver should turn the unit on before entering the water. The flashlight housing can be attached conveniently to a spear gun, weight belt, or a line.

The transistor circuit is a simple Hartley oscillator whose tone or repe-

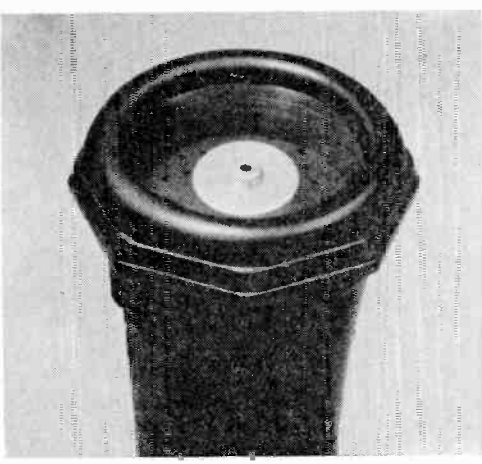


Earphone is mounted with cement on a disc cut from the perforated board.

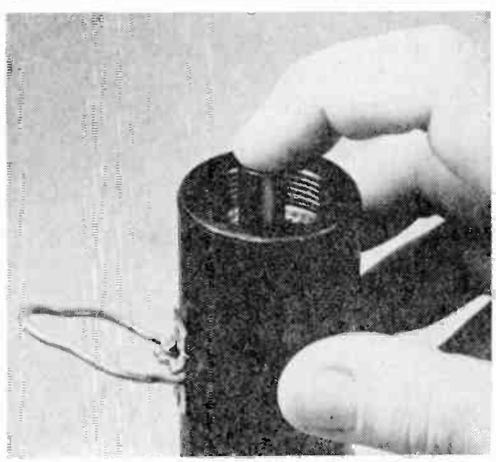
Switch is mounted on an aluminum bracket, bracket is attached to board.



Looking at front end, earphone which is used as a small speaker is protected by flashlight glass disc.



To turn on, remove waterproof end-cap and press S1, which will lock into position. Replace end-cap.



"CQ FISH"

Completed unit fits into watertight flashlight case after works come out.

tition rate is determined by R/C circuit *R1, R2* and *C1*. By varying potentiometer *R2*, you can create any sound from that of a bee to a grasshopper through the high-impedance dynamic earphone.

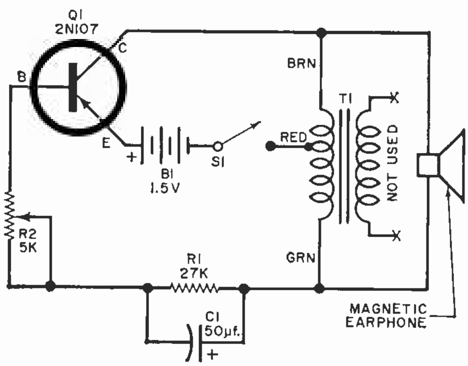
Construction. To build the unit, start by stripping the skin-diving flashlight down to its shell. Remove all switches, springs and hardware. Next, fill all holes with cement, using epoxy or household cement. Make sure the rubber gaskets (included with the original flashlight) seal all the openings when the basic flashlight is reassembled. You can test for leaks by submerging the unit in water and watching for air bubbles.

Cut a perforated mounting board into two pieces. One piece should be 4½" x 1⅜"; the other is formed into a circle of about 1½", or to fit the lens area of your flashlight. Cement the circle to the end of the rectangular board as shown in the illustrations. The bracket for switch *S1* is formed from scrap aluminum.

After you assemble the major components on the board, paying careful attention to the polarity of *Q1, C1* and *B1*, cement the back of the earphone to the center of the circular piece.

Testing. When the wiring is completed, turn the unit on and listen for the tone at the earphone. Varying the setting of *R2* should change the tone. If the unit works, coat all wiring with polystyrene "Q"-dope to minimize corrosion damage.

Now assemble the circuit into the flashlight housing and, once again, submerge the unit to make sure that it is watertight. If all is well, watch those fish sit up and QRZ! -30-



Switch S1 is a push-on/push-off type, and R1, R2, C1 determine frequency varied by potentiometer R2.

PARTS LIST

B1—1.5-volt battery (two Eveready #912's in parallel)
C1—50-µf., 25-volt miniature electrolytic capacitor
Q1—2N107 transistor or equivalent
R1—27,000-ohm, ½-watt resistor
R2—5000-ohm miniature potentiometer
S1—S.p.s.t. locking push-button switch
T1—Subminiature output transformer; 500-ohm, center-tapped primary, 8-ohm secondary (Lafayette 99-G-6129)
1—Pressure-proof skin-diving flashlight (U.S. Divers, Voit, Sportsways, or equivalent—available at most sporting goods stores)
1—Battery holder, two-cell type
1—High-impedance earphone, 7000-ohm dynamic (Lafayette 40-G-7801)
Misc.—Knob, transistor socket, switch bracket, perforated mounting board, wire, solder

BUILD PANIC ALARM

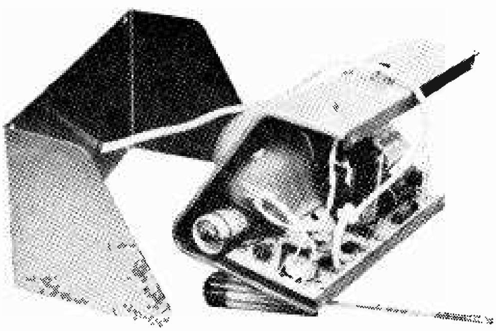
By ROY E. PAFENBERG, W4WKM

Guaranteed to start a panic every time an adventurous soul pushes that button

COINED during World War II, "push the panic button" has since become a colorful and descriptive addition to our everyday language. The phrase is used to describe any hastily conceived and ill-advised command or management reaction to an emergency situation that sends all hands racing helter-skelter in a flurry of frantic and ineffectual activity. In response to the popular appeal of the idea, dummy panic buttons can be found strategically located in the offices of many enlightened business executives.

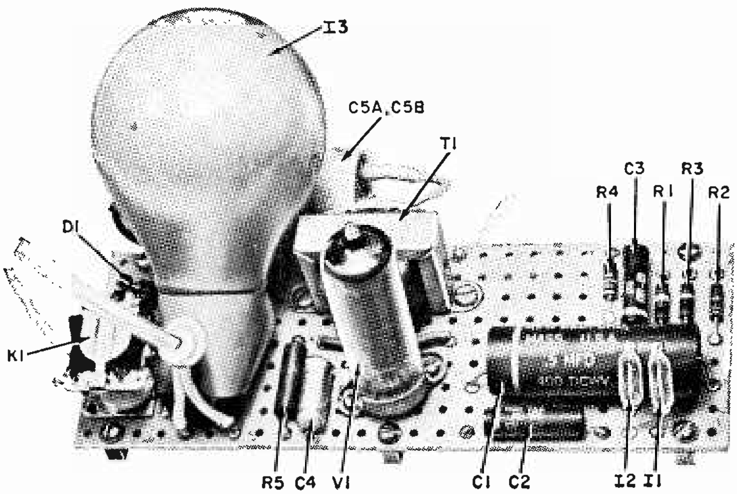
This article describes the construction of an electronic panic alarm that will electrify the deadest office. When activated, the device sounds off with a piercing blast of acoustical energy that combines the most desirable tonal character-

The author mounted his alarm in a sloping front cabinet, but there is no reason why other design housings won't work as well.



Perforated board is held to the bottom of the box with four bolts. The 25-watt lamp has no socket; the connections are soldered in place.

As mentioned above, the layout can be modified to suit the individual requirements of the builder. If you want to follow the author's model, this photograph will spot some of the more important components for you. Be sure that none of the circuitry contacts the metal chassis. See text for parts value changes to alter output tone.



istics of a fire engine siren, a submarine diving alarm, and a hound with its tail caught in the screen door.

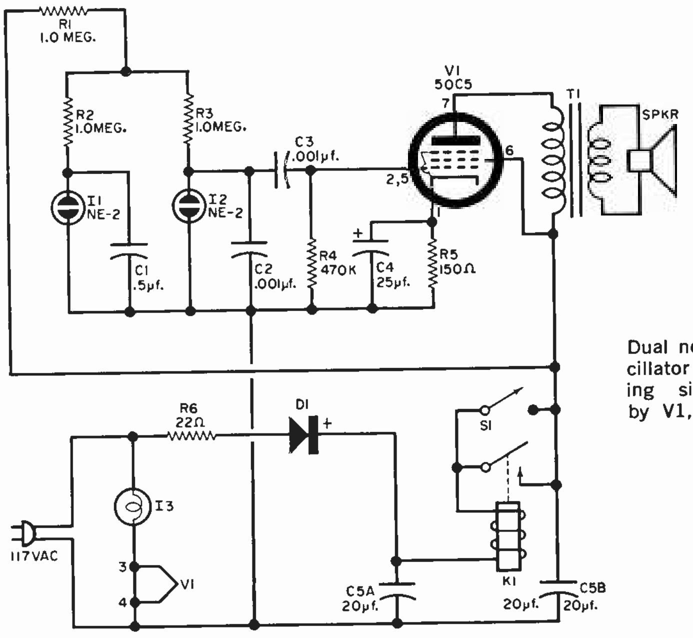
The panic alarm is activated by a deceptively labeled *PUSH TO TEST* switch. A special latching relay circuit is provided to keep the alarm sounding until the a.c. line cord is disconnected. The panic-stricken confusion that continues until someone finally unplugs the power cord adds greatly to the effectiveness (?) of the device.

A simple, easily wired circuit is used in the panic alarm. As shown in the photographs, the circuitry is housed in a small sloping-panel aluminum cabinet (Bud AC-1613). The front panel contains a speaker cutout with a red painted grille and a large matching, attention-getting red lamp. The *PUSH TO TEST* switch is mounted on the top of the cabinet.

Theory. The heart of the circuit is a rather unusual dual neon lamp relaxation oscillator. Because of the relatively long time constant of capacitor *C1* and resistor *R2*, the circuit of lamp *I1* oscillates at a subaudible rate. This results in a varying d.c. voltage at the junction of resistors *R1* and *R2*.

The time constant of capacitor *C2* and resistor *R3* is such that the circuit of lamp *I2* oscillates at an audible rate. Since the voltage for this circuit is obtained at the junction of *R1* and *R2*, the output frequency of this oscillator is swept at a rate determined by the frequency of the *I1* oscillator. Time constants of both circuits have been chosen to produce a very distinctive swept-tone siren effect. Output of the *I2* oscillator is coupled to a conventional audio output stage through capacitor *C3*.

A 25-watt, 117-volt red-frosted lamp



Dual neon lamp relaxation oscillator gives rising and falling siren effect. Amplified by V1, a 50C5, it is LOUD.

PARTS LIST

C1—0.5-μf., 400-volt capacitor
C2, C3—0.001-μf., 600-volt capacitor
C4—25-μf., 25-volt electrolytic capacitor
C5—20-20 μf., 150-volt electrolytic capacitor
D1—Silicon diode, 750-ma., 400-volt PIV (Lafayette SP-241 or equivalent)
I1, I2—NE-2 neon bulb
I3—25-watt, 117-volt light bulb, red frosting
K1—S.p.d.t. relay, 6-volt, 335-ohm coil (Potter & Brumfield RS5D or equivalent)
R1, R2, R3—1-megohm, ½-watt resistor
R4—470,000-ohm, ½-watt resistor
R5—150-ohm, 1-watt resistor
R6—22-ohm, ½-watt resistor
S1—S.p.s.t. push-button switch, normally open, momentary contact (Switchcraft FF-1001 or equivalent)
T1—Audio output transformer, 2000-ohm plate winding to 3.2-ohm voice coil winding
V1—50C5 tube
Misc.—4" speaker (3.2-ohm voice coil), cabinet (Bud Radio AC-1613 used by author), lamp cord, mounting hardware, perforated circuit board, solder, wire, etc.

(*I3*) is used in the power supply section of the circuit. This lamp, connected in series with the 50C5 tube heater, serves the dual function of indicator light and series-dropping resistor to reduce the line voltage to the 50 volts required by the tube heater.

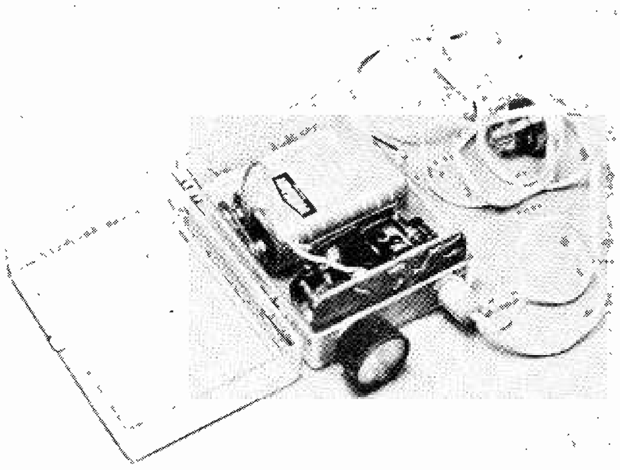
The B+ power supply uses diode *D1* in a conventional half-wave rectifier circuit. The winding and the normally open contacts of relay *K1* are connected in series with the B+ output. The normally open contacts of the *PUSH TO TEST* switch are connected in parallel with the relay contacts. When this switch is closed, the charging current of capacitor *C5b* causes the relay to operate, and the current drawn by the 50C5 tube holds the relay closed until power is removed by disconnecting the a.c. line power cord.

Construction. Although the circuit is noncritical and parts placement can be varied, the method of construction shown in the photographs is convenient. If a different method is used, two precautions must be observed. Since the circuitry is connected directly to the power line, care must be used to insure that no portion of the circuit makes connection to the metal cabinet. Secondly, in the relay specified for use as *K1*, the movable contact is connected directly to the frame of the relay. Therefore, any method of construction used must provide an insulated mounting for this component.

The speaker is mounted on the panel
(*Continued on page* 146)

POCKETABLE METRONOME

A variable-speed pacer will be a boon for any tyro instrumentalists



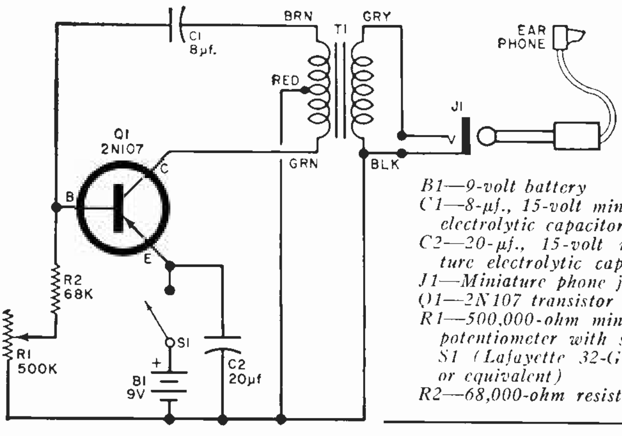
PEOPLE are rhythm-conscious, and if you are learning to type, play an instrument, dance, exercise, or any of countless other rhythmical functions, this metronome will mark the beat for you at a rate of from 80 to 300 clicks per minute. It is small enough to fit in a pocket, and the earphone stores nicely in the roomy case.

The metronome circuit is a simple relaxation oscillator with a 20-μf. emitter bypass capacitor (*C2*) to stabilize the circuit. Two holes in the circuit board are enlarged to accept jack *J1* and potentiometer *R1*. As these components also hold the circuit board to the plastic case, the jack hole should be enlarged sufficiently to pass the collar of the jack.

Before permanently wiring the circuit, check the range of clicks. If they are too slow, decrease the resistance of *R2*; if they are too fast, increase *R2*'s value. Potentiometer *R1* has a tapered resistance, and both outer terminals should be tried to see which gives the greater spread of click range.

Metronomes are usually bulky affairs, never thought of as portable. This one is a departure from the norm, with more applications than a normal metronome could shake its pendulum at!

—*Sal Stella*



Switch S1, on back of R1, closes when knob is turned; R1 varies click speed.

PARTS LIST

B1—9-volt battery
C1—8-µf., 15-volt miniature electrolytic capacitor
C2—20-µf., 15-volt miniature electrolytic capacitor
J1—Miniature phone jack
Q1—2N107 transistor
R1—500,000-ohm miniature potentiometer with switch S1 (Lafayette 32-G-7368 or equivalent)
R2—68,000-ohm resistor
S1—S.p.s.t. switch (part of R1)
T1—Transistor miniature output transformer (Lafayette 99-G-6127 or equivalent)
1—6-ohm earphone
1—Battery connector
1—7/8" x 1 7/8" circuit board
1—Plastic hinged box or other housing approx. 1" x 2" x 2 7/8"

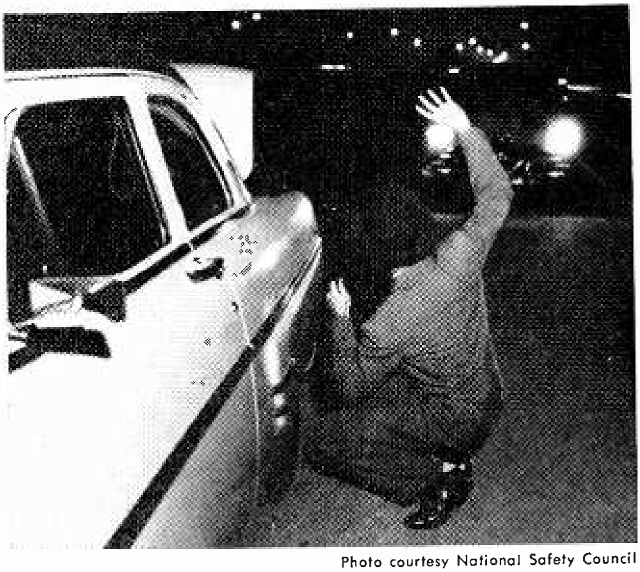


Photo courtesy National Safety Council

It's night. Suddenly a tire blows. You pull over to the side, but another car is coming up fast from behind...

For Greater Safety Flash Those Lights!

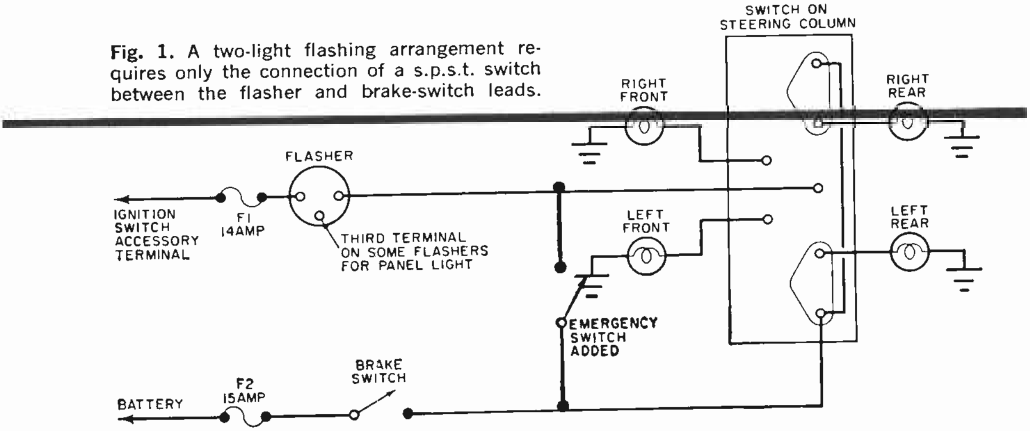
By LOUIS F. CORTINA

IF YOU'VE ever had to stop your car on or near the road while driving at night, you know how nerve-wracking this experience can be. Most of us have thought at one time or another of buying flares for use in such an emergency, but how many drivers actually carry them? The news stories concerning rear-end collisions with stalled vehicles point up the danger involved in not having some positive means available to alert other drivers.

Of course, you can pump your brake pedal to flash your rear lights, but this becomes tiresome very quickly. However, there is a practically tireless device on almost all cars which can be used to perform the same job—the flasher which operates your turn-signal lights. Some stalled drivers have the presence of mind to use this device in its normal manner, that is, to operate the turn signals. The danger here is that the driver in back may not realize until too late that the car is not moving, but standing still.

Two-Light Flasher. The additional wiring needed to make the flasher operate *both* rear lights is quite simple. The

Fig. 1. A two-light flashing arrangement requires only the connection of a s.p.s.t. switch between the flasher and brake-switch leads.



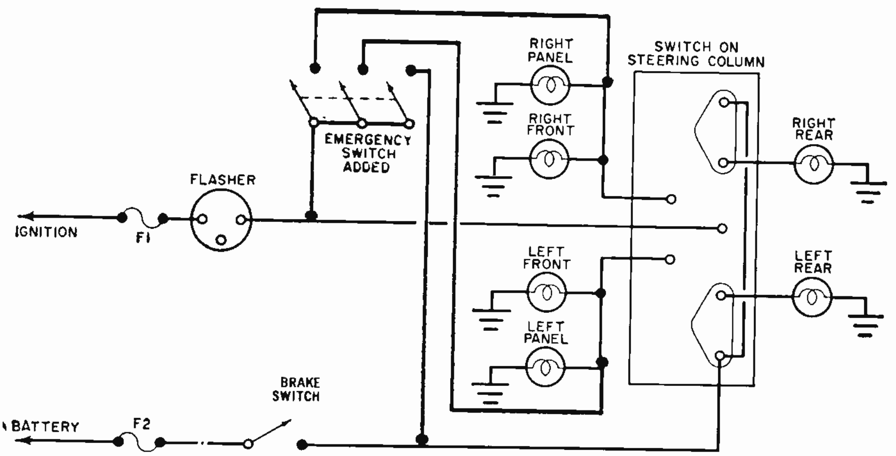


Fig. 2. Connected as indicated, a 3-p.s.t. switch provides four-light front and back flashing.

usual turn-signal switch has six leads; one from the flasher, one from the brake switch, and four leads to the various exterior lights. When the turn signal switch is in the center—or neutral—position, there is continuity between the brake-switch lead and the two leads which go to the rear lights of the car. If a path is provided from the flasher lead to the brake-switch lead, the rear lights will receive power through the flasher and will blink on and off in the same manner as the turn-signal lights, making an attention-getting device.

Figure 1, on page 15, shows a typical wiring layout and the necessary modification. The switch used is a s.p.s.t. type, and may be a toggle, rotary, or push-pull device rated to carry 3-5 amperes. Since most cars normally use two lights for signaling, one in the front and one in the back, the flasher will be operating under its normal load when flashing the two back lights.

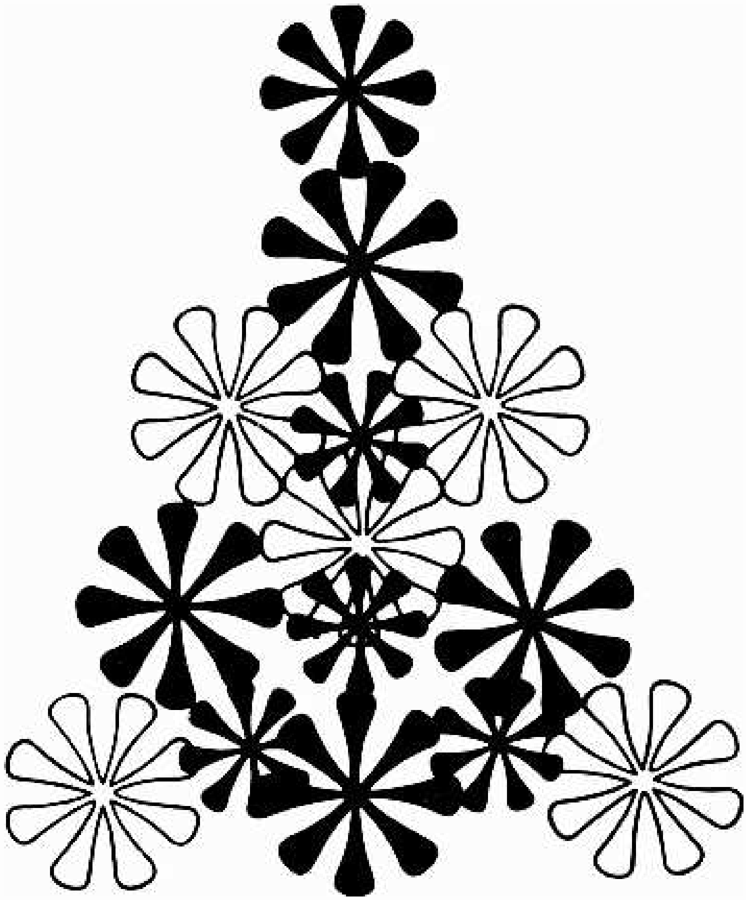
One exception is some General Motors cars which normally flash two lights on either side in the back, and one on either side in the front. If the flasher is connected to the four back lights, it will be operating with an overload and will run fast. To overcome this deficiency, one of the heavy-duty, variable-load flashers, designed for truck service or for vehicles towing a trailer, can be substituted for the original flasher. These variable-load units, which are manufactured by Ideal and Tung-Sol, will operate from one to eight lights of 21 or 32 candle power while maintaining a constant flashing rate. Replace a 6-volt flasher having three terminals with a Type 535 or 2535, a 12-volt unit having two terminals with a Type 536 or 2536, and a 12-volt unit having three terminals with a Type 550 or 2550.

Most cars made since 1949, as well as some earlier models, have a flasher socket under the instrument panel on the driver's side. It is only necessary to remove the original flasher and plug in the heavy-duty unit. Chrysler products from 1949 to 1954 have the flasher mounted on the engine side of the firewall. For those cars which do not use a flasher socket, remove the leads from the original unit and wire them to the corresponding terminals of the replacement unit.

Four-Light Flasher. While the simple hookup illustrated in Fig. 1 can be used in most states, California requires that any warning-light setup include "four or more approved turn-signal lamps . . . at least two of which must be toward the front and at least two toward the rear of the vehicle." Your local motor vehicle department can tell you the rules that apply in your area.

The added wiring needed to connect the flasher to all four light leads is not very involved. A three-pole, single-throw switch, either rotary or toggle, will do the job. An advantage of this method is that the panel indicator lights, which are usually paralleled with the corresponding front light on late-model cars, will also be energized. This keeps you from

(*Continued on page* 148)

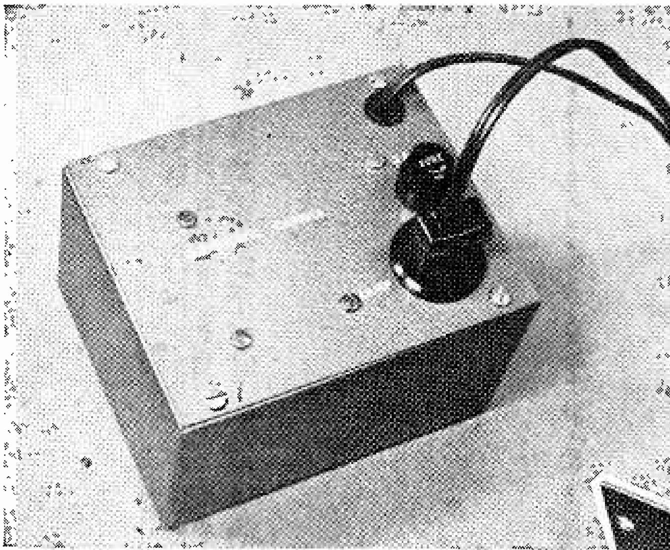


Electronic Candles Dance and Glow

Ordinary incandescent bulbs become sparkling, flickering holiday decorations when they're powered by the Electronic Candlelighter

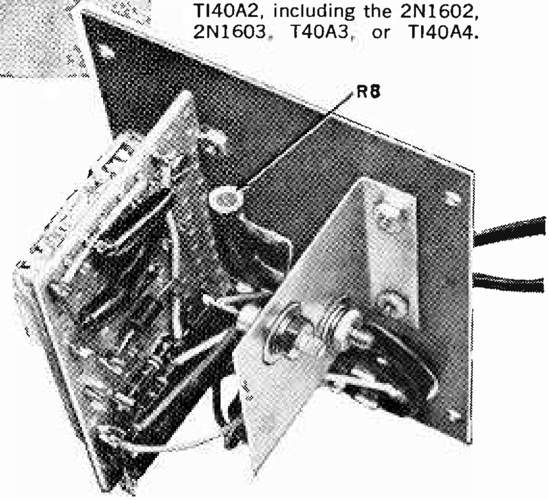
By JEFF H. TAYLOR

THERE'S NOTHING LIKE the warm glow of candlelight for festive occasions. Unfortunately, in modern times, the candle flame with its rhythmic, yet random, light has been largely replaced by the more intense, steady brilliance of incandescent bulbs. This article describes a method of reproducing the effect of candlelight, however, using ordinary electric light bulbs. And, unlike the candle, there's no smoke, melted wax, or fire hazards to contend with. You simply plug a lamp or string of decorative lights into the "Electronic Candlelighter," sit back, and enjoy the age-old effect of flickering, dancing candlelight.



The Candlelighter is built into a 3" x 4" x 5" aluminum box with a fuse and an output socket mounted on top panel for one lamp or a string of lights.

Component layout is shown in the photo below and those on the opposite page. Note R8 mounted to D4 and SCR1 by its leads; the exact value of this resistor depends on the load wattage, and can be estimated by using the table on page 19. Various substitute unijunction transistors such as the 2N489, 2N490, etc., series can be used in place of the 2N1670; some SCR's will replace the TI40A2, including the 2N1602, 2N1603, T40A3, or TI40A4.



How It Works. The "Electronic Candlelighter" provides a half-cycle sine wave to the lamp(s) continuously, plus other random currents during the remaining half-cycle. These random signals are generated by three neon-bulb relaxation oscillators operating at three slightly different frequencies. The oscillators beat with each other and the 60-cycle line frequency to produce a flicker in the lamp which is plugged into the socket.

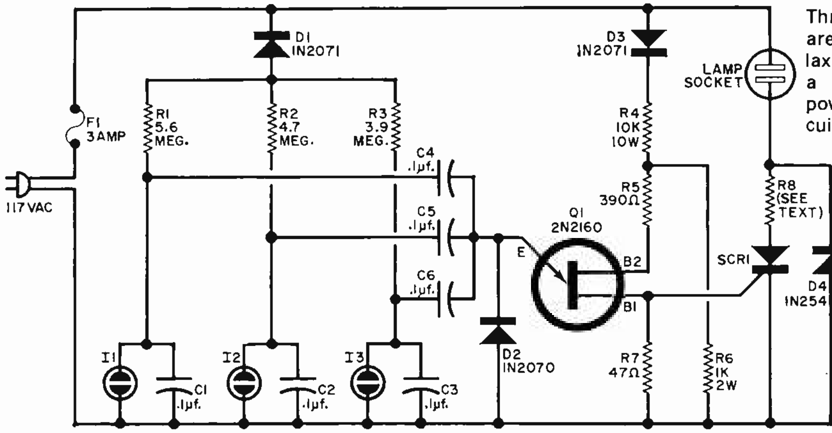
The unit has three basic circuits: the neon relaxation oscillators, the driver, and the power control circuit. The oscillators are capacitively coupled to the driver through *C4*, *C5*, and *C6*. These capacitors prevent oscillator interaction.

The neon lamp oscillators are supplied with a negative charging potential so that when they fire they produce the positive-going waveform necessary to forward-bias unijunction transistor *Q1*.

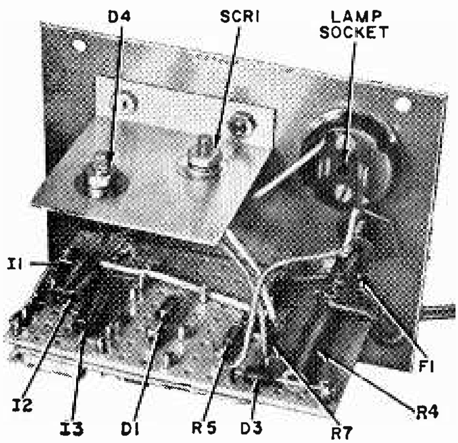
The driver circuit consists of the transistor (*Q1*) to which the oscillators are coupled. Base 2 of the unijunction is supplied with positive pulses through diode *D3*. The voltage on base 2 has a peak excursion of about 15 volts. The oscillator pulses at the emitter of *Q1* which are in phase with the half-cycle positive pulses on base 2 produce pulses at base 1 which are coupled to the silicon-controlled rectifier, *SCR1*. Diode *D2* provides d.c. restoration without loading the signal portion of the oscillator output.

PARTS LIST

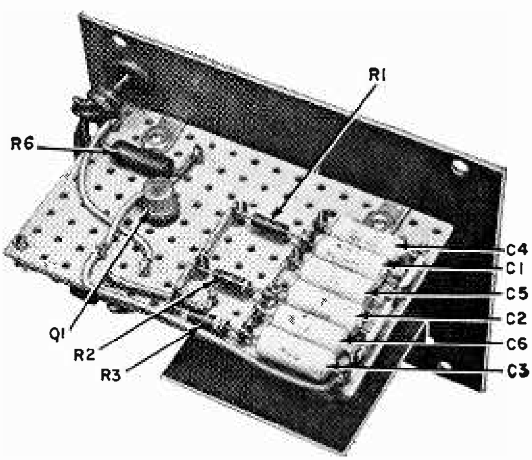
C1-C6—0.1-µf., 200-volt miniature paper capacitor
D1, D3—1N2071 silicon rectifier (TI)
D2—1N2070 silicon rectifier (TI)
D4—1N254 silicon rectifier (TI)
F1—3-amp 3AG fuse in panel-mounting holder
I1, I2, I3—NE-2 neon bulb
Q1—2N2160 unijunction transistor (TI)
R1—5.6-megohm, ½-watt resistor
R2—4.7-megohm, ½-watt resistor
R3—3.9-megohm, ½-watt resistor
R4—10,000-ohm, 10-watt resistor, ±5%
R5—390-ohm, ½-watt resistor
R6—1000-ohm, 2-watt resistor
R7—47-ohm, ½-watt resistor
R8—See text
SCR1—TI40A2 silicon-controlled rectifier (TI)
1—3" x 4" x 5" aluminum box
1—2¼" x 2½" piece of light aluminum
1—2½" x 4" piece of perforated phenolic board
1—Panel-mounting a.c. receptacle
Misc.—Transistor socket, line cord and plug, press-in solder terminals, wire, solder, hardware, rubber grommet, decals, etc.



Three basic circuits are used: neon relaxation oscillators, a driver (Q1), and power control circuit (D4 and SCR1).



Bend piece of light aluminum to form heat sink for D4 and SCR1; make sure they're not shorted to it.



Remaining parts are neatly laid out on a phenolic board which is mounted to box with small brackets.

How to Select Resistor R8

To determine the value of R8, use the table below. Choose the lamp wattage you want to use and read across for the approximate resistance value and wattage of the resistor that will give the best candlelight effect. Although no resistor is recommended for loads above 100 watts up to the unit's maximum rating of 300 watts, it may be desirable to use one in some cases, especially with strings of decorative bulbs. Optimum resistor values will range from 1 to 20 ohms at 20 watts.

Bulb Wattage	Resistance (ohms)	Power (watts)
7½	325	1
15	250	2
25	200	5
40	150	5
50	125	5
60	100	10
75	80	10
100	50	10

The power control circuit consists of a conventional rectifier (*D4*) which continuously provides half-cycle a.c. to a lamp load up to 300 watts, and the silicon-controlled rectifier (*SCR1*) which supplies the "flicker" pulses. A resistor selected to match the wattage of the load, *R8*, is placed between the anode of the silicon-controlled rectifier and the load to reduce the magnitude of the flicker, thereby producing a more realistic candle flame effect.

Building the Unit. As with the "Spookin' Light" (a somewhat similar project in POPULAR ELECTRONICS, Sept., 1964), it is imperative that none of the components in the "Electric Candlelighter" come in contact with the 3" x 4" x 5" aluminum box used as a cabinet, or the aluminum heat sink on which *SCR1* and *D4* are mounted. Use a 2½" x 4" piece of Vectorbord and press-in solder terminals for mounting all of the other components, following the general layout shown in the photographs. The semiconductors are all Texas Instruments types, but equivalent units made by other manufacturers could be employed instead.

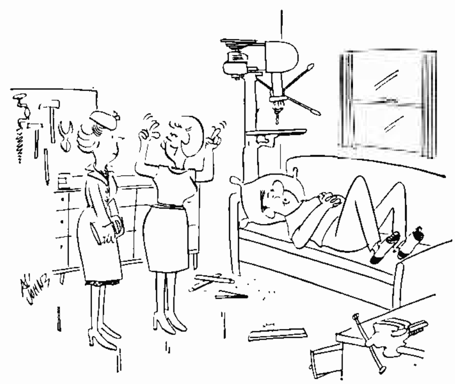
Due to the fact that NE-2's tend to be photosensitive, cover each one with black plastic tape before wiring them in place. Transistor *Q1* is mounted in a socket which is force-fitted into a hole drilled in the Vectorbord; the mounting board is attached to the front panel of the cabinet with two small angle brackets.

To make the heat sink, simply bend a 2¼" x 2½" piece of light aluminum to form a mounting bracket at one end (see photos). Drill mounting holes in the heat sink for *SCR1* and *D4*, and mount them with mica insulating washers. As an additional safety measure, check with an ohmmeter to make sure there is no electrical contact between the diodes and the heat sink.

To complete the unit, mount the lamp socket, fuse holder, heat sink and circuit board to the front panel, and install the line cord through a hole lined with a rubber grommet.

Operation. Select *R8* by referring to the table on page 19. The resistance values are not critical; simply select one close to the recommended value. Remember to calculate the *total wattage* if the unit is to be used with a string of decorative lights rather than with a single bulb. Check the wiring carefully, then try the unit out in a dimly lit room.

For a festive or romantic atmosphere, use electronic candlelight! —30—



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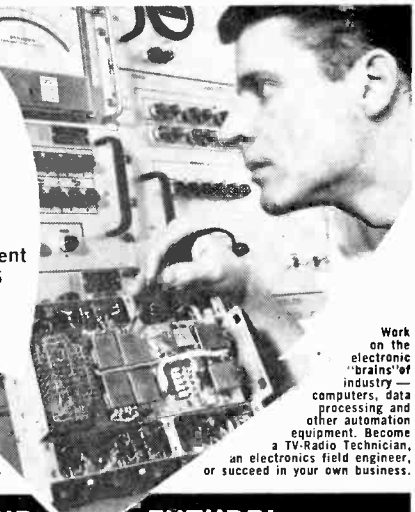

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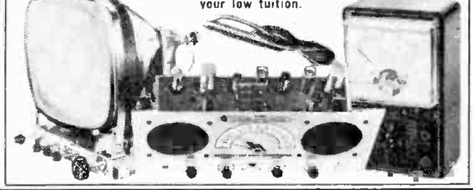

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CIRCLE NO. 35 ON READER SERVICE CARD

ADD D.C. restoration to TV

BY CHARLES E. COHN

When they cut the costs they leave out this important picture circuit

ALTHOUGH the d.c. restorer was regularly used in the earliest TV sets, it is a neglected feature in today's receivers. The omission is regrettable, since this circuit makes a valuable contribution to picture fidelity. However, it is not difficult to add to a set.

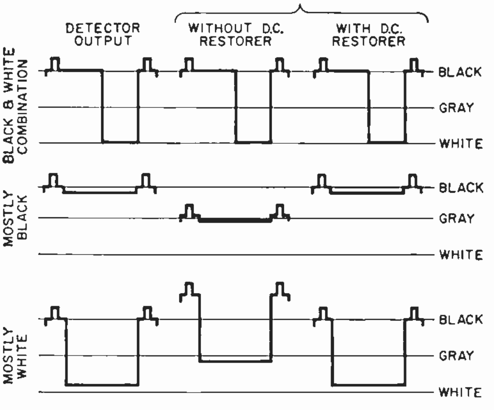
The need for d.c. restoration stems from the manner in which a signal is generally applied to the picture tube. To simplify comparison, assume the detector's video polarity is such that a positive signal (see drawing) corresponds to black information, with smaller voltages corresponding to lighter gray shades until white is reached with the smallest voltage.

If this signal is directly coupled from detector to picture tube, a given voltage always corresponds to the same shade. Reproduction of the black-to-white scale would then always be correct, provided only that the receiver's brightness control is properly set.

Where Restorer Comes In. While some TV receivers use d.c. coupling to the picture tube, most sets use *RC* coupling. The d.c. level of the signal is thus removed through the coupling capacitor, with the average amplitude of any signal being placed at the same level. This permits the standard black level to shift, depending on make-up of the signal at any given moment.

The drawing illustrates this action for typical signals. The first line shows a signal with the blacks and whites evenly distributed. The average level to the CRT, without restoration, is where it should be. The signal in the second line is mostly black. When capacitor coupling, however, moves the average level down toward gray, the scene is reproduced lighter than it should be. Also, with sync pulses not reaching the black level, retrace lines become visible. With a mostly white signal (third line), the shift toward gray makes the picture darker than it should be.

Where neither direct coupling nor a d.c. restorer exists, the latter can be added. The circuit senses the sync pulses, which are always at the same level just



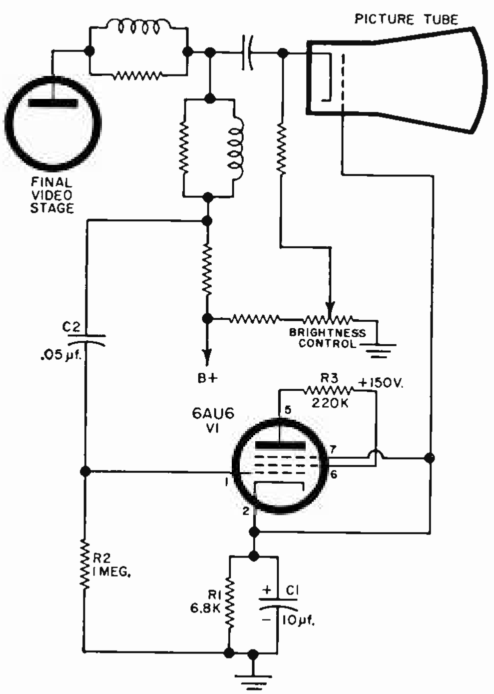
Without d.c. restoration, mostly black pictures tend to drop and mostly white scenes tend to rise into the gray area, reducing the dynamic contrast range.

beyond black, and adjusts CRT bias accordingly to compensate for the shift produced by capacitive coupling.

The circuit shown here is easy to install in an existing set, can be used wherever a video signal is applied to the picture-tube cathode, and the brightness control is also located there. This arrangement is usual. The circuit requires the addition of only one tube, two capacitors, and three resistors.

Circuit Operation. With the large cathode resistance, *R1*, *V1* is almost cut off. Positive video signal is applied to its grid. Without *C1* in the cathode, *V1* plate current would increase as video becomes more positive, the cathode voltage following the grid voltage. However, *C1* charges the cathode voltage to the most positive part of the signal, the sync pulses, and holds *V1* cut off over the rest of the cycle. The voltage on *C1* is applied to the CRT grid. Thus the CRT grid-cathode potential is always constant on a sync pulse.

Between sync pulses, *C1* slowly discharges through *R1*. The time constant of this combination is comparable to the duration of one frame, so that the circuit will not respond to more rapid changes in average level. However, the time constants of the coupling circuits in the video amplifier are sufficient to hold the black level for one frame.



Voltage developed across C1 is a function of the sync pulse amplitude. This voltage is used to bias the CRT and to maintain relative contrast levels.

Installation of the circuit poses no special problems. For *V1*, use that variant of the 6AU6 whose heater characteristics can be most conveniently incorporated in the set's heater circuit. Some point having no more than 150 volts of "B+" must be found for the plate and screen supply. Note that *C2* is connected directly to the end of the video-amplifier plate load resistor closer to the plate and after any of the peaking coils. This minimizes the effect of the added stray capacitance on the high-frequency response of the video amplifier.

The CRT grid is removed from its existing connection and taken to the cathode of *V1*. Many sets have retrace blanking circuits connected to this grid. Such blanking should not be necessary after the revision, with the black level held where it belongs. However, if blanking should still be needed, it can be retained by connecting in the CRT grid lead a resistance approximately equal to resistance to ground of the previous grid circuit and returning the blanking-pulse connection to the CRT grid. -30-

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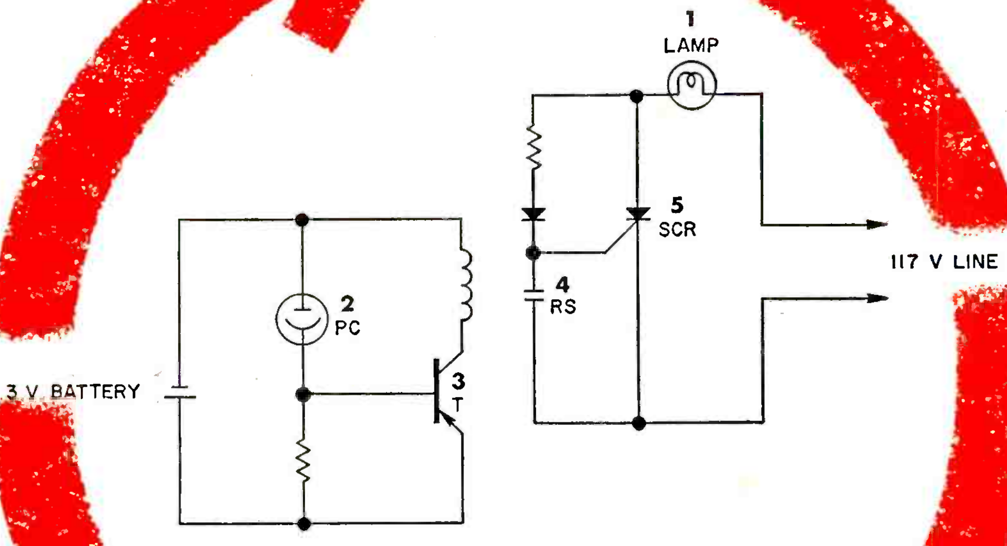

Lamp (1) illuminates photocell (2) which decreases in resistance causing transistor (3) to conduct, causing reed switch (4) to close, cutting off SCR (5), turning off lamp (1), causing photocell (2) to increase in resistance, cutting off transistor (3) allowing reed switch (4) to open, causing SCR (5) to conduct, turning on lamp (1) . . . . .

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FitzPatrick Elec. Supply Co., Holland, Muskegon
Fulton Radio Supply Co., Jackson, Lansing
Northwest Radio Supply Inc., Marquette
Orem Distg. Co., Saginaw
Radio Parts Co., Saginaw
Daystrom Products Corp., St. Joseph
Lafayette Radio Supply Co., Utica

MINNESOTA
Northwest Radio, Duluth
Stark Electronic Supply Co., Duluth, La Crosse, Minneapolis, St. Cloud, St. Paul
Admiral Dist. Inc., Minneapolis
Bonn Co., Lew, Minneapolis, Rochester
Electronic Center Inc., Minneapolis
Radio Electric Supply, Minneapolis
Gopher Electronics, St. Paul
SPTW-KEE-LINE Elect. Corp., St. Paul

MISSISSIPPI
Pate Electronics, Clarksdale, Tupelo
Columbus Electronics, Columbus
Parham Electronics, Greenwood
Crescent Electronic Sup., Gulfport
Ellington Electronic Sup., Jackson
May & Jackson Distributors, Jackson
Radio & TV Essentials, Laurel
TV Wholesale Sup., Natchez

MISSOURI
Suedekum Electronic Sup., Cape Girardeau
York Radio & TV, Hannibal
Henshaw TV Sup., Independence, Kansas City
Robertson Electronics, Jefferson City
Wholesale TV Supplies, Jefferson City
Four State Radio Sup., Joplin
Norman Electronic Sup., Joplin, Springfield
Burstein Applebee, Kansas City
Manhattan Radio & Equipment, Kansas City
McGee Radio, Kansas City
Radiolab, Kansas City
Acme Radio Sup., St. Joseph
Electronic Components for Industry, St. Louis
Electronic Mart, St. Louis
Hollander & Company, St. Louis
Van Sickle Radio Electronics, St. Louis
Olive Electronic Supply, University City

MONTANA
Electronic Supply Co., Billings
Electronic Distrs Inc., Great Falls

NEBRASKA
Radio Equipment, Beatrice, Grand Island, Norfolk, Omaha
Central Radio Sup., Hastings
Scott Electronic Sup., Lincoln, North Platte
Omaha Electronics, Omaha
Joachim Radio Supply Inc., Scotts Bluff
Tri-State Electronics, Scotts Bluff

NEVADA
Electronic Distributing Co., of Nev., Reno

NEW HAMPSHIRE
American Radio Corp., Dover

NEW JERSEY
Almo Radio, Atlantic City, Camden, Trenton, Vineland
Kearns Elect. Products Inc., Atlantic City
Gem Electronics, Bayonne, East Brunswick, East Orange, Paramus, Springfield, Totowa
Midstate Radio Supply Co., Berlin
Joe's Radio Shop, Bridgeton
General Radio Supply, Camden
Eastern Radio Corp., Clifton
Emsco Electronics, Hackensack
Nidisco, Hackensack, Jersey City, Passaic, Ridgefield, Trenton, Union City
State Elect. Parts Corp., Hanover
Leader Electronic Supply, Hillside
Bay Electronic Distg. Co., New Brunswick
Lafayette Radio & Elect., Newark, Paramus, Plainfield
Asbury Electronics Supply, Ocean Grove
Jersey Electronic Dist., Paterson
Witmal Elect. Corp., Paterson
Penn Electronics Pts., Pennsauken, Philadelphia
Atlas Elect. Inc., Perth Amboy
Carl B. Williams, Phillipsburg
Union Television Parts Co., Plainfield
Moyer Electric Supply, Pottsville
Sun Radio & Electronics, Princeton
Monmouth Radio Supply, Red Bank
Federated Purchaser, Shrewsbury, Springfield

NEW MEXICO
Kierulff, Alamogordo, Albuquerque
Graybar Electric Co. Inc., Albuquerque
Yucca Wholesalers Inc., Albuquerque
Basin Electronic Supply, Farmington
Valley Engineering, Los Alamos
Southwestern Elect. Parts, Santa Fe

NEW YORK
Fort Orange Radio, Albany
Havens Electric Co. Inc., Albany
Knickerbocker Appl. Service, Albany
Taylor, Edwin E., Albany
Adirondack Radio Supply, Amsterdam
Gem Electronics, Bayshore, Bellerose, Bronx, Brooklyn, Farmingdale, Forest Hills, Great Neck, Hicksville, Huntington, Menands, Mount Vernon, New York, Plainview, St. James, Valley Stream, West Bronx, Yonkers
Lafayette Radio & Electronics, Bronx, Brooklyn, Jamaica, New York, Scarsdale, Syosset
Rim Electronics Inc., Bronx
Economy Electronics Corp., Brooklyn
Electronic Equip., Brooklyn
Graham Electronics Dist., Brooklyn
Hygrade Electronics Co., Brooklyn
Laco Electronics, Brooklyn
Huron Elect. Supply Co. Inc., Buffalo

DISTRIBUTOR LISTINGS—CONTINUED

Mannfred Electronics, Corona
Electronic Supply Corp., Elmhurst
Eddy Electronics, Elmira
Arrow Electronics, Farmingdale, Mineola, New York
Emerald Electronics, Floral Park
Allen Electronics Inc., Flushing, L. I.
Ray Supply Inc., Glens Falls, Plattsburgh
Norman Radio Distr. Inc., Jamaica, L. I.
Johnson Radio Co., Jamestown
Arace Elect. Dist., Kingston
Greylock Electronic Dist., Kingston, Poughkeepsie
Peerless Radio Corp., Lynbrook
A&P Elect. Inc., Massapequa
Seaway Electronics, Massena
Certified Elect. Inc., Middletown
Atlas Electronics Corp., New York
Belco Distrs. Inc., New York
Calvert Electronics Inc., New York
Elect. Parts Distg. Co., New York
Elect. Tube Sales Inc., New York
Grand Central Radio, New York
Harvey Radio, New York
Metropolitan Supply Co., New York
Midway Radio & TV, New York
Milo Electronics Corp., New York
Terminal Hudson Elect., New York
Atlas Electronics Inc., Plainview
Higgins & Sheer Elect. Dist., Poughkeepsie
Anchor Elect. Distg. Corp., Richmond Hill
Rochester Radio, Rochester
Alfred Electronics Corp., Rockville Centre
Rome Electronics, Rome
Adirondack Electronics Inc., Schenectady
Electric City Radio Supply, Schenectady
Schenectady Elect. Distrs., Schenectady
B&D Distg., Staten Island
LNL Distg. Corp., Syosset, L. I.
Gordon Electronics Inc., Syracuse
Roberts & O'Brien, Syracuse
Salina Elect. Supply Co. Inc., Syracuse
Watertown Elect., Watertown
Melville Radio, White Plains
Thruway Elect., White Plains

NORTH CAROLINA

Freck Radio & Sup., Asheville
Dixie Radio Sup., Charlotte, Gastonia
World Electronics, Charlotte
Vickers Electronic Sup., Durham
Southeastern Radio Sup., Fayetteville, Greensboro, Hickory, Jacksonville, Kingston, Raleigh, Salisbury, Wilmington, Wilson
Electronic Wholesalers, Winston-Salem
Walker-Martin, Charlotte, Raleigh

NORTH DAKOTA

Bristol Distributing Co., Bismarck, Fargo, Grand Forks, Minot
John Iverson Co., Mandan, Minot

OHIO

Akron Electronics Supply Co., Akron
Main TV Supply Co., Akron
Olson Radio Company, Akeon
Sun Radio, Akron
Warren Radio, Akron, Lima, Toledo
Servex, Ashland, Delaware, Fremont, Mansfield, Marion, Mt. Vernon, Sandusky, Tiffin, Wooster
Canton Electronics, Canton
Sommer Electric Co., Canton
TV Parts, Canton
Buckeye Elec., Chillicothe, Columbus, Lancaster, Newark, Zanesville
Holub Dist., Cincinnati, Newport
Highes-Peters, Cincinnati, Columbus
Mytronic, Cincinnati
Newark-Herrlinger Elect., Cincinnati
Broadway Elec. Supply Co., Cleveland
Pioneer, Cleveland, Lorain, Sandusky
Seaway Elect., Cleveland
Custom Electronics, Inc., Dayton, Fairborn, Hamilton
Rankin & Houser Inc., Dayton
Srepco Electronics, Dayton, Hamilton, Middletown, Piqua
Stotts-Friedman, Dayton
Euclid Radio Parts Corp., East Cleveland
United Electronics, East Liverpool
Lima Radio Parts Co., Findlay, Lima, Van Wert
J&B Electronics, Fremont
Standard Radio, Springfield
D&R Radio Supply, Steubenville
Toledo Radio Specialties, Toledo
Rem Electronics, Warren
Glen Elect. Supply Corp., Youngstown
Ross Radio, Youngstown

OKLAHOMA

Trice Wholesale Electronics, Ardmore, Enid, Lawton, McAlester, Muskogee, Oklahoma City, Okmulgee, Ponca City, Tulsa
Norman Electronics Sup., Bartlesville
Bobs Amateur Electronics, Oklahoma City
John H. Cole, Oklahoma City
Industrial Electronics, Oklahoma City
Graybar Electric, Oklahoma City, Tulsa
Radio, Inc., Oklahoma City, Tulsa
Oil Capital Electronics, Tulsa
S&S Radio Sup., Tulsa

OREGON

Ace Electronics Inc., Eugene
United Radio Supply, Eugene, Medford, Portland
Walker, Verl G., Medford
Pacific Radio Supply, North Bend
Round-Up Electronics, Pendleton
Electra-Tech Inc./Newtronic, Portland
Johnson Co., Lou, Portland
Television & Radio Supply, Portland
Willamette Radio Supply, Salem

PENNSYLVANIA

A. A. Peters, Allentown
Gem Electronics, Allentown
Allegheny Electronics Inc., Altoona, Johnstown
Television Parts Co., Ambridge, Butler, New Brighton, New Castle
Powell Electronic Sales, Bristol
County Supply Co., Coatesville
Duncombe Co., J. V., Erie
Radio Distributing, Harrisburg
Barno Radio Company, Mc Keesport
Almo Radio, Norristown, Philadelphia
A. C. Radio Sply., Philadelphia
Allied Elec. App. Parts Inc., Philadelphia
Lectronic Distrs., Philadelphia
Lectronic Res. Labs., Philadelphia
Sidney Wagner Elect. Sply., Philadelphia
Simco Elect., Philadelphia
Electronic Parts Co., Pittsburgh
Triangle Electronics Co., Pittsburgh
Tydings Company, Pittsburgh
Electronic & TV Dist., Reading
Consolidated Distg., Scranton
Pursell, Fred P., Scranton
University Elect. Co. Inc., State College
Huston Elect. Distr. Inc., Tarentum
General Radio & Elect., Wilkes-Barre
Rosen Electronics, York
Wholesale Radio Parts, York

RHODE ISLAND

Jabbour Electronic Sply., Pawtucket
W. H. Edwards, Providence

SOUTH CAROLINA

Dixie Radio Sup., Anderson, Columbia, Florence, Greenville, Greenwood, Spartanburg, Sumter
Wholesale Radio Sup., Charleston
Southeastern Radio Sup., Columbia

SOUTH DAKOTA

Burghardt Radio Supply, Aberdeen, Sioux Falls, Watertown, Rapid City
Electronic Supply Co., Mitchell
Ellis Electronics, Rapid City
Gourley Distg. Co., Sioux Falls

TENNESSEE

Clark Radio Sup., Bristol, Morristown
Curle Radio Supply, Chattanooga
Harpe Electronic Distributors, Chattanooga
Warren Radio, Dyersburg, Memphis
Chemcity Electronics, Johnson City, Kingsport
Radio Electric Sup., Kingsport
Bondurant Bros., Knoxville
W&W Distributing Co., Memphis
Braid Electric, Nashville
Crescent Radio Supply, Nashville
Electra Distributing, Nashville

TEXAS

F&M Electronic Sup., Abilene, Midland
Graybar Electric, Abilene, Arlington, Dallas, Fort Worth, Odessa
Radio Communications Sup., Abilene
Alltronic Sup., Amarillo
West Texas Electronics, Amarillo, Lubbock, Midland
Beta Electronics, Arlington
Graybar Electric, Austin, Beaumont, Corpus Christi, San Antonio
Hargin Austin, Austin
Texas Electronic Sup., Austin
Wholesale Electronic Sup., Austin
Electronic Equipment & Engineering, Brownsville, Corpus Christi, Harlingen, Houston, Victoria
Rio Radio Sup., Brownsville, Harlingen, McAllen
Sterling Electronic, Beaumont, Bryan, Lufkin, Houston, San Antonio
Leader Electronic Sup., Corpus Christi
Wicks Radio Equipment, Corpus Christi
All State Electronics, Dallas
Allied Electronics, Dallas
Com-Supply, Dallas
Crabtrees Wholesale Electronics, Dallas
Southwest Radio Sup., Dallas
Trice Wholesale Electronics, Dallas, Ft. Worth
Wholesale Electronic Sup., Dallas, Ft. Worth, Sherman, Waco, Wichita Falls
Wilkinson Bros., Dallas
Mc Nicol Inc., El Paso
Sunland Supply Co., Inc., El Paso
Worth Electronics, Ft. Worth
Electronic Corp. of Texas, Galveston, Houston
Automatic Distributing, Houston
Busacker Electronic Equipment, Houston
Electronic Component Distributor, Houston
Gilbert Electronics, Houston
Bell Electronics, Killeen, Temple
Pan American Electronic Co., Laredo
B&L Radio & TV Sup., Lubbock
Diehl Radio & TV Sup., Port Arthur
Gunter Wholesale, San Angelo
Modern Electronics, San Antonio
Olsen Radio Sup., San Antonio
Radio & TV Parts, San Antonio
Sherman Electronics Sup., San Antonio
McCullock Wholesale TV Sup., Texarkana
Electronic Sup., Texas City
East Texas Electronics, Tyler
L&M Sales, Waco
Gose Radio Sup., Wichita Falls

UTAH

Ballard Supply Co., Ogden
Tri State Elect. Supply, Ogden
Alpine Electronic Supply, Provo
Manwill Supply Co., Salt Lake City
O'Laughlins Radio Supply, Salt Lake City
Ross Inc., S.R., Salt Lake City

VERMONT

Rutland Elect. Distr., Rutland
Electronic Sply. Inc., White River Junction

VIRGINIA

Certified Electronics, Alexandria
Arlington Elect. Wholesalers Inc., Arlington
Kann-Ellert Elect. Inc., Charlottesville, Winchester
Virginia Radio Supply Co., Charlottesville
Cain Electronics Inc., Hampton, Norfolk, Portsmouth
Electronic Wholesalers, Harrisonburg
Electrical Wholesalers Inc., Harrisonburg
World Elect., Norfolk
Electronic Supply Co., Petersburg
Bushee Elect. Supply, Richmond
Meridian Elect., Richmond

WASHINGTON

C&G Electronics Co., Aberdeen, Bremerton, Centralia, Longview, Olympia, Seattle, Tacoma
Advanced Electronics, Bellingham
Skagit-Whatcom Elect. Supply, Bellingham, Mt. Vernon
Geiger Radio, W. A., Ellensburg
Pringle Elect. Supply Inc., Everett
Columbia Electric Co., Kennewick
Radio Supply Co., Seattle
Northwest Electronics, Spokane
Spokane Elect. Supply, Spokane
Electra-Tech Inc./Newtronic, Vancouver
Yakima Wholesale Radio Co., Yakima

WASHINGTON, D. C.

Fairway Elects. Inc.
Silberne Radio & Elect. Sales
Sun Parts

WEST VIRGINIA

Bluefield Supply Co., Bluefield
Meyers Electronics Inc., Bluefield
Mountain Electronics Co., Charleston, Clarksburg
State Electronics Co., Fairmont
Electronics Supply Inc., Huntington
Chemcity Electronics, Parkersburg
General Elect. Distr. Inc., Wheeling

WISCONSIN

Elect. Expeditors Inc., Appleton, Green Bay, Milwaukee
Bushland Radio Specialties, Eau Claire
Harris Radio, Fond du Lac
Northern Radio & TV Co., Green Bay
Thompson Electronics, Janesville
Kenosha Electronics, Kenosha
Acme Radio Supply Co., Milwaukee
Dykro Distributors Inc., Milwaukee
Radio Parts Co. Inc., Milwaukee
Badger Electronic Parts Co., Racine
Koepsell Co., J. J., Sheboygan
Marsh Radio Supply Co., West Allis

WYOMING

Fleming Supply Inc., Casper
Garrod Eng. & Supply Inc., Laramie

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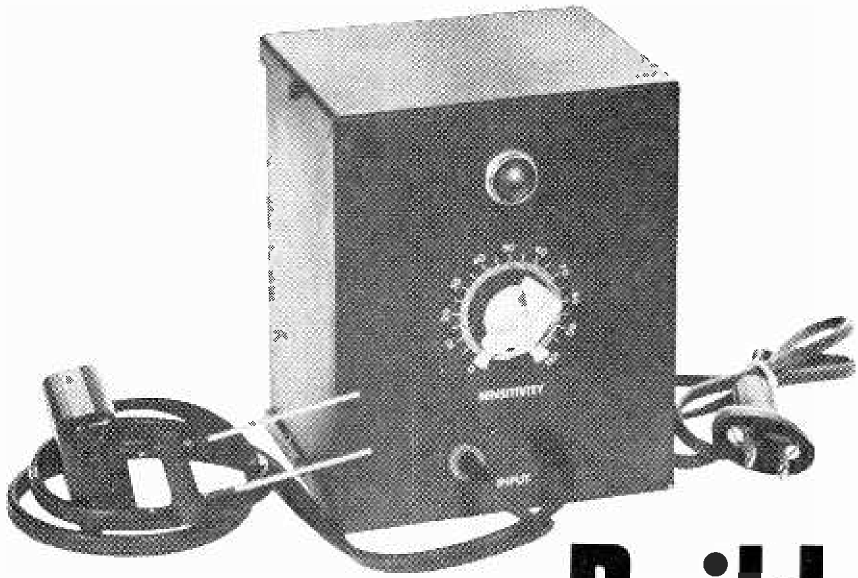


Build the Multi-Trol

By RYDER WILSON

WHILE ORIGINALLY designed to provide automatic cutoff for a commercial dehumidifier, the "Multi-Trol" has proved so versatile that it has been adapted to a variety of other applications. Electrical appliances that draw up to 800 watts can be turned on or off by a signal as small as 50 microwatts. Cadmium sulphide photocells, thermistors, humidity sensors, or even a carbon microphone can be used to trigger the unit as they respond to variations in light, heat, humidity or sound. When attached to a pair of metal probes in the ground, the Multi-Trol will serve as a soil moisture indicator and can be used to turn on electrically operated valves for automatic watering.

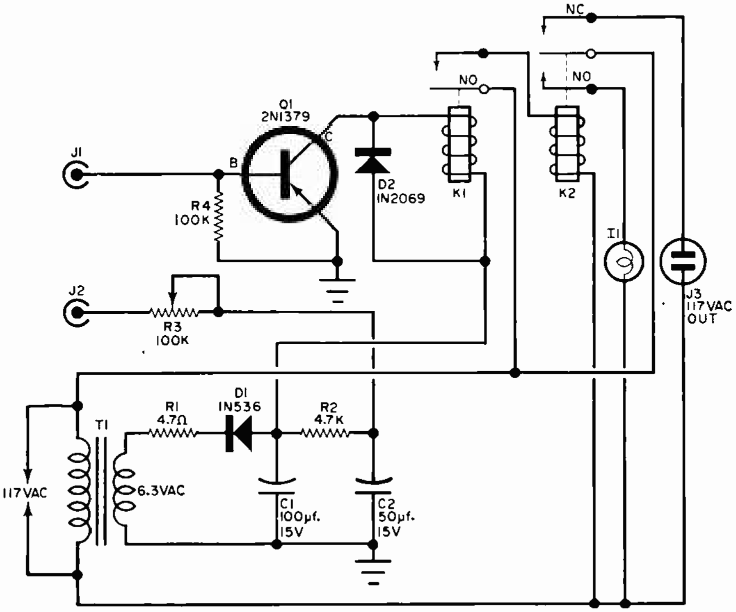
Circuit Design. The circuit was designed to provide maximum sensitivity and power handling with a minimum of parts. This is accomplished by using a very high-gain transistor (*Q1*) as a grounded emitter current amplifier to drive a sensitive relay *K1* which in turn operates power relay *K2*.

The 2N1379 transistor used had a measured d.c. current gain of 220 with a base input of 200 ma. A linear 100,000-ohm potentiometer, *R3*, in series with the base, sensor and supply voltage, controls the sensitivity by limiting the base current. Resistor *R3* may be changed to 1 megohm when the resistance across the input terminals is less than 50,000 ohms to give a little better control. Examples of such inputs would be low resistance photocells or humidity sensors.

A small silicon diode, *D2*, protects the transistor from transients developed across the coil of relay *K1*. Pilot lamp *I1* provides a visual indication that the power relay *K2* has operated, and this lamp may be replaced by a bell, buzzer, or any other warning device the builder desires.

Operating power is obtained from a

Use it to control almost any device with nearly any signal



You should have no problems in constructing the Multi-Trol as layout is not at all critical. The "NC" and "NO" designations at relays K1 and K2 refer to "normally closed" and "normally open" terminal points.

PARTS LIST

C1—100-μf., 15-volt electrolytic capacitor
C2—50-μf., 15-volt electrolytic capacitor
D1—IN536 silicon diode
D2—IN2069 silicon diode
I1—117-volt, 3-watt pilot lamp
J1, J2—Nylon insulated pin jack
J3—A.c. connector, female, recessed chassis mounting
K1—S.p.s.t., 550-ohm, 9.5-ma. relay (Sigma 11F-550-G/SIL)
K2—S.p.d.t., 115-volt relay (Potter & Brumfield MR5A)
Q1—2N1379 transistor
R1—4.7-ohm, 1-watt resistor
R2—4700-ohm, 1-watt resistor
R3—100,000-ohm linear potentiometer
R4—100,000-ohm, ½-watt resistor
T1—Filament transformer; primary, 117 volts; secondary 6.3 volts @ 1 ampere
1—4"x5"x6" aluminum Minibox

small filament transformer, *T1*. The transformer output is rectified by diode *D1* and filtered by capacitors *C1* and *C2*. This gives approximately 8.5 volts at the collector of *Q1*.

An appliance plugged into the Multi-Trol can be made normally off instead of on, by reversing the two connections to the normally open and normally closed contacts of relay *K2*.

Construction. The author's unit is built into a 4" x 5" x 6" utility box, but with some ingenuity the parts could be fitted into a smaller enclosure. Parts placement is not at all critical. The dehumidifier probe consists of a pair of No. 10 copper wires mounted in a Bakelite terminal block. This is then encased in a small plastic box and sprayed with plastic to make it waterproof. The two leads from the probe are terminated in pin plugs to conveniently fit jacks *J1* and *J2*.

When the probes are in one inch of water, the resistance across them is approximately 25,000 ohms. Neither the spacing nor the length of the probes is critical; they may be adjusted to suit the builder's convenience.

Using the Multi-Trol. Plug your dehumidifier into outlet *J3* and place the probe on top of the water bucket so that the two copper wires will be in approximately one inch of water, at the level where the dehumidifier is to be cut off.

HOW IT WORKS

The appliance to be controlled is plugged into a.c. connector *J3* which supplies its line voltage through the normally closed contacts of relay *K2*. Placing a resistance of about 50,000 ohms, such as a photocell, thermistor, or other resistive sensor, at the input causes a small current to flow in the base circuit of transistor *Q1*. This current is amplified in the collector circuit which actuates sensitive relay *K1*. This in turn supplies the power to relay *K2*. When relay *K2* operates, the a.c. voltage is removed from the load, and applied to indicator lamp *I1*.

Start with 10"-long probes, and cut them to the desired length. Plug the Multi-Trol into the nearest wall outlet, and it is ready to go to work for you.

Other Applications. An inexpensive cadmium sulphide photocell (for example, Lafayette Radio's Stock No. MS 855) can be used to convert the Multi-Trol to a controller for house lamps, photoflood lamps, or other electrical appliances. Connect the photocell to input terminals *J1* and *J2* and adjust the sensitivity control as required.

As an electronic thermostat, the circuit is just as sensitive and as easy to use as in the photocell application. Select a thermistor with a resistance of about 100,000 ohms (such as the Lafayette 51CA1), plug it into *J1-J2*, and set the sensitivity control to trigger the circuit at the selected temperature.

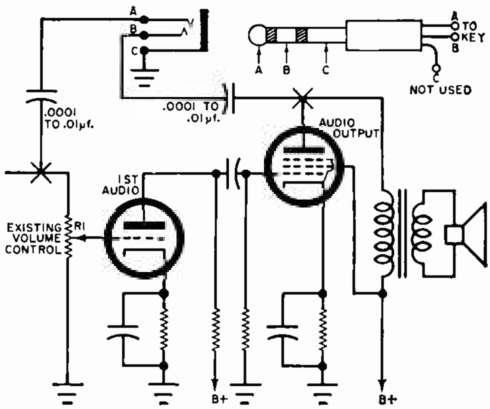
There are many other possible applications for the Multi-Trol. The average builder will enjoy discovering them for himself. -30-

Loudspeaker Code Practice

Any receiver can easily be converted to a loudspeaker code practice oscillator. By feeding a portion of the output signal to the grid of the first audio stage, a squeal is set up that is heard in the loudspeaker.

Simply hook a pair of capacitors from .0001 to .01 μf. at the points designated "x" in the schematic diagram. Mount a three-circuit (stereo) phone jack on the radio set and solder the open ends of the capacitors to the A and B lugs of the phone jack. Do NOT connect to the ground lug of the jack.

Attach a matching plug to your key, connecting as shown, and plug the key into the jack to practice code. The volume control on the radio will also serve as a volume control for code practice. And you can still use the radio as an ordinary receiver if you remove the key plug from the jack.



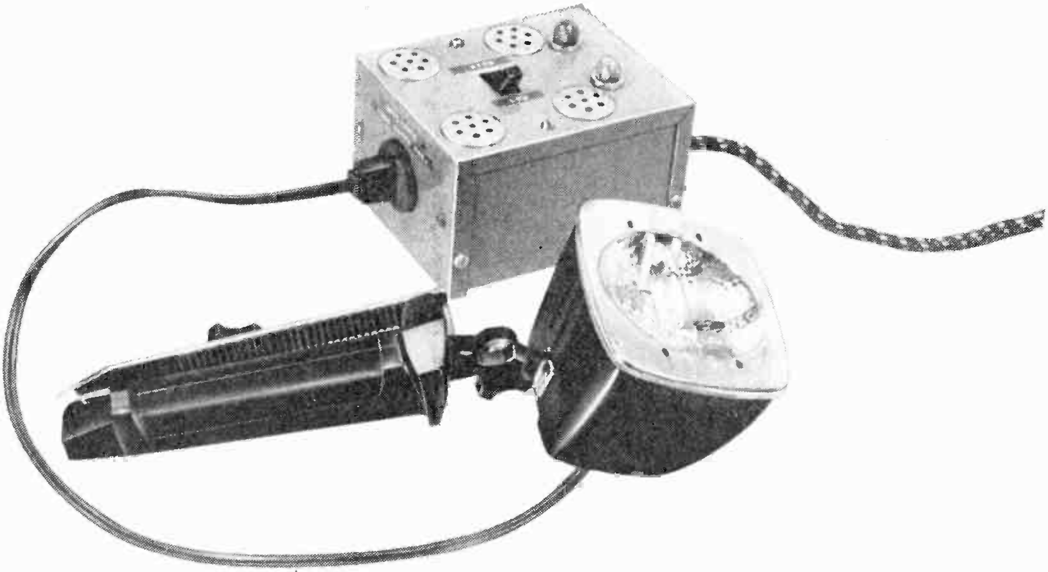
This modified radio code practice oscillator has plenty of pep, and is more than sufficient to sound off for a class full of budding hams.

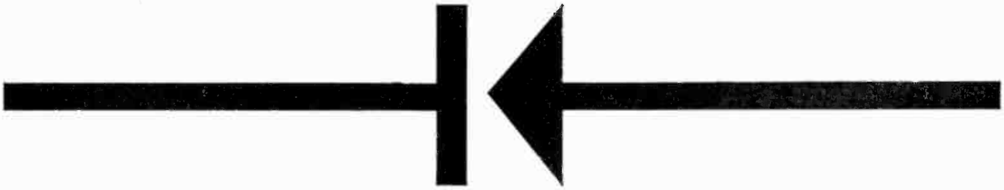
—*Frank A. Parker*

Customize Your Pilot Lamps

To give your equipment that "ultimate touch," add pilot lamps that can be read. Cut small discs from celluloid or plastic, and letter them with such legends as "ON," "OFF," or anything else that is appropriate. Letter the discs with decals, press-on letters, or with India ink. Most materials will take the ink if you lightly sand them first. In many cases, just one letter or number ("P" for power, "A" for amplifier, etc.) will be sufficient. The completed assembly looks like any pilot lamp—until you turn it on.

—*Tim Callan*





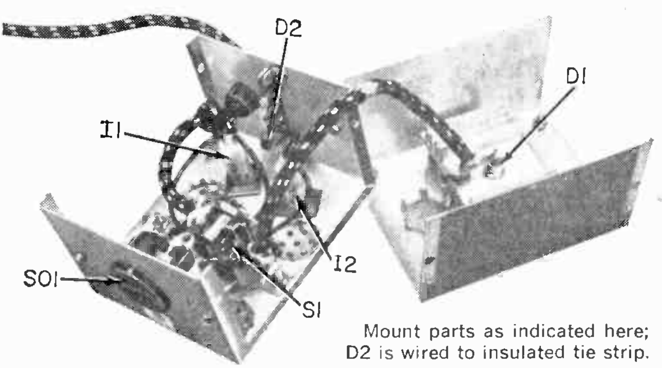
HIGH WATTAGE REDUCER

Use low-cost, high-amperage silicon diodes for easy power control

THIS HANDY PROJECT is a by-product of our space age. Without the impetus to develop high-amperage, solid-state rectifiers necessary for the space program, electronics experimenters would not have been able to buy "over-runs," surplus or seconds. As it is, silicon diode rectifiers with 20-ampere ratings are being offered for about $3. The multiple household uses for these devices have never been fully explored, so here are a few ideas on how to use them—you'll probably find many more.

As shown above, you can extend the life of your home movie high-intensity lighting equipment. You can halve the output of a 1000-1200 watt electric heater (as long as it does not incorporate a motorized fan), giving you controlled warmth and "reserve" heating power. The same applies to a soldering iron (no guns), or perhaps your electric cooker (again, no motor). You'll find the "Reducer" inexpensive and easy to build. Best of all, the unit itself consumes no power—it simply saves it.

Construction is simple, requiring only that the heat sink be well insulated from the aluminum box. The author used surplus ceramic bushings about 3/4" high, threaded on both ends. A 20-amp diode will run hot



Mount parts as indicated here; D2 is wired to insulated tie strip.

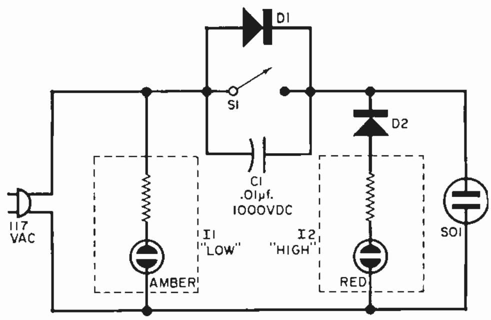
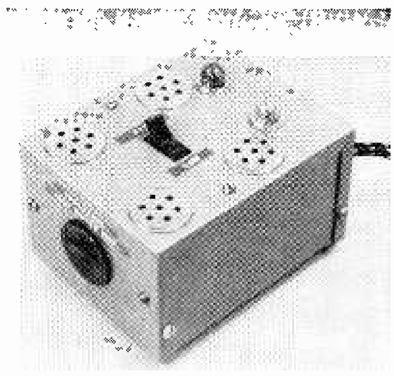


Diagram shows simplicity of High Wattage Reducer.



In addition to mounting D1 on heat sink, ventilation holes should be provided to dissipate heat generated in operation.

PARTS LIST

C1—0.01-µf., 1000-volt ceramic disc capacitor
D1—20-ampere, 400 PIV silicon diode, stud mounting
D2—50-ma., 200 PIV silicon diode
I1—Neon lamp assembly with built-in resistor, amber color lens
I2—Neon lamp assembly with built-in resistor, red color lens
S1—S.p.s.t. switch, heavy-duty (15-ampere minimum rating)
SO1—Chassis-mount a.c. socket
1—3" x 4" x 5" Minibox
1—Heat sink (Carl Cordover HSR-4 or equivalent)
Misc.—Four threaded ceramic bushings to hold heat sink, heavy-duty a.c. cord, terminal strip, wire, solder, hardware

in series with appliances that have a rated power drain of 1400-1500 watts, so the heat sink is a must—it also makes a convenient mount for the diode.

Holes for ventilation should be punched in the aluminum box as in the photos. Two neon lamps (optional) were incorporated in the circuit to show operation. When switch *S1* is open, *D1* and *D2* are back-to-back, and *I2* will go out. When switch *S1* is closed, both neons go on and the silicon diode is switched out of the "Reducer" circuit.

—Frank A. Parker

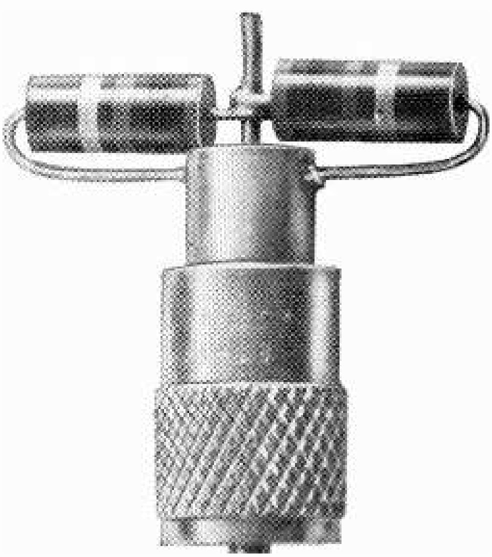
CB Dummy Load

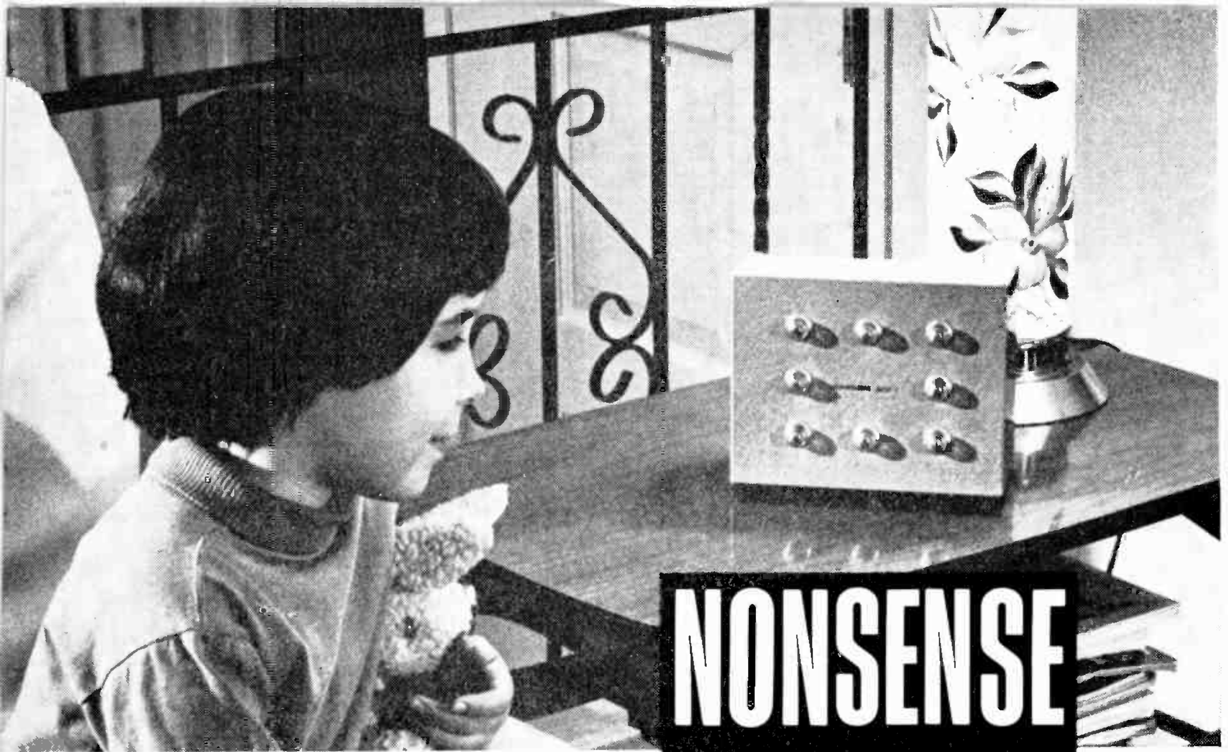
CITIZENS BAND regulations prohibit the practice of tuning up your transmitter while putting a "dead" carrier on the air. The commonly-used light bulb dummy antenna prevents this, but it changes resistance with brightness.

The dummy load shown at right is easily made by soldering a bus bar to the center post of a coax connector and two resistors between the bus bar and the shell. If your CB transmitter uses 52-ohm coax line, make the load of two 100-ohm, 2- or 3-watt resistors. For 72-ohm line, use two 150-ohm, 2- or 3-watt resistors. Be sure that the resistors are carbon and not wire-wound. Wire-wound units will introduce inductance and upset readings.

Tune up with the dummy load using the internal metering in your CB unit or the r.f. probe of a VTVM clipped across the load. A reading of 13-13½ volts corresponds to 3.5 watts output with 52-ohm line.

—Alex F. Burr, 16W2941





NONSENSE BOX

The most useless thing ever published, but your children will think it's great

By ALAN L. DANZIS

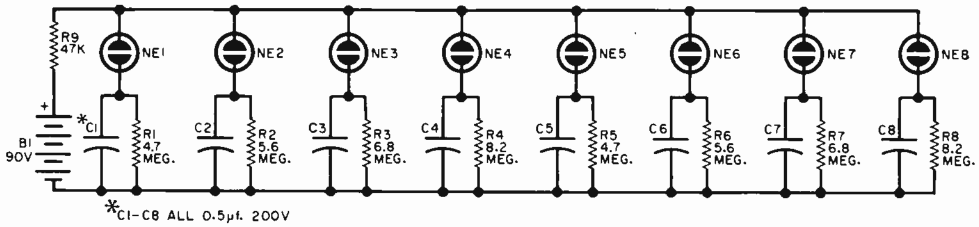
YOU MIGHT tell your kids it's a scintillation counter detecting cosmic messages from outer space. Or, you casually can mention to friends the fact that it's a miniaturized digital computer reading out answers in binary computations. Chances are they'll believe every word you say; only *you* will know that this box is actually "nonsense."

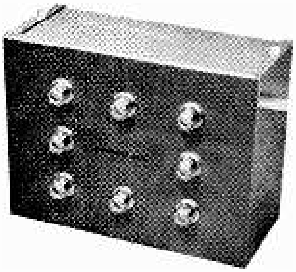
The "Nonsense Box" consists of eight neon lamp flashing circuits flashing at various independent time rates, and all powered by a single 90-volt battery. The current drain imposed by this circuit is around 65 microamperes and the battery should last well over a year. Of course, this is one of the *advantages* (?) of the Nonsense Box—there is no switch to turn it off.

How It Works. Each flashing circuit consists of a neon glow lamp, a 0.5-μf. 200-volt capacitor and a resistor of one of four specified values from 4.7 to 8.2 megohms. Take a look at the first flashing circuit (*NE1*, *C1*, and *R1*). Since there is no current flowing in the circuit, there is no voltage drop across *R1*, or resistor *R9* in series with the battery. This permits *NE1* to fire (conduct) setting up a voltage drop across *R1* and charging *C1*. As the charge across *C1* rises, the voltage across the neon bulb drops, and *NE1* is extinguished. Now *C1* slowly discharges through *R1* (the old *R/C* time constant effect) until sufficient voltage builds up across the neon bulb to fire it and cause the whole process to repeat itself.

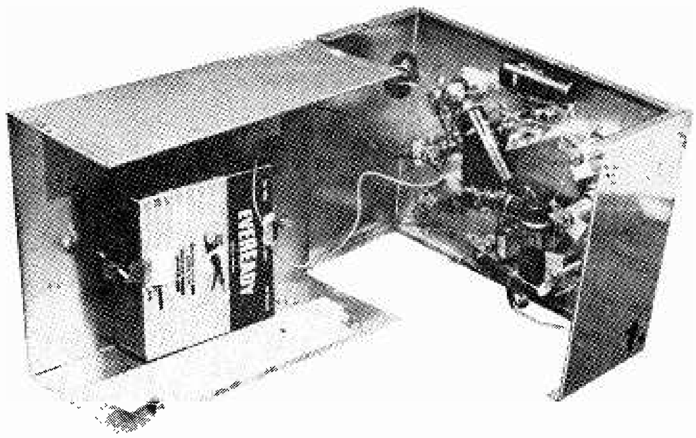
Even though the flashing circuits are doubled up (*C1/R1* and *C5/R5* have the same values), small capacitor and resistor mismatches insure that no two flashing circuits have the same time constant. Resistor *R9* helps insure the random nature of the firing pattern.

Construction. The Nonsense Box can be made of either metal or wood. It





The neon lamps can be arranged in any pattern desired—circle, square, etc.



The interior wiring of the Nonsense Box can be as haphazard as you want. Be sure to clamp the battery in place to prevent it being shaken loose.

PARTS LIST

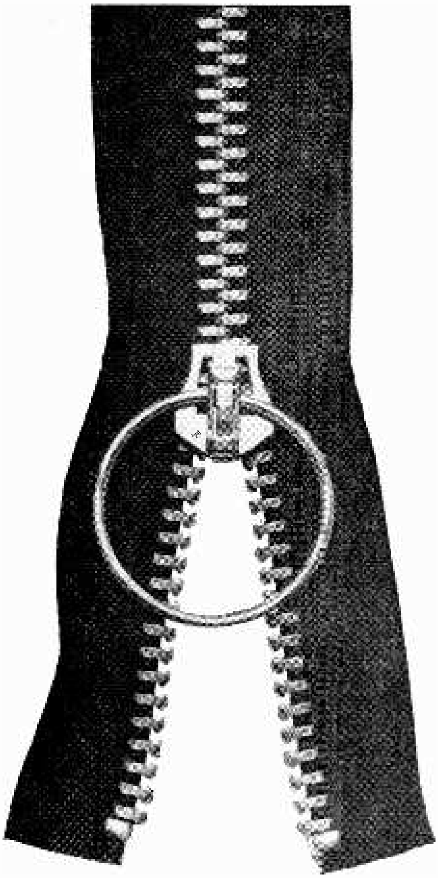
B1—90-volt "B" battery (Burgess type V60 or Eveready type 479)
C1-C8—0.5-μf., 200-volt paper capacitors (eight required)
NE1-NE8—NE-51 type neon bulb (eight required)
R1, R5—4.7 megohms
R2, R6—5.6 megohms
R3, R7—6.8 megohms
R4, R8—8.2 megohms
(All resistors ½-watt)
R9—47,000 ohms
8—Neon lamp sockets (Dialco type 810-B with clear plastic lens)
Misc.—Mounting box, battery retaining clamp, wire, solder, etc.

should have sufficient space inside to comfortably hold the neon bulb sockets and permit the battery to be mounted rigidly in place. The latter measure is especially necessary since many people will try to shake the Nonsense Box to make it turn off.

Care should be exercised in laying out the holes for mounting the neon lamps. The spacing is not critical, but uniformity is desirable. The lamps could be arranged to make a person's initial, or in the square fashion shown in the photos.

Wiring is noncritical—even the battery polarity may be reversed. It is suggested that one terminal of each of the eight lamp sockets be wired together. Solder one end of *R9* to this common connection and leave the other end temporarily free. Now solder one end of resistors *R1-R8* and capacitors *C1-C8* to each of the unused lamp socket terminals according to the wiring schematic. Bring all 16 free leads from these capacitors and resistors to a common bus bar and solder. The two leads from the battery connect to the free end of *R9* and the common bus bar.

The Nonsense Box should start flashing immediately—and only you will know that it's all "nonsense." —30—



Zip through Scott's new solid state FM stereo tuner kit in one afternoon

Four to six hours! That's all you need to zip through Scott's new LT-112 FM stereo tuner kit. Start after lunch—enjoy superb stereo at dinner.

Scott solid state circuitry is the key to the LT-112's superior performance. Costly silicon transistors give performance unapproached by any other kit on the market. The LT-112 is kit-brother to Scott's best-selling 312 solid state stereo tuner, of which *Audio* said, ". . . one of the finest tuners anywhere."

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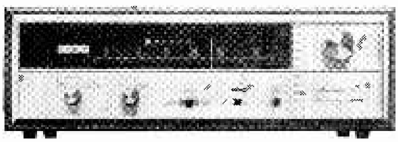
You'd never believe a kit so easy to build could be so packed with features. Built into the LT-112 is a new Scott invention . . . the Tri-modulation meter, used for a Signal Strength Indicator, Zero Center Indicator, and Alignment Meter.

See your Scott dealer today, and pick up an LT-112 tuner kit . . . $179.95 plus one enjoyable afternoon will net you a lifetime of listening pleasure.



SCOTT®

For complete information on Scott's kits & components write: Dept. 521-10, H. H. Scott, Inc., 111 Powdermill Road, Maynard, Mass.
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CHAPTER

2 AUDIO STEREO HI-FI PROJECTS

If you are one of those electronics experimenters who think that audio/hi-fi/stereo construction is a thing of the past, you'll be surprised at the content of this chapter. The kickoff project is a novel speaker enclosure embracing an unusual principle called "bi-coupling." Constructed by well-known enclosure designer, David Weems, the "Bi-Coupler" (page 40) is a modified labyrinth using 8" full-range speakers. Builders of the "Bi-Coupler" will be pleasantly surprised by the smooth sound and stereo effectiveness. Next project in line is the "Stereo S'Lector" (page 44) —a convenience for those who like automation in their FM listening.

The "Vibrato Simulator" and "Volume Expander" are also projects that can be classified as "unusual." The "Simulator" (page 47) will appeal to budding musicians who have a guitar, and the "Expander" (page 51) is a device for the serious audiophile. The latter can be used monophonically as well as in the featured stereo version.

Shutting your hi-fi off with the record player is not new, but the ideas presented on page 58 sure are. You'll admire the versatility of the "Hi-Fi Interlock" and the safety features it incorporates. Last but not least is the "Shotgun Sound Snooper" (page 61). This highly directional microphone has created considerable interest and the designers have completely revised the story to include answers to many questions raised by readers of POPULAR ELECTRONICS.

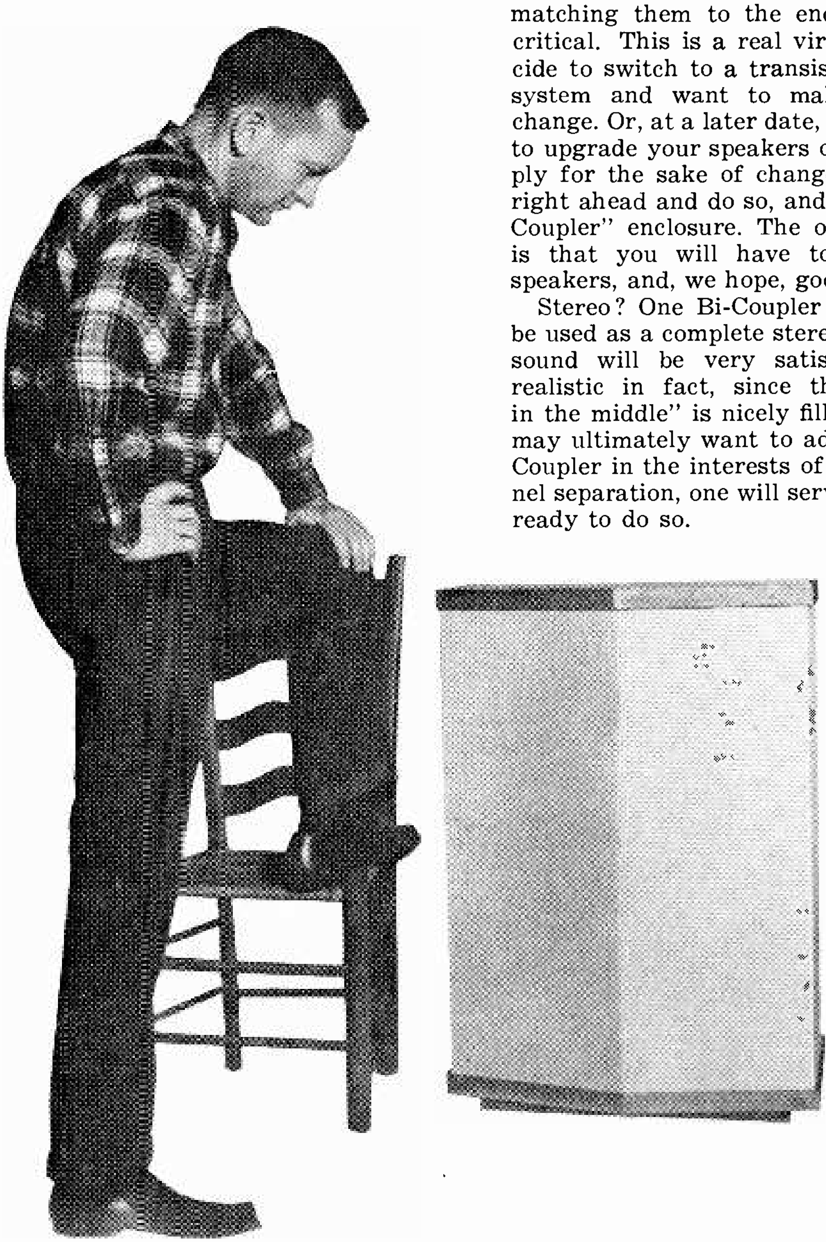
For Better Sound

Great for either stereo or mono listening, this

By DAVID B. WEEMS

HERE is a versatile, labyrinth speaker system that gives you an almost unlimited choice of speakers because matching them to the enclosure is not critical. This is a real virtue if you decide to switch to a transistorized stereo system and want to make a speaker change. Or, at a later date, you may want to upgrade your speakers or change simply for the sake of change—you can go right ahead and do so, and keep the "Bi-Coupler" enclosure. The only limitation is that you will have to stick to 8" speakers, and, we hope, good ones.

Stereo? One Bi-Coupler can certainly be used as a complete stereo system. The sound will be very satisfactory—quite realistic in fact, since that old "hole in the middle" is nicely filled. While you may ultimately want to add another Bi-Coupler in the interests of greater channel separation, one will serve until you're ready to do so.



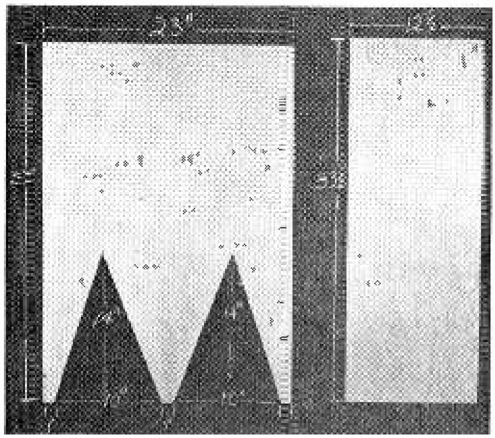
Build the Bi-Coupler

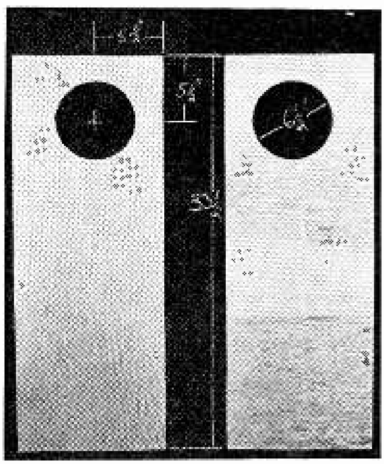
flexible little system features two full-range speakers

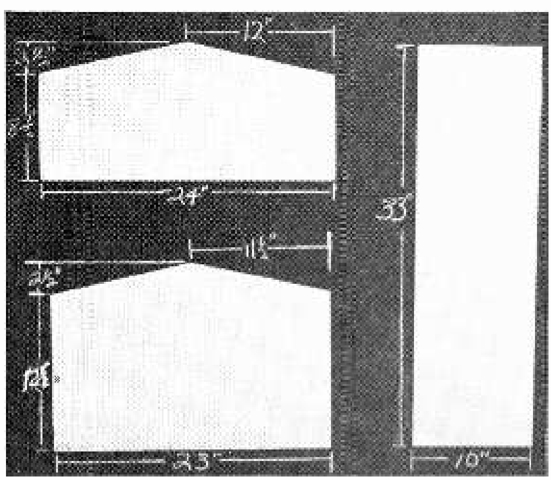
Theory. The labyrinth type enclosures have other virtues but they seem to have fallen by the wayside, although some manufacturers used them for years. The Bi-Coupler is a modified labyrinth with some special features. First, as you might guess from the name, it is compartmentalized. The benefits of multiple full-range speakers are well known, but when more than one such speaker is mounted in a single compartment, there is no guarantee that optimum results will be obtained.

The phase relationship of sound waves on a single baffle gets pretty confusing with more than one speaker, particularly behind the speakers where reflections play an important role. Instead of mutual coupling, the result is likely to be mutual cancellation at some frequencies. The midrib in this enclosure separates the speakers, insuring that they are in phase on the rear wave, which produces bass reinforcement.

Good high frequency dispersion is obtained from the angled baffles, which also reduce midrange peaks due to reflections from the rear walls. A less obvious advantage to treble reproduction is contributed by the outside shape of the enclosure. A cabinet with corner angles greater than 90° theoretically reduces diffraction effects which, again, are a source of phase distortion and can-







The basic parts of the Bi-Coupler are shown in these photos along with their dimensions. The two front pieces, above, are each 12½" x 33½"; note spacing and diameter of speaker cutouts. At right, above, is the rear partition and one of the two sides; the diagonal cutouts in the partition create labyrinth effect. Directly at right is the top, bottom, and the midrib. All parts (including a cabinet back if desired) are cut from a single sheet of 4' x 8' x ½" plywood.

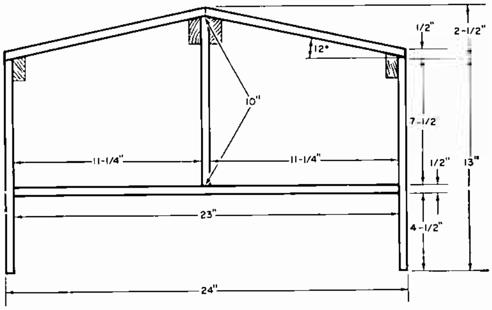


Diagram of the top of the Bi-Coupler's enclosure shows how it is assembled. The front edges of each side, those of the four cleats, and both edges of the front baffles are cut to a 78-degree angle.

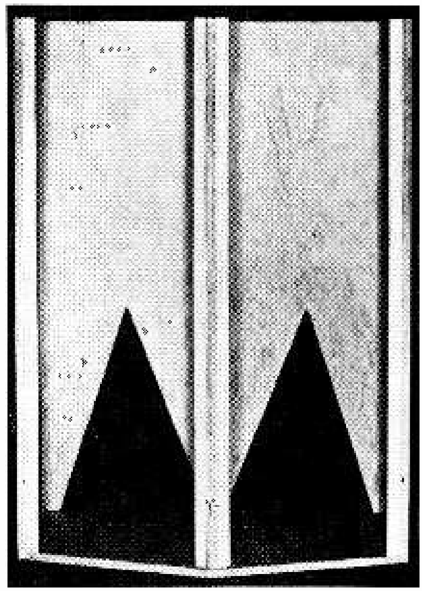


Photo at right shows the rear partition, the sides, midrib, and four long cleats mounted to the bottom.

cellation. Finally, the front of the enclosure approximates the same shape a sound wave assumes when it is emitted from a point source, an aid in coupling the speakers to the air.

Panel vibration should be avoided in any type of enclosure. In this case, the specified ½" plywood is adequate because an open "pipe" is subject to less pressure build-up than a "box," and also because the panels are narrow and well braced. You may question the advisability of using ½" material for the midrib which is subject to stress produced by both speakers. Reconsider. The speakers are mounted symmetrically with regard to that panel, which means that if they are connected in phase the change in pressure from one speaker should exactly cancel the change in pressure from the other speaker! It's an imperfect world, but that was the plan.

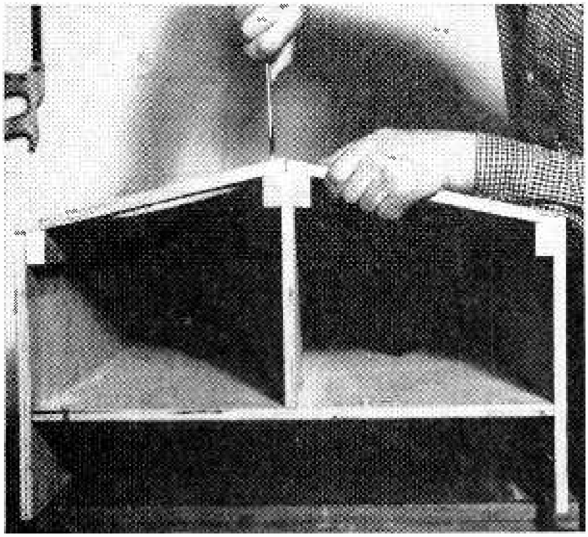
Bi-Coupler Construction. The parts for the enclosure can be cut from a single 4′ x 8′ sheet of plywood with enough left over to make a back if desired. The back was not needed for the author's version because the sides fit tightly against the walls of the room in which it is installed. By placing the cabinet on its back on a rug, you can quickly compare the possibilities—complete or backless.

The sides and front pieces of the enclosure are first cut to a width of 12½", but the front edge of each side is then cut or planed to an angle of 78° as shown in the illustrations. The 1" x 2" cleats should also be cut to this angle. If a power saw is used, set the saw blade at 12°, since 0° gives a cut of 90°. Both edges of the front baffles are later cut at the same angle.

Assembling the Cabinet. For a solid job, use glue, screws, and nails. First, glue and nail the 1" x 2" cleats to the midrib, then glue and nail the midrib on a line down the center of the partition (the section with the diagonal cutouts), adding screws when it's in position. Glue and nail the bottom to the partition and midrib. The 1" x 2" cleats can now be glued and screwed to the sides; glue and screw the sides to the bottom and rear partition.

Speaker holes should be cut in each front baffle and then the angled cuts made at the baffle edges. It may be necessary to take off a small amount at each edge to secure a proper fit for these parts. When fitted, glue and screw the front baffles in place. Then locate the speaker mounting bolts, which can temporarily be secured with glue.

The next step is to place the top in position. By reaching in through the speaker holes, an outline of the sides, "fronts," midrib, and partition can be marked under the top with a pencil. The short cleats can be glued and screwed to the underside of the top in the prop-



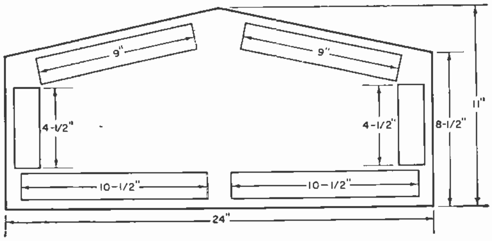
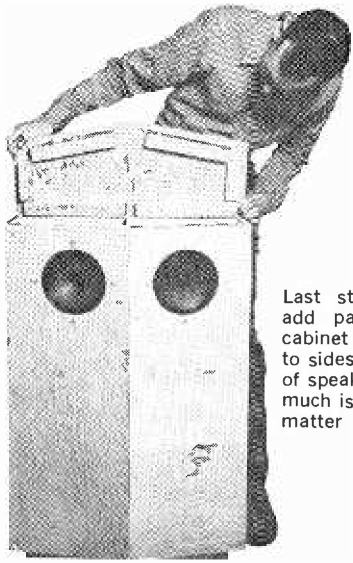


Diagram above shows placement of top cleats; these are positioned ½" from edges.

Nails, glue, and screws are used to tightly bond the parts of the enclosure together, and eliminate vibration.



Last step is to add padding in cabinet top, and to sides and rear of speakers. How much is mostly a matter of taste.

BILL OF MATERIALS

Cut from one 4′ x 8′ x ½″ plywood sheet:

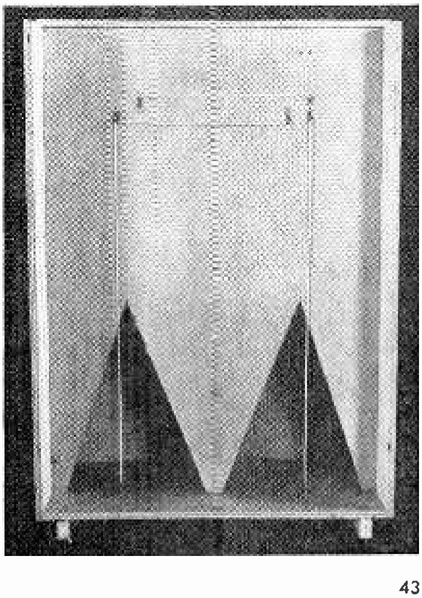
4—12½″ x 33½″ pieces for sides and fronts
1—10″ x 33″ piece for midrib
1—23″ x 33″ piece for rear partition
1—11″ x 24″ piece (less cut-offs) for top
1—15″ x 23″ piece (less cut-offs) for bottom

Cut from 1″ x 2″ lumber (actual material size approx. ¾″ x 1½″):

4—33″ pieces for front and side cleats
2—10½″ pieces for top cleats
2—9″ pieces for top cleats
2—4½″ pieces for top cleats
1—21″ piece for foot (optional)
2—10½″ pieces for foot (optional)

Misc.—Four dozen #6 x 1½″ screws, 6-d box nails, glue, eight 3/16″ x 1½″ bolts for speakers, grille cloth

Terminals permit the speakers to be connected in series, parallel, or separately.

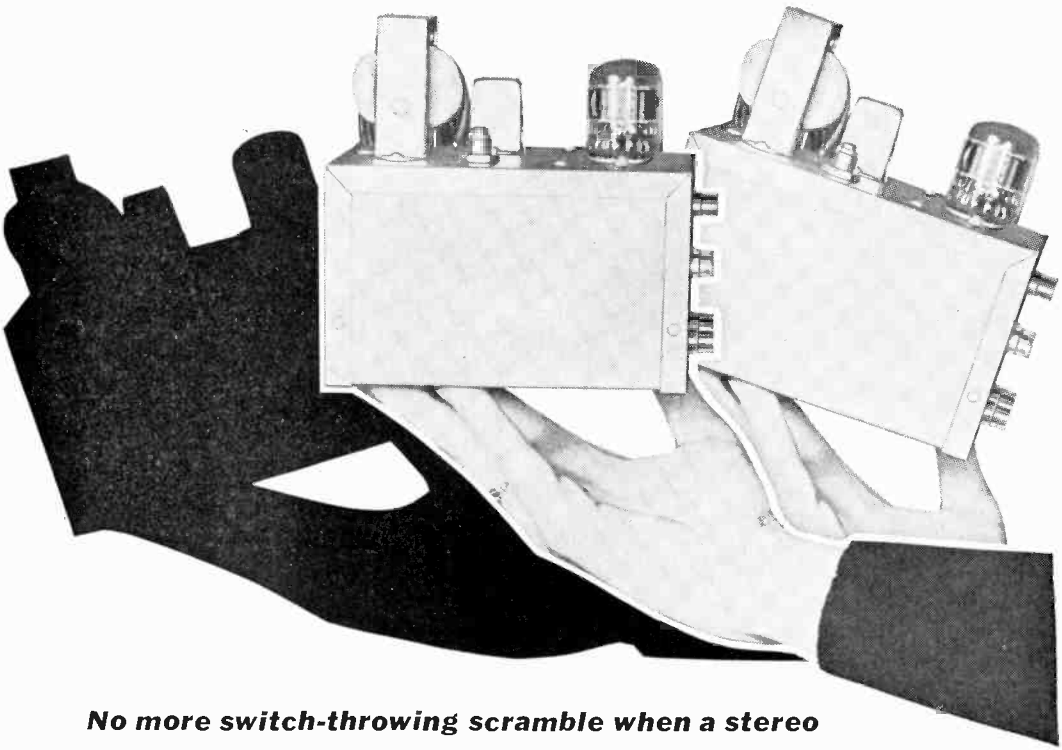


er position to receive screws from the outside of the cabinet.

It is a convenience to have an outside connection for each speaker post. In the prototype, this was done by drilling holes in the rear partition and running wires from the speaker terminals to bolts on the back. Thus, the speakers can be connected in series, parallel, or to separate circuits as desired without tearing into the cabinet. When the speakers are mounted, a test should be run to determine how much padding is necessary.

(Continued on page 147)

THE Stereo S'Lector



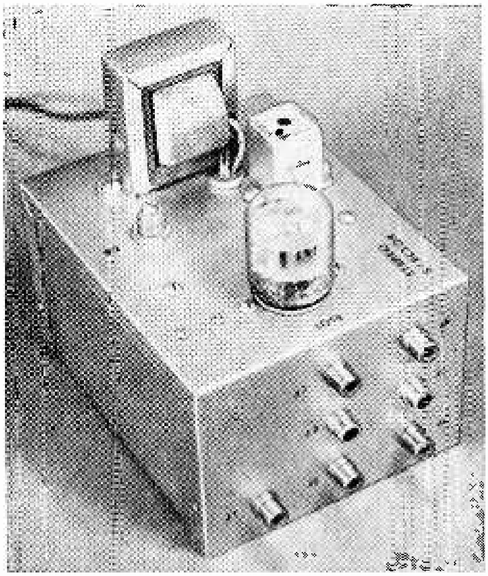
No more switch-throwing scramble when a stereo station comes in! The S'Lector does it for you

By ALTON B. OTIS, JR.

IF you have a mono FM tuner and an outboard multiplex adapter, the "Stereo S'Lector" is for you! In addition to giving you a visual indication that a stereocast is coming through, it will automatically switch the multiplex adapter into the circuit and connect the adapter's output to the stereo tuner terminals of the amplifier—a feature found only in the more expensive commercial FM stereo tuners. The cost of the parts required to build the S'Lector is nominal—only about $15.00.

How it Works. The single compactron tube, *V1,* is a 6D10 which has three separate triodes in one envelope. The multiplex signal from the tuner is applied to *V1a,* which is a low-gain amplifier with a high input impedance. From there, it goes to a variable-mu, high-gain amplifier, *V1b*. The output of *V1b* is fed to a filter consisting of *L1* and *C5*. This removes all but the 19-kc. components of the signal.

The 19-kc. signal is rectified by diode *D1* and the resulting d.c. voltage is applied to the grid of relay control *V1c*. When no 19-kc. signal is present (as in a monophonic signal), the relay remains pulled in, connecting the normal output of the tuner to the amplifier. A 19-kc. signal will apply a negative voltage to the grid of *V1c,* which causes the relay to open, connecting the tuner stereo out-



Finish the Stereo S'Lector with a coat of spray paint and press-on letters for jack identification.

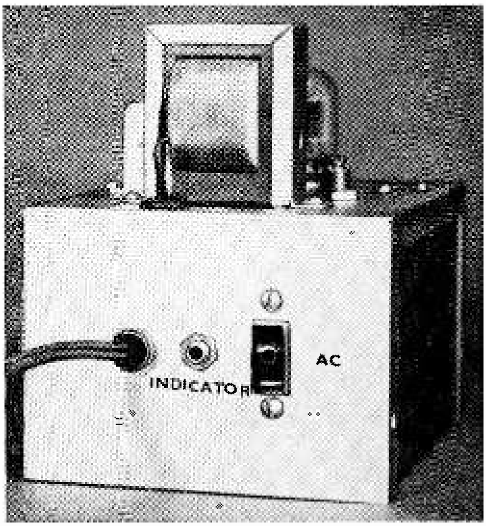
put to the amplifier, and simultaneously turning on the stereo indicator lamp (*I1*).

Building the Unit. The Stereo S'Lector is constructed in a 3" x 4" x 5" aluminum Minibox. Parts layout is not critical, but the photos show the layout used satisfactorily by the author.

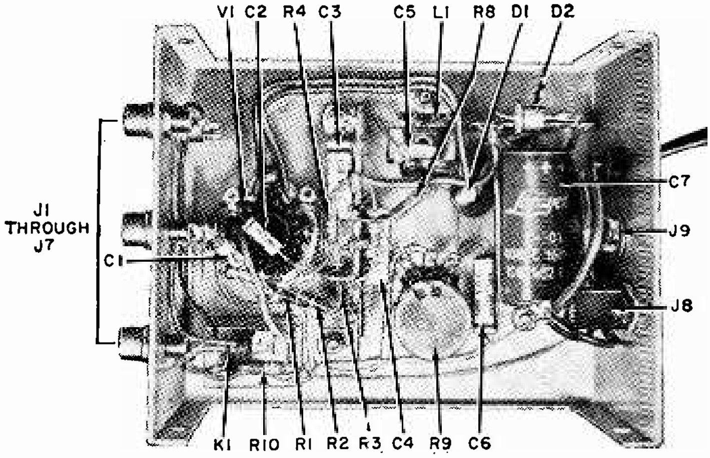
Coil *L1* is mounted by means of a flange provided with the coil. Power rectifier *D2* is mounted on a three-lug (center ground) terminal strip which is attached under one of the power transformer mounting screws. A single solder lug under the other transformer mounting screw serves as a ground for capacitors *C6* and *C7*. Capacitor *C5* mounts directly across the terminals of *L1*, and *D1* is connected directly between *L1* and *R9*.

Two of the four poles of relay *K1* are used for switching the output between the tuner and multiplex adapter. The other two relay poles can be used to trigger external indicators (as shown here) or for other signaling or switching functions.

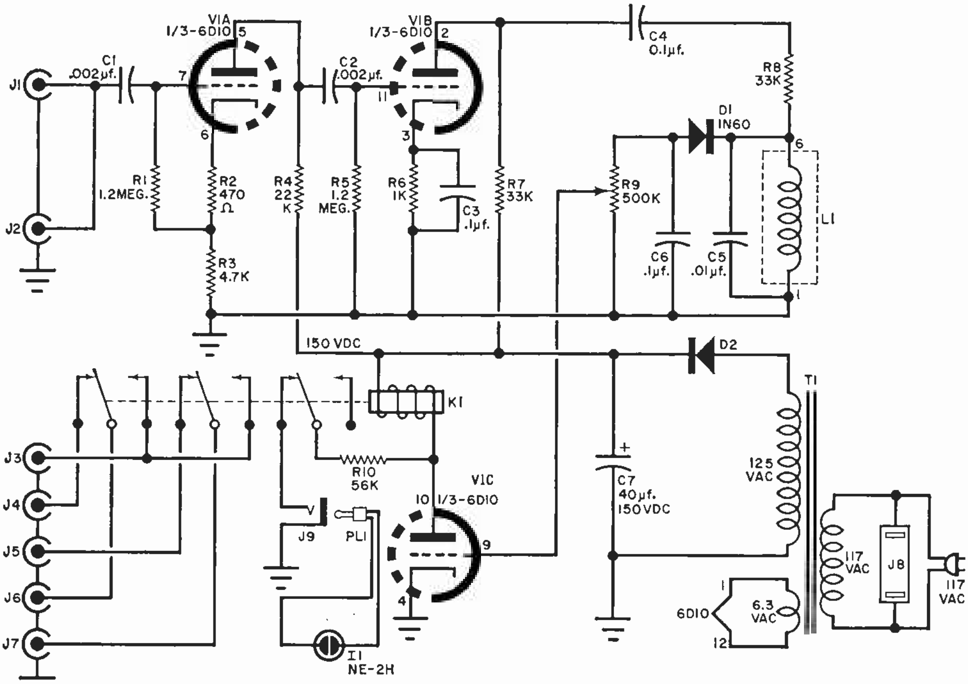
Tuning Up. Check the unit carefully for short circuits, and remove all solder splashes and wire bits. Before installing the 6D10, plug the unit in; the voltage



Indicator lamp jack is connected to miniature plug so lamp can be mounted at tuner or amplifier panel.



Parts layout is not at all critical but author's model is detailed in photo at left with parts call-outs.



A single compactron tube does the work of three in the Stereo S'Lector circuit.

PARTS LIST

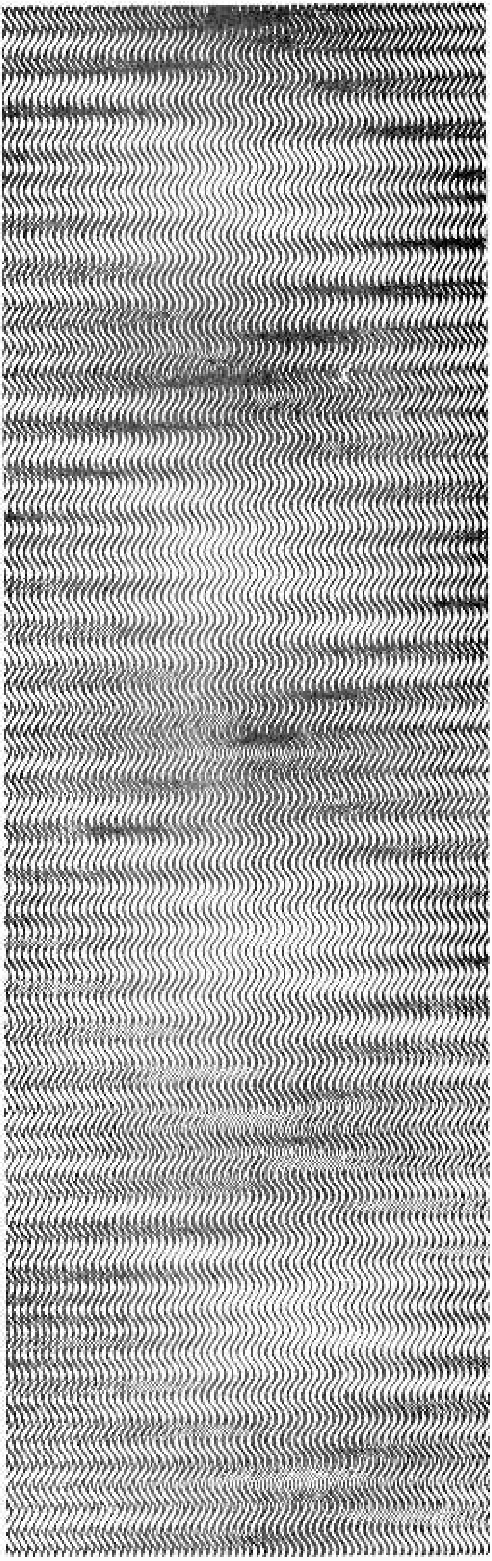
C1, C2—0.002-µf., 200-volt Mylar capacitor
C3, C4, C6—0.1-µf., 100-volt Mylar capacitor
C5—0.01-µf. ceramic disc capacitor
C7—40-µf., 150-volt electrolytic capacitor
D1—1N60 diode (or equivalent)
D2—50-ma., 400-PIV silicon rectifier
I1—NE-2H neon lamp
J1-J7—Phono jack (single-hole type)
J8—117-volt accessory outlet
J9—Miniature phone jack
K1—4-p.d.t. relay, 5300-ohm coil, 6.6-ma. pull-in (Lafayette 99-G-6094 or equivalent)
L1—19-kc. oscillator coil (J. W. Miller 1354)
PL1—Miniature phone plug
R1, R5—1.2-megohm, ½-watt resistor
R2—470-ohm, ½-watt resistor
R3—4700-ohm, ½-watt resistor
R4—22,000-ohm, ½-watt resistor
R6—1000-ohm, ½-watt resistor
R7, R8—33,000-ohm, ½-watt resistor
R9—500,000-ohm linear taper potentiometer
R10—56,000-ohm, ½-watt resistor
T1—Power transformer; primary, 117 volts; secondaries, 125 volts, 15 ma., and 6.3 volts, 0.6-amps. (Lafayette 33-G-3405, Stancor PS-8415, or equivalent)
V1—6D10 compactron tube
1—3" x 4" x 5" aluminum Minibox
Misc.—12-pin compactron socket, terminal strips, wire, solder, line cord, etc.

across capacitor *C7* should read about 200 volts. Install the tube and allow a short warm-up period. Voltage across *C7* should now read about 140-150 volts, d.c. If it is substantially lower, pull the plug and inspect the unit again for shorts.

Connect the Stereo S'Lector to the tuner with jacks, as follows: *J1* to multiplex output of tuner; *J2* to input of multiplex adapter; *J3* to monophonic output of tuner; *J6* and *J7* to the stereo amplifier inputs; *J4* and *J5* to the output of the multiplex adapter.

With the tuner set to a strong stereo station, adjust the slug in *L1* for maximum a.c. voltage across the coil. The reading may fluctuate at this point, depending on the program material. Starting with the wiper of *R9* at the ground end, advance the wiper toward *D1* until the relay drops out, then about five or ten degrees more. The unit is now adjusted and ready for use.

The model built by the author has performed very reliably, never confusing interchannel noise and a stereo broadcast. If you build the S'Lector, you'll find it a valuable adjunct to your stereo system, one that you will wonder how you ever got along without. —30—



VIBRATO SIMULATOR

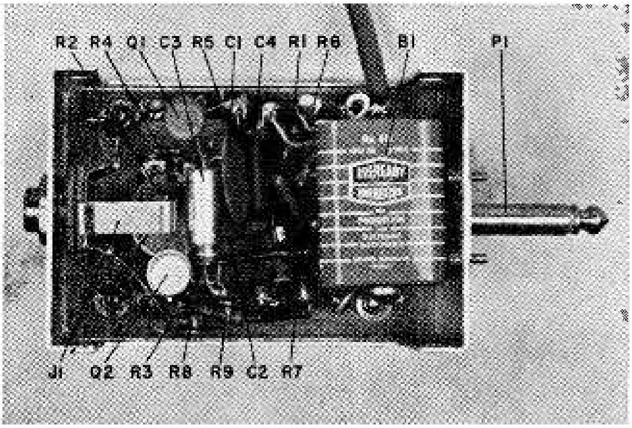
By FRED IPPOLITO, Jr.

Low-cost transistorized circuit is inserted between guitar and amplifier. Player controls simulator with homemade foot switch

THIS article describes the construction of a simple, low-cost, transistorized vibrato simulator which can provide most musical instrument amplifiers with a vibrato effect. When used in conjunction with a guitar and amplifier, it produces a pleasant-sounding amplitude-modulated signal, similar to the effect of varying the volume control on the guitar.

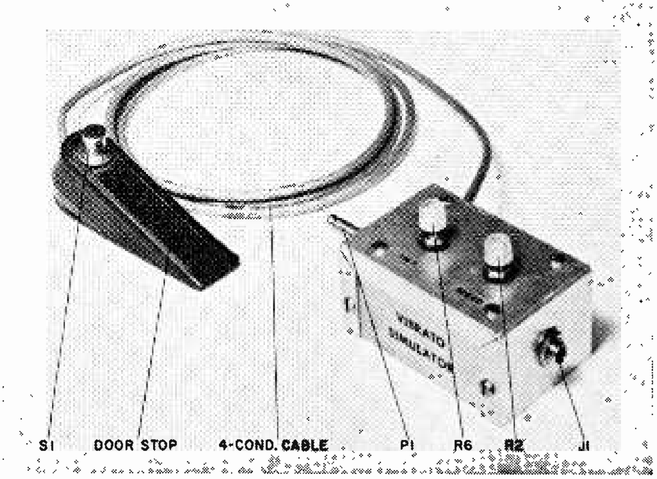
The vibrato simulator is battery-operated and completely self-contained. No external power source is required and no circuit modifications to the amplifier are necessary. Installation of the simulator consists of plugging it into the amplifier and plugging the instrument into the simulator. The current drain on the battery is so low that in normal use the life of the battery should approach its shelf life. Construction costs are small, less than $10, even when all the parts are purchased. But you will probably have some of the parts available, reducing the cost even further.

Two controls are provided; one for adjusting the desired intensity and the other for adjusting the vibrato speed. A foot switch is also provided so that the musician can switch the vibrato effect in or out while playing.



Underside view of the simulator shows compact, sturdy construction used by the author. All connections are made to the potentiometer terminals or to one of the 66-terminal tie strips mounted at either end of the box.

With the self-contained battery, the author wired the simulator so it would always be off unless momentary d.p.s.t. switch S1 was closed. The guitarist slips this switch on its doorstop mount under his right or left foot.

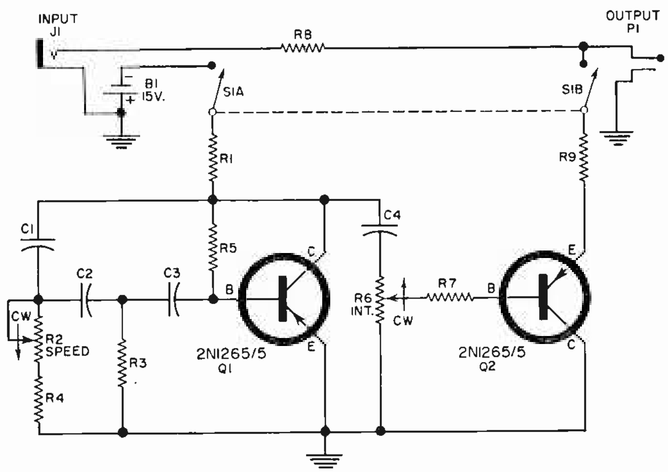


About the Circuit. Transistor *Q1* is used in a sub-audio phase-shift oscillator circuit to produce the vibrato speed or frequency. Transistor *Q2* is used in a voltage-divider network to modulate the incoming signal. The effectiveness and efficiency of the vibrato oscillator is remarkable. Using a 15-volt battery, the sine-wave output signal at the collector is 8 volts peak-to-peak, with a current drain on the battery of only 300 μa.

Common, low-cost transistors can be used. In testing the circuit, the writer tried at least ten 2N1265/5 transistors, with each providing satisfactory results. Although a 15-volt battery is used to provide sufficient output for this application, the circuit will oscillate with a voltage of 9 to 12 volts.

The oscillator operates at a frequency of 6 cycles, since this is the most commonly used frequency in commercially available units and in electronic organs. Potentiometer *R2* provides for an oscillator range of approximately 4 to 14 cycles. Resistor *R4* prevents oscillator cutoff at the maximum clockwise rotation of *R2*, which is the fastest speed.

Capacitor *C4* couples the oscillator signal to potentiometer *R6,* which is used to adjust the vibrato intensity. Switch *S1* is a momentary d.p.s.t. (normally open) type, used to make and break both the oscillator and modulator circuits. It is mounted in a molded plastic door stop and is used as a foot switch so that the vibrato effect can be switched in and out.



Theory of operation of this circuit is described in the text at the bottom of the facing page. Although the author plugged his simulator right into the amplifier, some builders may find it necessary to use an extension cable instead of rigidly mounting P1 to the aluminum box.

PARTS LIST

B1—15-volt battery (Eveready 411 or equivalent)
C1—0.5-μf. capacitor—see text
C2—1.5-μf. capacitor—see text
C3—5-μf. capacitor—see text
C4—0.05-μf. ceramic disc capacitor
J1—Phone jack (Switchcraft L-11 or equivalent)
P1—Flat-type phone plug (Switchcraft 220 or equivalent)
Q1, Q2—2N1265/5 transistor (Sylvania)
R1—30,000-ohm ½-watt resistor
R2—10,000-ohm potentiometer (Philmore PC-51 or equivalent)
R3—3300-ohm, ½-watt resistor
R4—3000-ohm, ½-watt resistor
R5—620,000-ohm, ½-watt resistor
R6—500,000-ohm potentiometer (Philmore PC-54 or equivalent)
R7—470,000-ohm, ½-watt resistor
R8, R9—100,000-ohm, ½-watt resistor
S1—D.p.s.t. momentary push-button switch (normally open)
1—3¼" x 2⅛" x 1⅝" chassis (Bud CU-3001A or equivalent)
1—5-foot, 4-conductor shielded cable (Belden 8434 or equivalent)
1—Molded plastic door stop—see text

The output signal appearing at *P1* is fed to the instrument amplifier and will vary in amplitude at a rate equal to the oscillator frequency. Transistor *Q2* does not act exactly as a switch with only a full "on" or full "off" condition. It responds to the magnitude of the sine-wave signal applied to its base. Therefore, the percent of modulation or intensity can be adjusted through *R6*. The values of *R8* and *R9* (100,000 ohms) were chosen to provide up to 50% modulation. Raising the value of *R9* will decrease this percentage while lowering the value will increase it. Changing the value of *R8* will accomplish the same thing but in the reverse of the above conditions.

Construction. The unit was completely assembled in a 3¼" x 2⅛" x 1⅝" Minibox (Bud CU-3001A), with a shielded cable going to the external foot switch. Although there is no critical requirement for parts placement, it is advisable to keep resistors *R8* and *R9* and the signal wires of *J1* and *P1* away from other components in the simulator. It is also advisable to use just one or two ground lugs and make certain that a good mechanical and electrical ground is obtained.

When selecting capacitors *C1* and *C2*, consider using the Sprague "Hypercon" ceramic disc type, part numbers HY-330 and HY-135 respectively. These are high-capacitance, low-power-factor miniature ceramic discs. They are also low-priced. The manufacturer rates them with a capacitance tolerance of guaranteed minimum value. In checking an assortment of these capacitors on a bridge, it was found that the 0.47-μf. units (HY-330) invariably exceeded 0.5 μf. and the 1-μf. units (HY-135) were closer to 1.5 μf. When selecting capacitor *C3*, consider using a 4-μf. electrolytic rather than a 5-μf. unit. The low-priced variety of miniature electrolytics have capacitance tolerances of −20 to +150, the higher tolerance usually being the case.

The capacitors listed above were used in the author's model with excellent results. Of course, if standard-sized components are employed, which normally have a ± 20% tolerance, the specified values of 0.5 μf., 1.5 μf., and 5 μf. should be used.

Phone plug *P1* is a flat type with the plastic case removed. Drill a hole at one end of the chassis large enough to pass the plug connectors through. Drill three additional holes corresponding to the screw holes on the plug to facilitate mounting it to the chassis. The three screws removed with the plastic cover can be used for this purpose.

Mount the phone jack (*J1*) on the opposite end of the chassis. The two miniature potentiometers (*R2* and *R6*) are mounted on the bottom of the chassis. All electrical components are assembled using two 6-terminal strips mounted on the chassis bottom.

The foot switch is a momentary d.p.s.t. push-button type mounted in an ordinary molded plastic door stop, which can be purchased at most hardware stores. Since the simulator is battery-operated and does not have a pilot light, a momentary switch was used to eliminate the possibility of leaving the oscillator on when the simulator was not in operation. A push-on, push-off type switch can be employed if desired.

The cable for the foot switch is a miniature four-conductor shielded type (Belden 8434). This cable is excellent for this purpose because it contains two pairs of wire separately shielded. Using an unshielded cable, it was noticed that a small transient pulse caused by the opening and closing of *S1(A)* was picked up through the wires of *S1(B)* and transmitted to the amplifier as a click. If desired, two small-diameter, two-conductor cables (one shielded) can be employed. Use the shielded pair for the modulator circuit since this will also help minimize stray hum and pickup.

The author made some attempt to keep the unit small, which necessitated the use of miniature parts. These parts are generally more expensive and less readily available than standard size parts. There are, however, many different ways in which the simulator can be built. For example, the entire unit can be assembled in a chassis fabricated to also serve as a foot switch (Bud chassis C-1606 can be used). This would eliminate the need for the shielded cable to the foot switch and would preclude the possibility of transient or hum pickup. The unit can also be assembled in a chassis which has provisions for mounting it to the amplifier case or chassis.

Another possibility would be to replace the 15-volt battery with an a.c.-operated power supply and assemble the entire unit in a chassis attached to the instrument amplifier chassis. In this case, the simulator could be switched on and off with the instrument power switch. The oscillator circuit could be left running, which would eliminate the need for switch *S1(A)*, and an s.p.s.t. switch could then be used for *S1(B)* to make and break the modulator circuit.

Operation. Once the vibrato simulator has been assembled, all that remains to be done is to put it to use. Plug the unit into the guitar amplifier and the guitar cable plug into connector *J1*. Adjust the guitar and amplifier controls for normal operation. With the foot switch open, the guitar operates in the normal manner. Depressing the foot switch couples the vibrato circuit into the amplifier input. Adjust *R2* for the desired vibrato speed and *R6* for the desired intensity.

It is unlikely that trouble will be encountered unless, of course, an error has been made in wiring. In case of trouble, carefully re-check the wiring, especially the terminals of *J1* and *P1*, since it is easy to reverse these connections and thereby ground the input or output of the unit. The oscillator can be checked for oscillation by connecting a VTVM between the collector and ground. A reading of approximately −3 volts should be obtained. Also, the pointer of the meter will be moving at the oscillator rate. Check to see if the circuit oscillates through the complete rotation of *R2*.

It is possible to get a 2N1265/5 transistor with an extremely low gain factor. Therefore, try another transistor of the same type if everything else appears normal. The only other factor that could cause a problem is the variance in capacitance tolerances of *C1*, *C2*, or *C3*. —30—

BUILD A Hi-Fi VOLUME COMPRESSOR-EXPANDER

By ROGER H. RUSSELL

Add dynamic realism to FM stereo and to your tapes and records. Superbly designed and inexpensive to build, this little unit is alone in its class

WHILE NEW GADGETS for the audiophile have not been slow in making an appearance on dealers' shelves, at least one has been consistently shoved aside or completely ignored: the volume compressor-expander. Here, for the first time, is a method of controlling the dynamic range of your hi-fi system for less than $25.00. And the low cost is not the only attractive feature. Hirsch-Houck laboratory tests reveal that this volume compressor-expander is virtually unmatched in its performance, even when compared to commercial units costing much more.

What exactly is volume compression-expansion? It's as simple as this: The dynamic (loudness) range of live program material is usually much wider than a recorder or broadcast transmitter can handle. If, for example,

Controls on front of unit (photo above) are threshold controls which determine the level at which expansion or compression takes place. Panel lamps I1 and I2 glow in proportion to the voltage of the audio tapped from speakers; switches control power, function.

Controls at rear of unit are d.c. balance pots which are adjusted initially. A cartridge, tuner, or other audio source is connected to inputs; outputs go to amplifier. Speaker jacks allow unit to sample amplifier output at speakers and react accordingly.

the gain is set halfway up, the soft parts will be accompanied by noise (tape hiss, hum, etc.) and the loud parts will be distorted from overdriving the recording or broadcast amplifier. Unfortunately, the solution to this problem—turning up the amplifier on soft passages and turning it down on loud ones—destroys the dynamic range of the original program material.

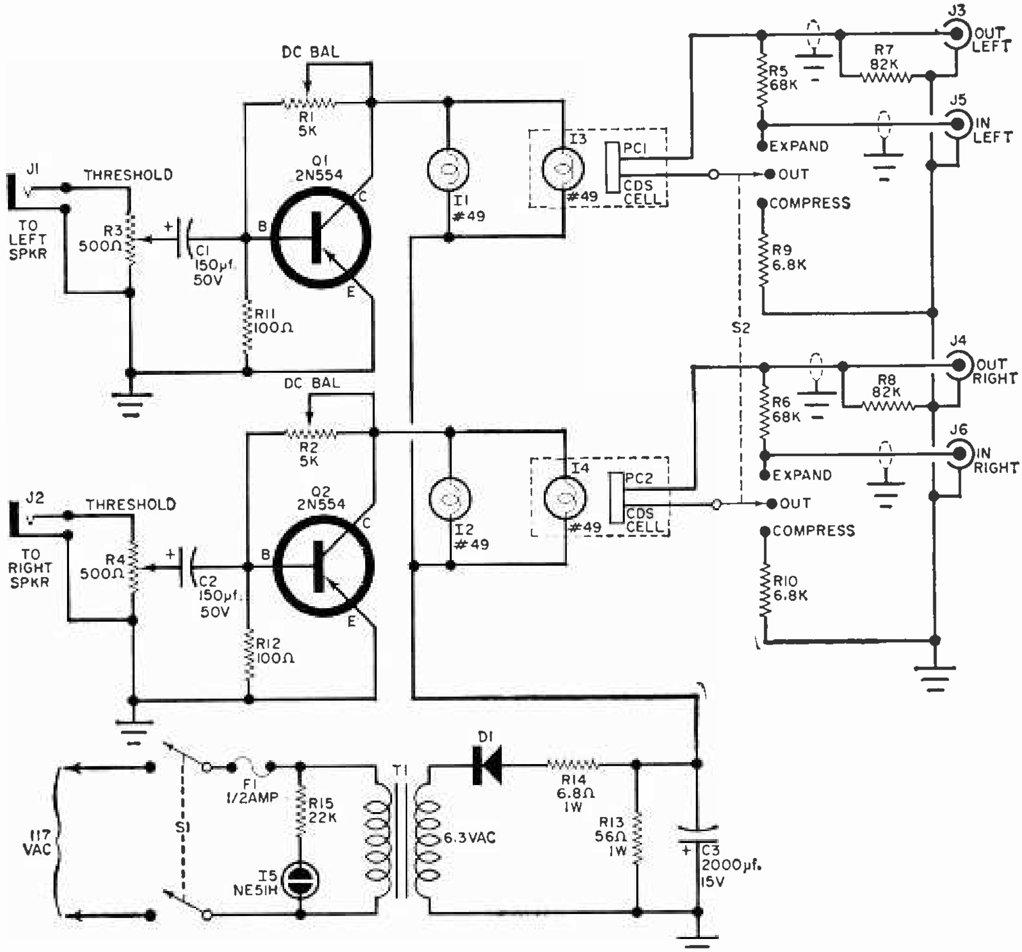
Since automatic volume compression is used to some extent in all commercial recording and broadcasting, volume expansion offers the audiophile an easy way to restore dynamic realism to a broadcast or to a tape or disc recording. On the other hand, the volume compression of which this unit is capable will be useful for those who want to listen to background music or who want to listen to the hi-fi without disturbing their neighbors.

How It Works. The idea of using a lamp and cadmium sulphide photocell in a feedback circuit is not new, but few experimenters have had the chance to try this circuit in their hi-fi systems. Use of transistor amplifiers—unique with this unit—allows expansion and compression at relatively low listening levels.

Output voltage at the speaker terminals of each stereo channel is used to drive a transistor amplifier/limiter which, in turn, controls the intensity of a lamp. The intensity of the lamp causes the resistance of a cadmium sulphide photocell to change. The CdS cell is switched in a voltage divider to either aid or retard the input voltage to the amplifier.

Since the input impedance of the transistor amplifiers is high compared to the impedance of the speakers, connecting the unit to the speaker terminals has virtually no effect on speaker performance. With the d.c. balance controls (*R1* and *R2*) adjusted so the lamps just go out with *no* audio at the speakers, a slight voltage input at the bases of *Q1* and *Q2* will fire the transistors and the lamps will begin to glow. The lamps will glow brighter as higher voltage is applied to the point where the transistors begin to saturate. The amplifiers act as limiters at this point—since a higher input will not increase output—preventing the bulbs from burning out.

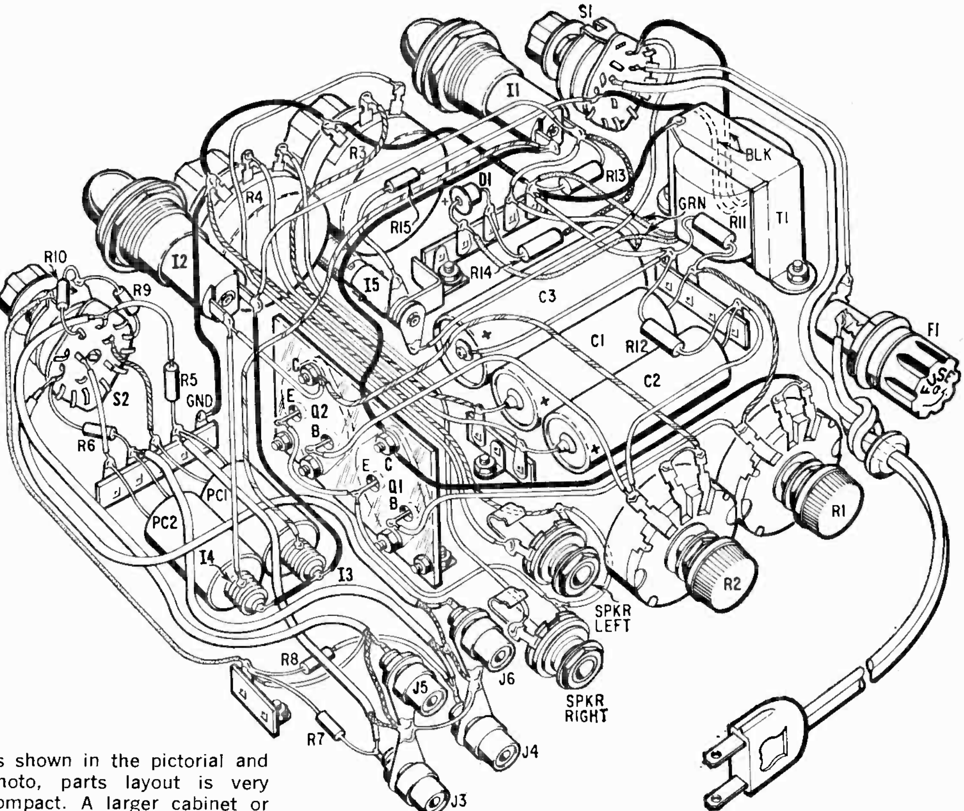
Photocells *PC1* and *PC2* are placed next to lamps *I1* and *I2* respectively, and vary in resistance from almost infinity when the lamps are dark to a few hundred ohms when they are brightly lighted. For volume expansion, the photocells are switched into the part of a voltage divider circuit in series with the audio source (tuner, phono cartridge, etc.) and the audio amplifier. Resistors *R5* and *R7* in the left channel, and *R8* and *R6* in the right channel, are selected



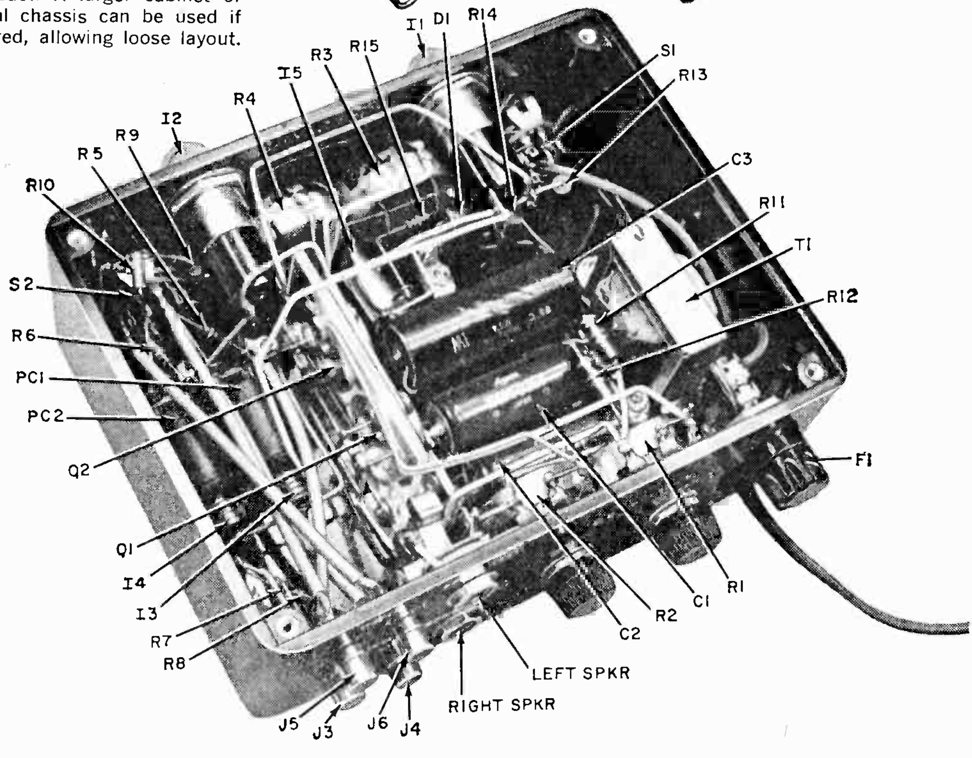
Simple circuit is duplicated for each channel. Basically, it consists of a transistor amplifier that drives a pilot bulb. Photocell for each channel is in a voltage divider circuit which changes value as the light falling on the cell changes.

PARTS LIST

C1, C2—150-μf., 50-volt electrolytic capacitor
C3—2000-μf., 15-volt electrolytic capacitor
D1—200-PIV, 750-ma. "top hat" silicon diode
F1—½-ampere fuse, type 3AG
I1, I2, I3, I4—#49 pilot lamp (GE)
I5—NE-51H neon bulb
J1, J2—Standard open-circuit phone jack (for speaker connections)
J3, J4, J5, J6—Phono pin jack (single mounting hole type)
PC1, PC2—Cadmium sulphide photocell (Lafayette 19 G 2101 or equivalent)
Q1, Q2—2N554 power transistor (Motorola) or equivalent
R1, R2—5000-ohm, 4-watt wire-wound potentiometer
R3, R4—500-ohm, 4-watt wire-wound potentiometer
R5, R6—68,000-ohm, ½-watt, 5% resistor
R7, R8—82,000-ohm, ½-watt, 5% resistor
R9, R10—6800-ohm, ½-watt, 5% resistor
R11, R12—100-ohm, 1-watt, 5% resistor
R13—56-ohm, 1-watt, 10% resistor
R14—6.8-ohm, 1-watt, 10% resistor
R15—22,000-ohm, ½-watt, 10% resistor
S1, S2—4-pole, 3-position rotary switch (Lafayette 99 G 2002 or equivalent)
T1—Filament transformer, 6.3 volts @ 1 ampere
1—Bakelite cabinet (Lafayette 19 G 2002, 2¼" x 5¼" x 6¾", or similar)
1—Panel for cabinet above (Lafayette 19 G 3702)
2—Panel lamp assemblies for I1 and I2 (Dialco 930 series less resistor or equivalent)
1—Bayonet-type bulb holder for I5
1—Fuse holder for 3AG fuse
1—Length of polystyrene tubing, ¾" o.d., ⅝" i.d. (Lafayette 13 G 5126 or equivalent)
1—⅛" polystyrene sheet cut to 1¾" x 2¾" for mounting Q1 and Q2
Misc.—Rubber grommets, terminal strips, 6-32 x ¼" hardware, knobs, wire, shielded cable, a.c. line cord, small brackets for mounting Q1-Q2 mounting board, cement, tape, plastic lens for I5, etc.



As shown in the pictorial and photo, parts layout is very compact. A larger cabinet or metal chassis can be used if desired, allowing loose layout.



to give the desired amount of expansion—about 6 db in this case—as the resistance of *PC1* and *PC2* changes. Voltage relationships for expansion can easily be seen in the curve below. With the unit in the "out" position (*PC1* and *PC2* out of the circuit), any increase in audio input results in an equal increase in output as shown by the straight-line "out" curve.

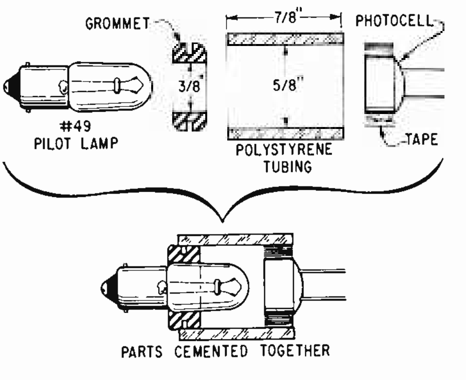
In the "expand" position, a small increase in the input causes a large increase in output, and this *unequal* change in voltages is where expansion occurs. Did we get something for nothing? No, because the output was 6 db less than the input to start with (6 db is the "line" or insertion loss of the unit), but the amplifier doesn't know this. On "expand," it sees the output only as a fast rising voltage.

For compression, *PC1* and *PC2* are switched into voltage dividers that now include *R9* and *R10* as well as *R5* and *R7* and *R6* and *R8*. Here, *PC1* and *PC2* are connected in parallel across the audio source in combination with *R9* and *R10* respectively. As shown by the "compress" curve below, a large increase in input results in a small increase in output. This unequal change is where compression occurs, to a maximum of 15 db. The amplifier now sees the output as a slowly rising voltage.

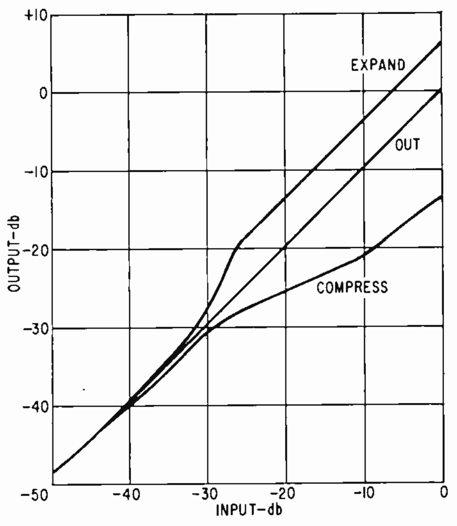
The amount of expansion is determined by the size of resistor *R5* with respect to resistor *R7*, and the size of *R6* with respect to *R8*. If *R5* and *R6* are made larger, more expansion may be obtained; if they are made smaller, less expansion will result. On "compress," smaller values for resistors *R9* and *R10* will give more compression; larger values will give less.

Construction. Although a metal chassis can be used for the compressor-expander, a Bakelite instrument case was selected for ease of construction—it can be drilled and filed much like wood—and compactness. Place drafting tape on the front and rear of the case and use a pencil to locate holes to be drilled. Larger holes should be filed or reamed as large drills can cause chips around the hole being cut.

Mount the components using lock washers on the inside to prevent slippage on the smooth Bakelite. The power transistors do not require a heat sink in this application and are mounted on a piece of clear polystyrene. If transistors *Q1* and *Q2* are mounted on a metal



Photocell-pilot lamp assemblies—one for each channel—are constructed as detailed here (see text).



Hirsch-Houck laboratory curve shows 6 db expansion and a maximum of 15 db compression for P.E. unit.

chassis, insulation must be used between them and the chassis.

Assembly of the two photocell-lamp units is easy. As shown on page 45, cut a ⅞" length of ⅝"-i.d. polystyrene tubing for each. Push a #49 lamp into a ⅜" grommet and insert the grommet and bulb into one end of the tube. Wrap ¼" wide tape around each photocell, using enough so they will fit smoothly in the ends of the tubes opposite the bulbs. Cement each assembly in place. Both of the assemblies should be painted black so that external light won't affect the resistance of the photocells. To make sure they are light-tight, measure the resistance of the photocell-lamp assemblies in normal reading light—if it's less than one megohm, check for leaks. Caulking compound is a good material for sealing leaks around the bulbs and photocells.

Wiring the Unit. Two separate grounding systems are used in the compressor-expander to avoid possible hum loops in the amplifier to be used with it. The speaker ground leads and power supply ground form one system; the shielded leads for the input-output circuit and photocell section form the other system.

Wiring is straightforward. Use different colors of wire for leads associated with the left and right channels to make checking the circuit easy; use shielded wire for the input-output circuit connections. Polarity of *D1* and *C1*, *C2* and *C3* must be observed.

Care should be taken when soldering to the lugs of the germanium power transistors, which can be easily damaged by heat from the soldering iron. Use a heat sink between the solder joint and the body of the transistor, or use a transistor wafer socket. If a wafer socket is used, the leads can be soldered to the socket prior to pushing over the transistor lugs. This will make it possible to avoid direct soldering to the transistor.

Resistors associated with the input-output circuit should be accessible as you may want to experiment with the amount of expansion and compression in the future.

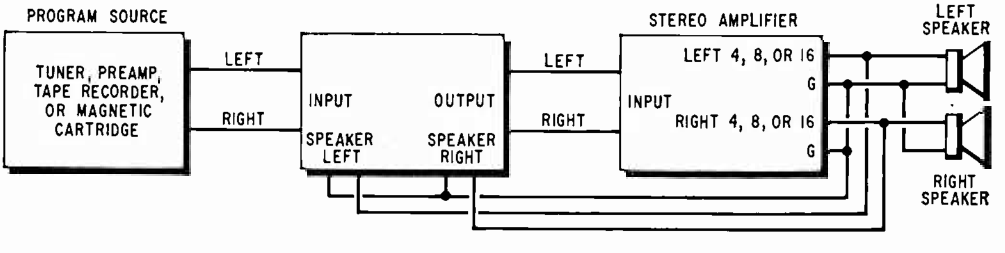
As finishing touches, add rubber feet to the cabinet, and label the controls with decals.

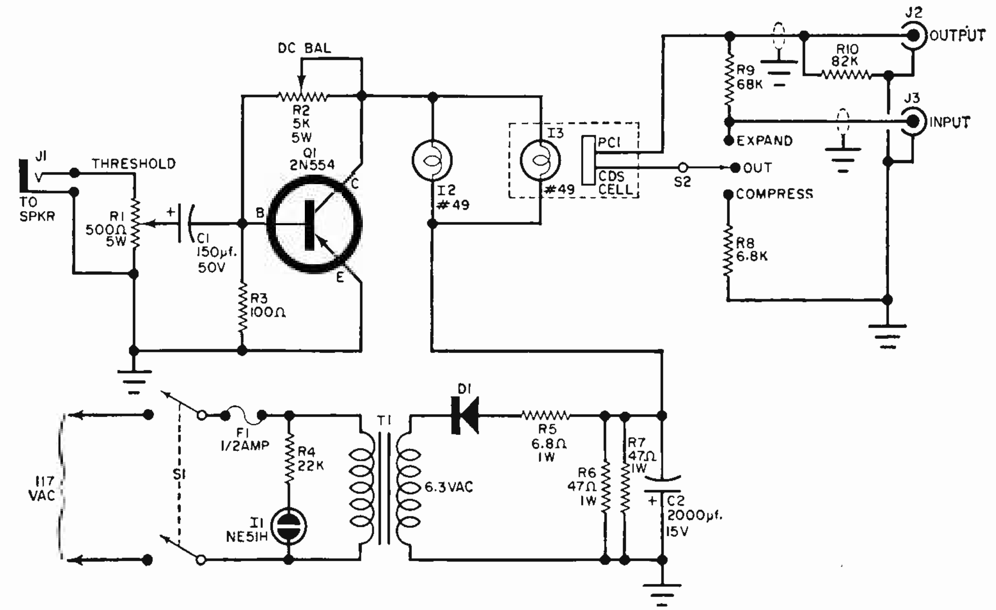
Hookup and Final Adjustments. Connect the compressor-expander into your stereo system as shown in the drawing below. The amplifier input impedance should range between 50,000 ohms and 1 megohm. The transistor portion of the circuit must be connected to the power amplifier speaker terminals; be sure to connect the ground of the speaker terminals to the ground of the transistor circuit. The input-output circuit can be connected between the preamp output-power amp input, tuner or tape recorder output-preamp input, or the magnetic cartridge output-preamp input.

To use the compressor-expander, turn it on and set the amplifier volume control to zero. Adjust the d.c. balance controls (*R1* and *R2* at the rear of the case) so the corresponding front panel lamps, *I1* and *I2*, just go out. Next, set the front-panel threshold controls, *R3* and *R4*, to maximum clockwise and turn up the amplifier volume to a normal

> **HIRSCH-HOUCK REPORT**
>
> The 6 db expansion was definitely more pleasing than the 8.5 db of a comparable commercial unit. The compression was more than adequate. Under conditions of compression or expansion there was no high-frequency loss. The unit was easy to install and adjust, and did all that could be expected. Well planned and constructed . . .

Simply connect compressor-expander between audio source and amplifier.





Circuit diagram of the compressor-expander for monophonic use. See text below.

listening level. Expansion or compression can then be selected.

Optimum setting of the threshold controls has been found by the author to vary from one type of program material to another. On the average, they are set to produce full illumination on the loud parts and no illumination on the soft parts.

Special Notes. The compressor-expander can be used between a magnetic cartridge and preamplifier when no other connections are possible. If it is necessary to use the compressor-expander in this fashion, provision must be made to reduce the possibility of a.c. hum pickup. This is done by cementing a piece of kitchen aluminum foil to the bottom of the Bakelite case underneath the photocell assembly. The foil is grounded internally through the flathead screw that holds the assembly in place. Care must be taken that no other screws are connected to the aluminum foil to form a "ground loop."

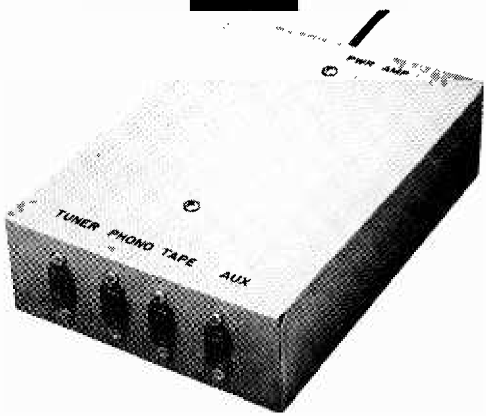
There are a few stereo amplifiers on the market that do not have a common speaker ground connection. These amplifiers are generally transistorized and present an unusual problem when connected to the compressor-expander. The amplifier can be permanently damaged if the stereo channels are coupled together through the compressor. The only safe solution to the problem of using amplifiers lacking a common speaker ground with the compressor-expander is to construct the compressor-expander with two separate power supplies. In effect, the builder would assemble two monophonic versions of this circuit and each channel would have its own ground to each speaker—thus removing the coupling between the channels through the common power supply.

The circuit diagram for either a strictly single channel (monophonic) version of the compressor-expander or one of the two identical stereo units for speaker isolation is shown above. The only circuit change between this version and the stereo version on page 55 (except parts numbering) is that R13—the power supply bleeder—becomes two resistors (R6, R7) to compensate for the increased supply voltage when the second channel power demands are removed.

Needless to say, whichever version of the unit you build, it will greatly enhance your listening pleasure. -30-

For less than $15 you can build real convenience into your hi-fi stereo system

Build Hi-Fi INTERLOCK



By CHARLES J. ULRICK

IN THIS AGE of automation, it's ridiculous to have to throw more than one switch to accomplish one ultimate function. If, for example, you want to listen to a record, why should you first have to turn on the phonograph, then the amplifier? With the "Hi-Fi Interlock," turning on the phonograph (or the FM tuner or the tape recorder) also turns on the amplifier. An auxiliary benefit accrues in that turning *off* the primary device also turns off the secondary, or controlled device, preventing the possibility of leaving the amplifier on all night to cook up lots and lots of heat.

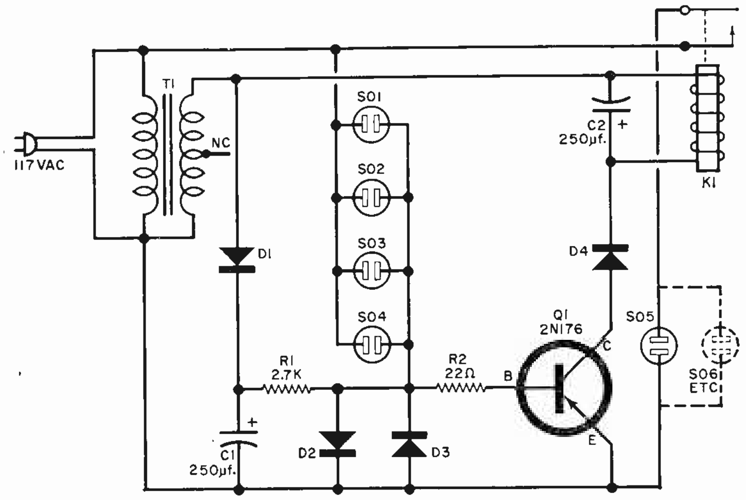
How It Works. Diodes *D2* and *D3* are connected back-to-back in series with sockets *SO1* through *SO4*, and then across the a.c. line. A load applied to these sockets will cause a voltage drop in the diodes, activating the relay-controlling circuit at *Q1*, and causing relay *K1* to pull in and apply full 117-volt a.c. to socket *SO5* where the controlled devices are connected.

When a load is applied at sockets *SO1* through *SO4*, diode *D2* or *D3* will conduct (one or the other, depending on the a.c. polarity at the time), providing a negative base voltage for transistor *Q1*. This base is normally held positive by the bias supply formed by diode *D1*, capacitor *C1* and resistor *R1*. Diode *D2* limits the voltage to 0.75 volt. Resistor *R2* is used to limit base current, and capacitor *C2* is used as a filter for the half-wave d.c. that is applied to relay *K1* by transistor *Q1*.

Mounting the Components. All of the components are mounted in a small, open-end chassis. While parts placement is not critical, you can obtain a general idea of the arrangement the author used by examining the pictorial diagram on page 60.

Mount the larger components first—the transformer, relay, and transistor. Next mount diodes *D2* and *D3*, then the

Devices plugged into sockets SO1 through SO4 will control voltage at socket SO5. If your record player doesn't draw sufficient current to trip this circuit, wire a 7-watt light bulb across phono motor; another solution is to slightly increase value of R1.



PARTS LIST

C1, C2—250-µf., 12-volt electrolytic capacitor
D1, D4—400-PIV, 750-ma. silicon rectifier
D2, D3—200-PIV, 12-amp. silicon rectifier (Allied Radio Stock No. 39 A 926-D or equivalent)
K1—S.p.s.t. relay, 6 volts d.c., 10-amp. contacts (Guardian IR-505-A6 or equivalent)
Q1—2N176 transistor
R1—2700-ohm, 2-watt resistor
R2—22-ohm, 2-watt resistor
SO1-SO5—Chassis-mounting a.c. receptacle
T1—Filament transformer: primary, 117 volts a.c.; secondary, 6.3 volts a.c. @ .6 amp
1—2" x 5" x 7" aluminum chassis
1—1¾" x 3¼" x 5" aluminum open-end chassis
14—½" standoff insulators
Misc.—A.c. line cord and plug, rubber grommet, assorted wire, hardware, solder, etc.

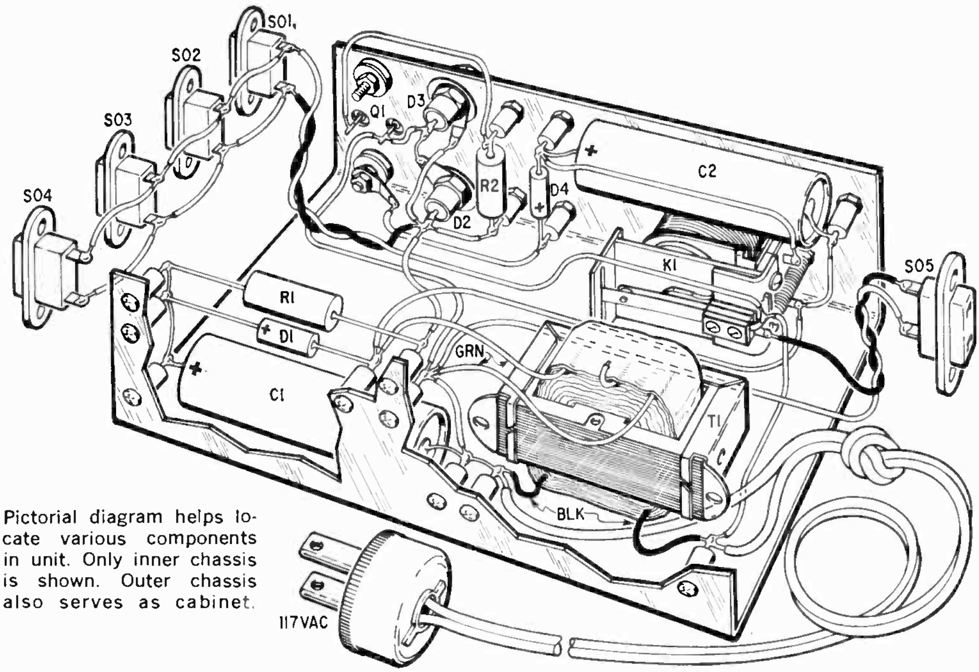
standoff terminals. Transistor *Q1* and diodes *D2* and *D3* should be mounted on the mica forms supplied as mounting kits for these components.

Drill two holes in the base of the open-end chassis in order to mount it on the larger chassis. Use the small chassis as a template to locate the mounting holes in the larger chassis before proceeding with the wiring.

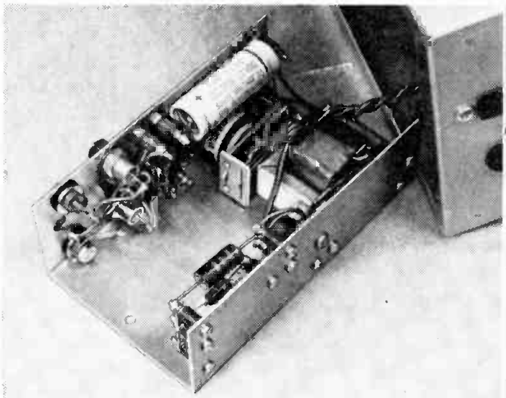
Because transistor *Q1* must go on during the negative half-cycles of the a.c. line, the transformer voltage must also be negative at that time to turn it on. To phase the transformer, connect a secondary lead to a primary lead and apply 117 volts a.c. across the primary. Measure the voltage at the open secondary and primary, and if it is higher than the 117 volts, untwist the two transformer leads you connected together, and substitute the other secondary lead. Be sure to remove the primary voltage while making these tests. When the transformer is properly phased—resulting in a voltage *lower* than the line voltage—solder the leads.

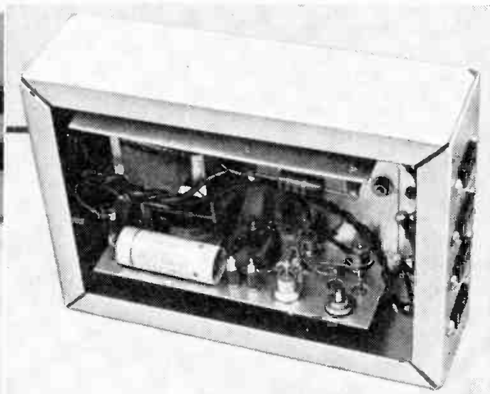
To insulate diodes *D2* and *D3*, drill larger holes than are required for the mounting studs. A pair of mica washers above and below the hole will keep the diodes from touching the chassis. Transistor *Q1* must also be insulated from the chassis, and in addition to using oversize holes for the two terminals, it will be necessary to insulate the transistor case as well. Toward this end, a mica sheet is placed under the transistor, and fiber shoulder washers are used for the mounting screws. After *D2*, *D3* and *Q1* have been mounted, an ohmmeter should be used to check for continuity to the chassis. If such continuity is present, additional adjustments in positioning are indicated.

Drilling and Wiring. The larger chassis also serves as a cabinet for the unit. The two mounting holes that were marked are first drilled, and then additional holes for the line cord and a.c. sockets are marked off. A hand nibbler is a great help in cutting the square-cornered holes for the sockets. Do not mount the sockets or the small chassis until after



Pictorial diagram helps locate various components in unit. Only inner chassis is shown. Outer chassis also serves as cabinet.





After wiring, subchassis (above, left) is installed in larger chassis and fastened in place.

the unit has been tested and is working properly.

Following the schematic diagram, carefully wire the small subchassis, twisting the wires to the sockets before soldering them into place. Before wiring the line cord into place, knot it so it will act as a strain relief.

Be sure to deburr all mounting holes to guarantee proper fit. This can best be accomplished by the judicious use of a ½" or ¾" twist drill, gently rotated by hand.

Using the Interlock. To install the interlock in a high-fidelity stereo system, plug the various controlling units into sockets *SO1* through *SO4*. The interlock is then plugged into a wall outlet and the unit to be controlled is connected at *SO5*. If it is necessary to control more than one unit, a cube-tap can be connected to *SO5*, or more sockets can be added. Other applications for the interlock will be found in the ham or CB shack, or wherever remote or automatic power switching is needed. —30—

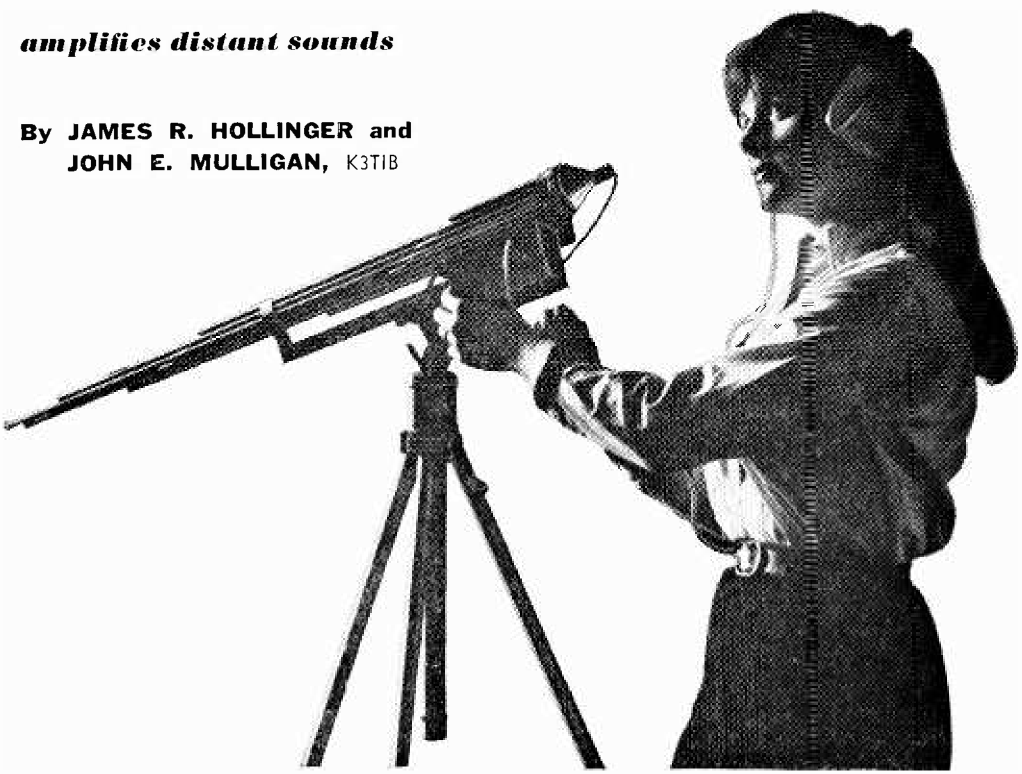
Build the SHOTGUN SOUND SNOOPER

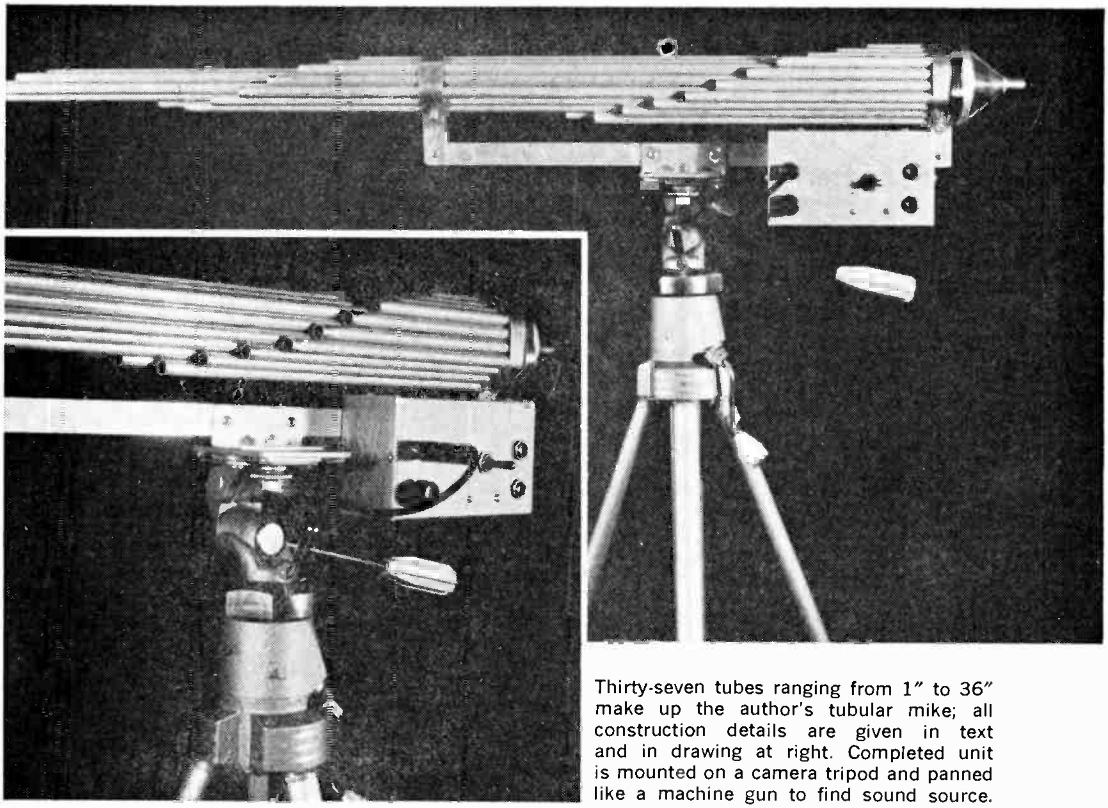
Operating on "organ pipe" principles, this amazing tubular microphone amplifies distant sounds

By JAMES R. HOLLINGER and JOHN E. MULLIGAN, K3TIB

ONE WINDY DAY last fall, the authors hustled a skeptical friend out into a field bordering on a wooded area to test a homemade long-range tubular microphone. Waiting until the friend had crossed the field and disappeared completely, we panned the mike toward the spot where he had last been seen. At first only the sounds of birds were heard; then, on the last swing, came the sound of crashing brush and a voice mumbling "Mary had a little lamb." When we told him later that we had enjoyed his nursery rhyme, he looked at us incredulously. At a range of 250 yards, under adverse wind conditions, we had picked his voice out of the woods!

The tubular microphone, one of the less publicized but one of the most spectacular long-range listening devices, might be described as a bundle of open-end tubes designed to pick up and amplify sounds of different frequencies by virtue of different tube lengths. The principles involved are familiar: In re-





Thirty-seven tubes ranging from 1″ to 36″ make up the author's tubular mike; all construction details are given in text and in drawing at right. Completed unit is mounted on a camera tripod and panned like a machine gun to find sound source.

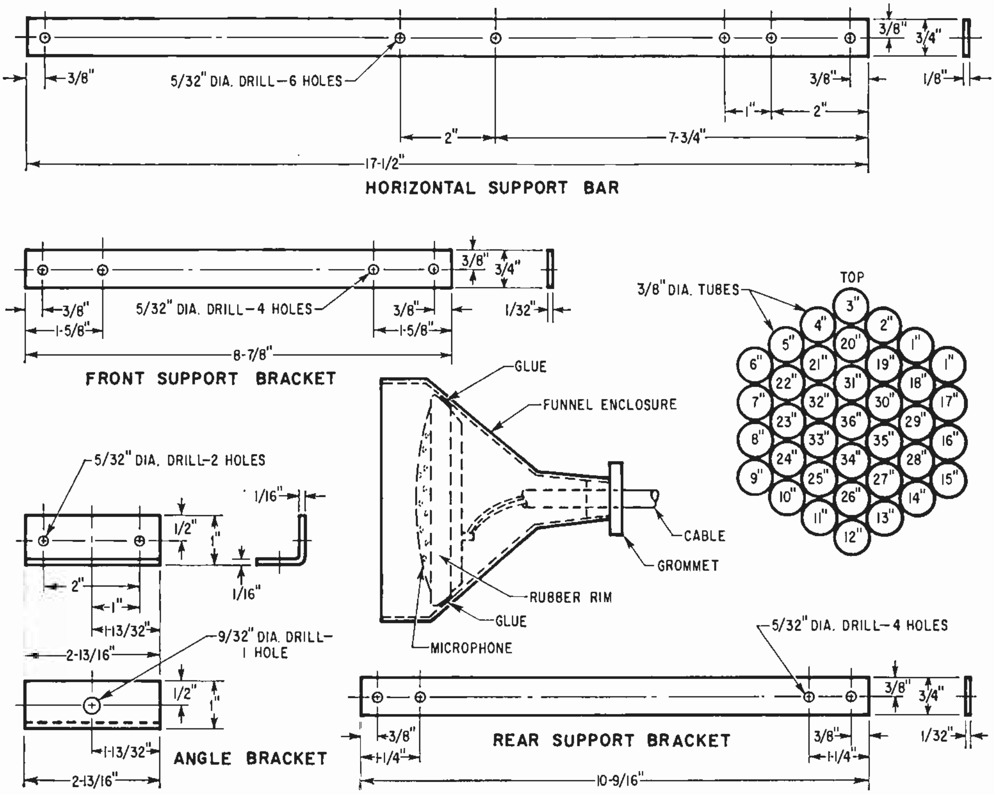
sponse to sounds of various frequencies, the air columns within each tube vibrate and, in doing so, amplify the original sounds.

Applications of the tubular mike, which has far greater sensitivity, better frequency response, and superior directional characteristics than parabolic types, are many. Bird and animal watchers are delighted with the added dimension of sound when it is applied to nature studies. Small boat operators may find the unit of value as a navigational aid, especially in fog or conditions of poor visibility. The tubular mike can pick up conversations from busy streets, and under the right conditions, can actually pick up conversation through closed windows 40 or more yards away.

Design and Construction. As you might assume, tubes are cut to resonate over a specific range of frequencies. To calculate tube length, first find wavelength by dividing the speed of sound (1100 feet per second for practical purposes) by the frequency. For example, the wavelength of 256 cycles equals 1100 ÷ 256, or 4.296 feet. *Tube length,* however, is half this, or 2.14 feet, since tubes open at both ends resonate at a wavelength twice as long as their length.

In designing a tubular mike, it is necessary only to assemble enough tubes to cover the frequency range of sounds you want to hear. The exact number of tubes is not critical, but should be the greatest number that can be efficiently covered by the microphone element. The range of tube lengths may vary too. Some builders may wish to use tubes longer than those suggested here for increased pickup of the lower frequencies. The graduated lengths should be stepped evenly from the shortest to the longest so frequency nulls are avoided.

The "Shotgun Sound Snooper", designed for portability, is built with 37 aluminum tubes, 3/8″ O.D., ranging from 1″ to 36″ in length, and graduated in 1″ steps. The 37th tube is an extra 1″ length added to complete the hexagonal symmetry of the pickup. The tubes can be conveniently cut from ten 6′ lengths, using a tubing cutter or fine-tooth hack-



Easily worked aluminum is used for fabricating the pickup. The tubes can be conveniently cut from ten 6′ lengths of 3/8″ diameter stock, the support brackets from a sheet or strip of 1/32″ aluminum. The horizontal support bar is made from heavier s‘ r‘. Angle bracket mounts to standard camera tı l.

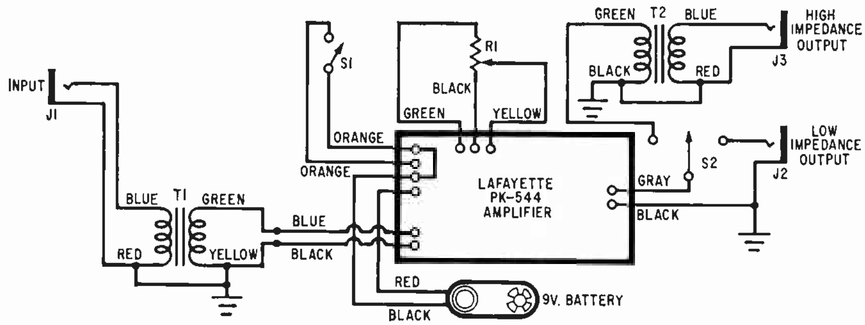
BILL OF MATERIALS FOR MICROPHONE

- *1—56′ length of 3/8″-O.D. aluminum tubing (ten 6′ lengths preferable)*
- *1—Crystal microphone cartridge, approx. 2 1/8″-diameter (Lafayette PA-27 or equivalent)*
- *1—Household funnel, 2 3/4″-diameter (or equiv.)*
- *1—3/4″-wide, 1/32″-thick aluminum stripping for support brackets, battery bracket (approx. 2′ required)*
- *1—3/4″-wide, 1/8″-thick aluminum strip for horizontal support bar (approximately 1 1/2′ lengti required)*
- *1—Standard camera tripod*
- *Misc.—Glue (fast-drying rubber base contact cement or epoxy glue), 8-32 machine screws and nuts, rubber grommet, microphone cable solder, etc.*

saw. Dress the edges with a fine file to remove burrs. Assemble the tubes as shown in the drawing above, starting with the 36″ length and gluing the 35″ tube to it for the entire length. The authors used fast-drying rubber base cement, but epoxy glue can be used for greater strength. In any case, be sure the tubes are flush at one end by checking each one against the others as you glue them in place. Don't worry about the spaces between the tubes; they simply become air columns.

Cut and drill the front and back support brackets from easily worked 1/32″-thick aluminum as shown in the dr ings. The brackets are shaped aroı the tubes to form a tight fit; it will l if you bend each one at the exact ceı to form a slight V before you shape Make the horizontal support bar fı 1/8″ aluminum as shown, and cut of piece of aluminum angle to form the gle bracket.

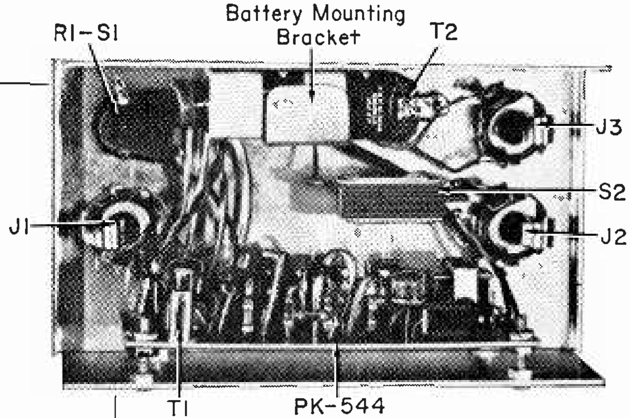
Cartridge Mounting. The microph cartridge enclosure is made from a 2 diameter household funnel, but can be improvised from sheet metal. The shape of the enclosure is not important, provided it permits the microphone car-



Wire amplifier and other components as above; T2, S2, J3 are optional.

AMPLIFIER PARTS LIST

J1, J2, J3—Standard open-circuit phone jack
R1—10,000-ohm miniature potentiometer with s.p.s.t. switch S1 (Lafayette 32-G-7364 or equiv.)
S1—Part of R1
S2—S.p.d.t. toggle switch
T1—Transistor input transformer; 200,000-ohm primary, 1000-ohm secondary (Lafayette 99-G-6034 or equivalent)
T2—Transistor output transformer; 2500-ohm primary, 11-ohm secondary (Argonne AR-114 or equivalent)
1—Lafayette PK-544 5-transistor audio amplifier or other high-gain amplifier
1—9-volt transistor battery (Burgess 2U6 or equivalent)
1—Aluminum box, approximately 2 1/8" x 3" x 5 1/4" (LMB #136 or equivalent)
1—Miniature knob (Lafayette 32-G-2405)
1—18" length of single-conductor shielded microphone cable
1—Set of headphones, high or low impedance
Misc.—4-40 x 5/8" machine screws and extra nuts, scrap aluminum, contact cement or epoxy glue, wire, solder, etc.



Follow parts placement indicated (unit is inverted in this photo) to avoid possible feedback problems.

tridge to be mounted very close to the ends of the tubes. Hold the wide end to the tube cluster and mark the sides to indicate the corners of the hexagonal shape. Place the funnel on a smooth, solid surface, and make dents at each of the six corners of the hexagon with a small ball peen hammer. With the flat head of the hammer, flatten the areas between the indentations for about 1/4" in from the edge of the funnel. Place it over the end of the tube cluster and peen again if necessary. A tight sliding fit is desirable, but a loose fit can be remedied with tape.

As shown in the drawing on page 63, the rubber-rimmed microphone cartridge is mounted in the funnel with glue. It is important at this point to make sure the cartridge will position as close as possible to the ends of the tubes without actually touching them when the enclosure is fitted to the tubes. The cartridge must be insulated from the enclosure, either by the rubber rim which is part of the recommended cartridge, or by some equivalent means. The space behind the microphone element may be packed with a sound insulating material such as glass wool or foam plastic to help reduce pickup from the rear. Before placing the cartridge, first connect a length of mike cable and install a rubber grommet in the small end of the funnel; apply glue to the rubber rim of the mike cartridge and to the funnel. Press the cartridge into the funnel, truing it up and clamping it into position until the glue is dry.

Final Assembly. Place the rear support bracket over the tube cluster 1/4" forward of the flush end and tighten it onto the

(*Continued on page* 144)

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CHAPTER 3

THE FABULOUS DIODES

Throughout the past 11 years, the publishers of POPULAR ELECTRONICS and the ELECTRONIC EXPERIMENTER'S HANDBOOK have presented numerous basic articles on such diverse subjects as transistors, transformers, automotive electronics, CB, etc. The article on the following 16 pages is about germanium and silicon diodes. It is a capsule summary of the numerous applications of diodes, how this new breed of diodes operates, and the strange names they bear. Your Editors would appreciate your comments on articles of this type and votes on whether these articles should or should not appear in the ELECTRONIC EXPERIMENTER'S HANDBOOK in the future.

Many electronics experts agree that the usefulness and versatility of the diode will—within another three years—exceed that of the transistor

By LOUIS E. GARNER, Jr.

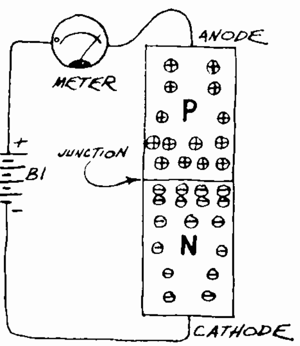
Since the transistor is only a little over a decade old, many hobbyists—and especially newcomers to electronics—feel that *all* semiconductor devices are quite young. The truth of the matter, however, is that the semiconductor diode is one of the *oldest* of radio-electronic components, predating even the venerable electron tube as a widely used device.

A majority of the early radio receivers employed a crude type of point-contact diode as their detector—essentially, a small piece of galena (a crystalline lead sulphide mineral) to which contact was made with a fine wire dubbed a "cat's-whisker." Unreliable, of varying sensitivity, and time-consuming to adjust, this early semiconductor device was widely used, and often cursed. It was, in fact, the search for a superior detector that led to the development of the electron tube.

While the semiconductor diode was eclipsed for a while by the electron tube and, to some extent, fell into disuse and was forgotten, the success of the transistor has brought the device back into its own—but not as the unreliable, finicky, open-air, and ugly galena crystal. Instead, the modern diode comes in thousands of types and styles and is indeed a fabulous creation. Like the phoenix, it has been reborn, but with more vigor, reliability, and versatility. In addition to its ability to detect radio frequencies, the modern diode—in some of its forms—has acquired the additional capabilities of amplification and oscillation.

By definition, a diode is a two-electrode device. However, many modern diodes have three and even four terminal connections. While these multi-electrode devices are still diodes as far as their basic operating characteristics are concerned, the addition of extra electrodes permits the devices to perform some new and, as we shall see later, rather interesting feats of electronic wizardry.

How Diodes Work



Diodes are essentially a junction of *p*- and *n*-type semiconductor materials. The diode derives most of its capabilities from its nonlinear, unidirectional electrical characteristics, i.e., its ability to conduct freely in one direction while acting as a high resistance or open circuit in the opposite direction.

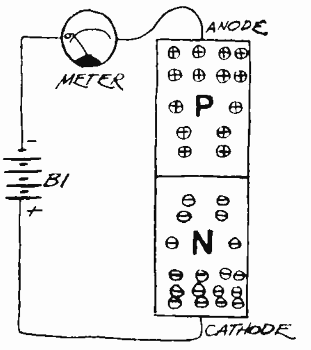
The *p*-type material has a surplus of more or less evenly distributed positive-charged "holes." The *n*-type material has a surplus of evenly distributed, negative-charged free electrons. Suppose that a battery or other d.c. voltage source were connected in series with the meter and diode, so that a positive voltage would be applied to the *p*-type material and a negative voltage to the *n*-type. Under these conditions, the positive holes would be repelled by the positive voltage and would migrate towards the junction. At the same time, the free electrons in the *n*-material would be repelled and accumulate near the junction.

Thus, a surplus of positive and negative *current carriers* would accumulate at the junction, with a certain percentage "spilling over" into the opposite materials. Holes would migrate into the *n*-type material, where they would be absorbed and become neutralized by the surplus free electrons. At the same time, electrons would enter the *p*-type material, neutralizing holes there. New holes and electrons would be created by the applied d.c. potential and these, in turn, would migrate towards the junction. The result, then, would be a heavy flow of current, as indicated on the meter. The diode, under such conditions, is said to be biased in its *forward* (or conducting) direction.

Let's consider the opposite situation now. With the battery voltage reversed, the positive holes accumulate at the negative terminal, while the free electrons gather at the positive terminal. The junction region is depleted of current carriers and, therefore, there can be no "carry-over" through the junction. Under these conditions, current flow is very low and the diode acts as a high resistance. It is biased in its *reverse* (or nonconducting) direction.

Going a step further, let's see what happens when the supply voltage is increased with the diode reverse-biased. At this point, we must remember that while there are a *majority* of holes in the *p*-type material there are also a few free electrons present (these are called, appropriately, *minority* current carriers). By the same token, there are a few positive-charged holes in the *n*-type material.

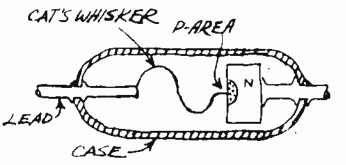
As the electrical pressure (voltage) is increased, these minority carriers start to accumulate in the junction area. Eventually, a certain amount of "carry-over" can take place, and the diode switches rapidly from a nonconducting to a conducting condition. In a way, we can say that the junction has "broken down." The diode current increases very suddenly and, unless there is something to limit current flow (such as a resistor in series with the battery), the diode will be destroyed. The voltage at which this reverse breakdown occurs is called the *zener* voltage.



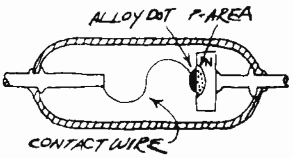
How They Are Made

Diodes are manufactured using essentially the same techniques that are employed in producing transistors. Thus, we have point-contact, alloyed-junction, grown-junction, mesa, planar, and epitaxial types. (Refer to "Transistors—Types and Techniques," POPULAR ELECTRONICS, November, 1962, page 65.) The same types of semiconductor materials are used, including *n*- and *p*-doped germanium and silicon. In addition, some diodes are manufactured of intermetallic and metallic compounds, including copper oxide and sulphides, cadmium sulphide, gallium arsenide, and various selenium compounds.

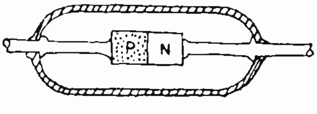
Physically, small diodes can be mounted in plastic, glass, metal or ceramic cases, while larger types can be assembled on flat plates, on cooling fins, or in electron tube-shaped envelopes. Externally, some may appear to be resistors or capacitors, others look like tiny buttons



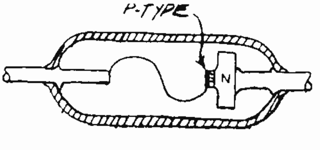
POINT CONTACT.



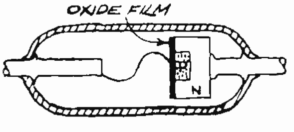
ALLOYED-JUNCTION



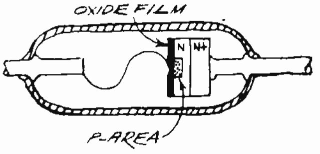
GROWN-JUNCTION



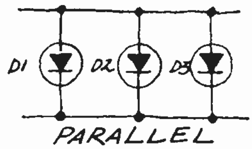
MESA

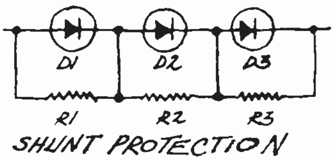


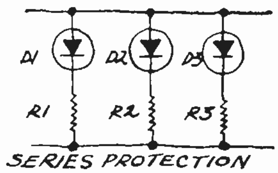
PLANAR



EPITAXIAL





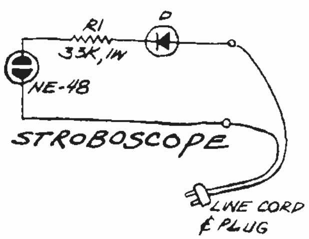


similar to a mercury cell battery, while still others seem to be transistors, for they are assembled in similar cases.

Aside from basic electrical specifications and materials of construction, there are many, many types of diodes. Some are designed for operation in their zener region . . . others are light-sensitive . . . still others have a variable capacitance characteristic. While most are single-junction devices, there are multilayer, multijunction types. Special schematic symbols are used to identify these different types.

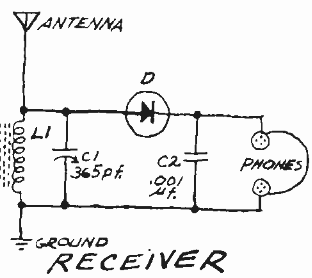
Where greater voltage or current handling capability is needed than is available in a single diode, several units can be connected in series or in parallel. The series connection is used where higher voltages must be handled, while the parallel connection is used to increase current carrying ability. A straightforward series or parallel connection can be employed where the individual diodes have virtually identical characteristics. If the diodes' characteristics are not identical, however, the voltage (or current) distribution may be such that one or more of the diodes are destroyed. To avoid this, shunt or series resistors can be employed to equalize voltages (or currents). Shunt resistors are used when the diodes are connected in series, series resistors when the diodes are wired in parallel.

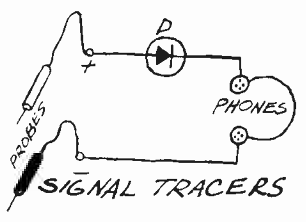
General-Purpose Diodes

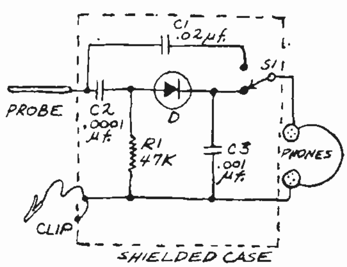


Manufactured of germanium, silicon or selenium, and designed for a broad range of circuit applications, general-purpose diodes are identified by the basic diode schematic symbol. A line represents the cathode, while the anode is identified by an arrowhead. This symbol derives from the original point-contact diode, with the arrowhead indicating the direction of "classical" current flow—just the opposite of electron flow. The general-purpose types include such popular units as the 1N34 (and 1N34A), 1N38, 1N39, 1N56A, 1N58 and 1N66. In practice, the cathode lead is generally identified by a color-band, polarity marking, or similar symbol on the diode's body.

The adjacent diagrams illustrate typical general-purpose diode applications. Almost any general-purpose diode can be used in these circuits, provided the maximum ratings are not exceeded. Low-voltage types may be used in the receiver circuit, while a high-voltage type should be used in the stroboscope.







ZENER DIODES

Physically, low-power zener diodes look very much like general-purpose diodes. In fact, *any* standard diode can be used as a zener diode. Commercial zener diodes, however, are especially processed and selected for their performance in the zener region. Some zener diodes are manufactured primarily for use as voltage *regulators* and are so designated. Others are selected for close breakdown voltage tolerance and are referred to as *reference diodes*. Since the zener breakdown, when it occurs, builds up with the suddenness of an avalanche, zener types are sometimes called *avalanche* diodes. Finally, some firms manufacture special zener types which they identify as *Stabistors*.

Zener diodes can be series-connected, either to obtain higher voltage ratings or multiple output voltage. A typical *multi-regulator* circuit consists of an unregulated d.c. source, an adjustable current limiting resistor, *R1*, and a chain of zener diodes, *D1*, *D2*, etc. In operation, the regulated *d.c.* voltage available between *any pair* of output terminals is equal to the sum of the zener diode voltage ratings between the two terminals. For example, if *D3* is rated at 3.6 volts and *D4* at 6.8 volts, 3.6 volts will be available between terminals *C* and *D*, 6.8 volts between *D* and *E*, and 10.4 volts between *C* and *E*.

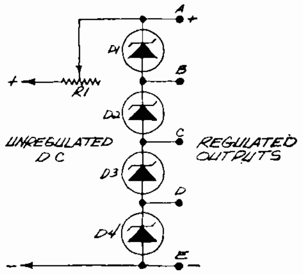
Zener diodes can be used as an *a.c. line regulator*. Two diodes are connected "back-to-back." One breaks down on positive line peaks which exceed its rated value while the other breaks down on negative peaks, in both cases dropping the excessive line voltage across the current limiting resistor.

A *d.c. voltage regulator* circuit is similar to that of the a.c. regulator, except that a single diode is used.

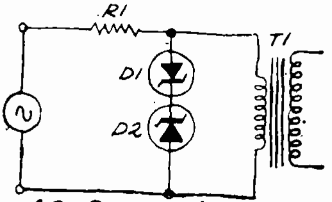
The same principle used in the a.c. regulator can be applied in a simple *square-wave generator* or clipper. The applied a.c. voltage should be from 10 to 20 times the rated zener breakdown voltage for best action and good, sharp output square-wave signals. The series resistor is large enough to protect the diodes from excessive currents. Used in conjunction with an audio generator, this circuit will provide square waves for checking audio amplifiers.

A *voltage-sensitive* relay circuit can be used for remote control applications. In operation, the application of a d.c. voltage below either zener diode's breakdown voltage will have no effect. If the voltage is increased until, say, *D1* 's rating is exceeded, relay *RLY1* will close, but relay *RLY2* (assuming *D2* has a higher rating than *D1*) will remain open. If the voltage is then increased still further, until *D2*'s rating is exceeded, *RLY2* will also close. This circuit is well-suited to applications requiring sequential relay operation with remote voltage control.

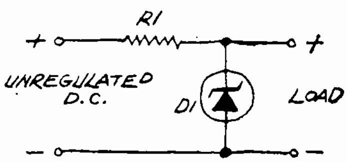
Zener diodes can also be employed in *meter protection*



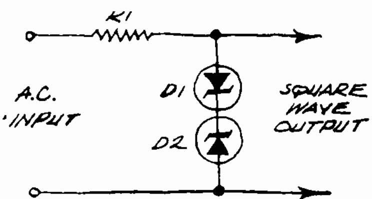
MULTI-REGULATOR



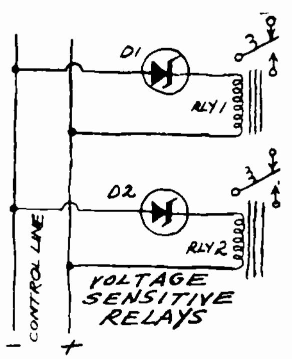
A.C. REGULATOR



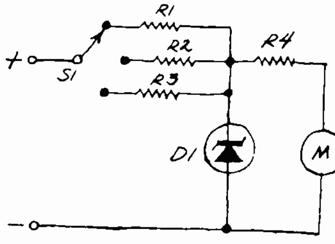
D.C. REGULATOR



CLIPPER



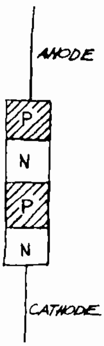
VOLTAGE SENSITIVE RELAYS



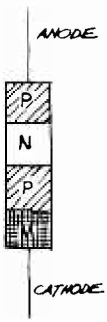
MULTIMETER PROTECTION

circuits. In the circuit shown here, *R1*, *R2*, *R3* and *R4* are the multimeter's multiplier resistors and *S1* is the range switch. The zener diode, *D1*, protects the meter against accidental overload damage. Its rating should be just slightly greater than the voltage required for a full-scale meter reading, but below the meter's maximum rating. Resistor *R4* is chosen so that its resistance, combined with the meter resistance, is considerably greater than the diode's resistance when in a breakdown state.

DIODE SWITCHES



BISTABLE

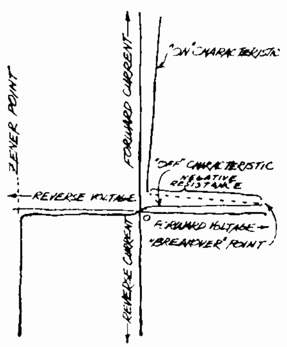


DYNISTOR

A diode switch is analogous to a mechanical switch in that it has two states—"off" and "on." When in an "off" state, it acts like an open circuit; and when "on," it conducts heavily. In practice, both standard and zener diodes may be used as switches by applying a bias voltage to hold the devices in a nonconducting state, then adding a control signal voltage of sufficient amplitude to cause heavy conduction. There are, however, a whole new class of semiconductor diodes and diode-like devices which are specifically designed for use as switches. Included in this class are the *bistable diode, dynistor, silicon-controlled switch, binistor, and double-based diode.*

The *bistable diode* is made up of four alternate layers of *p*-and *n*-type silicon. For this reason, it is also called a *4-layer diode.* In use, the bistable diode does not conduct and remains "off" when biased in its forward direction until the applied voltage reaches a predetermined trigger or "firing" voltage. At this time, the diode switches rapidly into a heavy conducting state, remaining "on" until the applied voltage is dropped to a very low value. When reversed-biased, it behaves very much like a conventional diode, acting as an open circuit until its zener breakdown voltage is reached. (See diagram below.)

Somewhat similar to the bistable diode, except that its basic material is germanium and its fourth layer is metallic rather than *n*-type semiconductor material, is the *dynistor.* The dynistor's forward characteristics are essentially similar to those of the bistable diode, but the unit does *not* block reverse current flow.



The *silicon-controlled switch* (SCS) is a four-layer device closely resembling the bistable diode, but with an electrical connection made to the third layer. A small "trigger" voltage applied to this electrode, called a *gate,* will switch the device from a nonconducting to a conducting state quite rapidly, even though the cathode-anode voltage is below that normally required to trigger. Several versions of this device are offered by various manufacturers. In its basic form, the SCS can only be switched "on" by a gate signal . . . afterwards, it can be returned to its stable "off" state only by dropping the anode-cathode voltage to a low value. Slightly modified forms which can also be switched *off* by the application of a reverse bias to the gate are called *Trigistors* (Clevite-Shockley) and *Transwitches* (Transitron). A germanium version of the device is called a *Dynaquad* by its manufacturer (Tung-Sol).

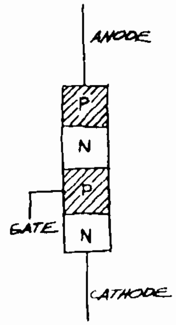
It is possible, of course, to provide an electrical connection for the second as well as the first, third and fourth layers in a four-layer device. In this case, we have another gate electrode and, to differentiate between the two gate connections, the one nearest the anode is called the *anode gate* (G_A), while the one nearest the cathode is termed the *cathode gate* (G_C).

One manufacturer of the four-layer, four-connection "diode" suggests that the anode gate connection be used as an output terminal. The device is then called a *binistor*, and new designations are assigned to each of the electrodes. The anode is called an *injector*, the anode gate a *collector*, the cathode gate a *base*, and the cathode the *emitter*.

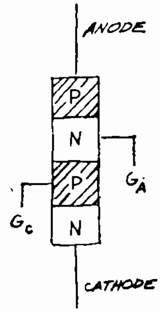
At right is a generalized characteristics curve applicable to the whole "family" of four-layer diodes (except for the dynistor, which conducts when reverse biased). These devices do not conduct appreciably in either their forward or reverse direction until either their zener voltage is exceeded (in reverse bias mode) or their trigger or forward "breakover" point is reached. Once the breakover voltage is attained, the devices switch rapidly to a heavily conducting state, acting as low resistances even at low voltages. The effect of a trigger applied to a control gate is to reduce the anode-cathode voltage point at which breakover occurs. In effect, then, these four-layer switches have three forward states—an "off" state in which they do not conduct, a *transition* state during which they exhibit a negative resistance characteristic, and an "on" state in which they conduct heavily.

There is yet another diode switch, different in construction from the class of four-layer devices we've just discussed—the *double-based diode*, now more popularly known as the *unijunction transistor* (or UJT). This device consists of a bar of *n*-type germanium or silicon with ohmic contacts at each end, designated *Base 1* (B_1) and *Base 2* (B_2), and a *pn* junction slightly off-center. If B_2 is made positive with respect to B_1, the emitter-B_1 junction behaves like a high value resistor . . . up to a point. If sufficient voltage is applied to the emitter-B_1 junction, the device will switch suddenly from a high resistance to a low resistance (virtually a short circuit) state, passing quickly through a negative resistance transition region.

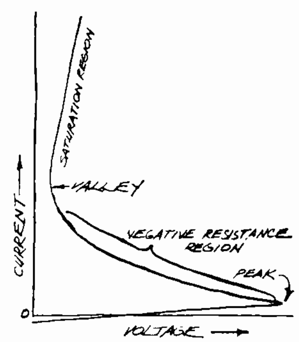
A *relaxation oscillator* circuit employing a bistable diode is shown at right. In operation, the voltage applied by

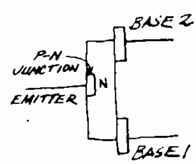


DYNAQUAD

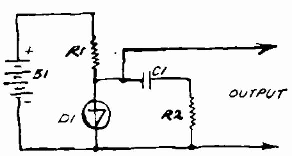


BINISTOR



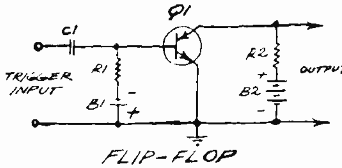


UNIJUNCTION

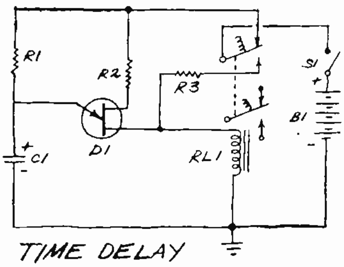


RELAXATION OSCILLATOR

the d.c. source (*B1*) charges the capacitor (*C1*) through series resistors *R1* and *R2*. The bistable diode, *D1*, remains in an "off" or nonconducting state until the capacitor voltage reaches the diode's trigger voltage, at which time the diode switches to a low-resistance conducting state and discharges the capacitor through its internal resistance and *R2*. Then the action repeats itself. In general, the battery voltage is considerably greater that the diode's trigger voltage. Resistor *R1* is much larger than *R2*. Both *R1*, *R2*, and *C1*, are chosen so that their combined time constant is appropriate to the repetition rate (frequency) desired.



The *flip-flop* circuit shown here is similar to those used extensively in computers. A controlled switch such as a Trigistor or Transwitch might be used (*Q1*). In operation, *Q1* is normally in a nonconducting or "off" state, and full battery (*B2*) voltage appears at its upper terminal. If a positive pulse is applied to the device's gate through blocking capacitor *C1*, the device switches to a heavily conducting state, dropping *B2*'s voltage across the load resistor, *R2*, and developing a negative output pulse. The device remains "on" until a negative pulse is applied through *C1*, at which time it reverts to the original "off" state, developing a positive output pulse. Battery *B1* applies a fixed gate bias to the device through *R1* to insure stable operation.



A *time-delay relay* using a unijunction transistor is at left. The relay closes a specified period of time after *S1* is closed, and then remains closed until *S1* is opened to "reset" the circuit. A simple *RC* time constant network is formed by *R1* and *C1* to furnish the delayed emitter voltage which "fires" the UJT. Base 2 voltage is furnished through *R2* and, of course, the upper relay contacts. Once the UJT fires, the relay is pulled in, removing the emitter and base 2 voltages and applying a "holding" voltage to the relay coil through *R3*. The second set of relay contacts is used to actuate an external circuit.

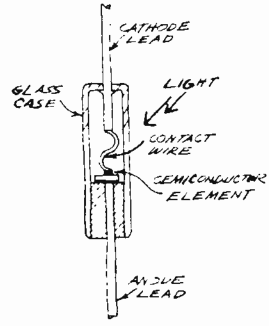
PHOTODIODES

Nearly all semiconductors are sensitive to light. When light strikes the surface of the material, electrons are freed from their valence bonds and, in some cases, positive-charged holes are created. Under the proper conditions, enough electrons may be released so that a small voltage develops. This has led to the development of a large group of light-sensitive semiconductor diodes—or *photodiodes*.

Commercial photodiodes may be divided into three broad groups—*photoresistive* devices, *photovoltaic* devices, and *light-activated switches*.

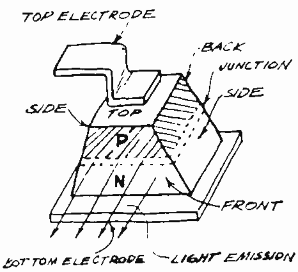
Photoresistive diodes have a resistance inversely proportional to the amount of light falling on their sensitive surface—the stronger the light, the lower their resistance. Any of the standard semiconductor materials, including germanium, silicon, and selenium, can be used for their manufacture, but a good many are made with semiconductor compounds such as cadmium sulphide.

Photovoltaic diodes ("sun batteries") generate a d.c. voltage when light falls on their surface. In general, the amplitude of the voltage developed is proportional to the intensity of the light, up to a maximum fixed by the type of material used in construction, while the amount of current that can be delivered is proportional to the unit's exposed sensitive area. Most present-day photovoltaic diodes use either silicon or selenium as their basic material.



LIGHT ACTIVATED

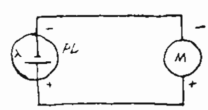
Light-activated switches are similar to four-layer diode switches, except that they are mounted in a transparent glass (or partial glass) enclosure to enable light to reach the junction area. Their operation is similar to that of diode switches, too, but with the gate trigger signal replaced by light energy. The *Photran,* a unique type, has an electrical connection provided for the normal gate terminal, resulting in a three-electrode light-sensitive device.



LASER

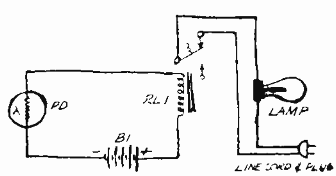
The semiconductor *laser* is a special type of "photodiode" which *emits* light. Typically, these units are made of intermetallic compounds. Such a device may consist of a small *pn* junction of gallium arsenide with the front and back faces cut perfectly parallel to each other perpendicular to the junction plane and highly polished. When heavy current pulses are passed through the device, intense coherent light is emitted perpendicular to the polished surfaces along the *pn* junction. Typical pulse currents may run as high as 20,000 amperes per square centimeter. Electrical-to-light energy diode converters of this type are nearly 100 per cent efficient. The emitted light, for a gallium arsenide diode, is in the infrared region.

The standard *photographic light meter* circuit at right is basically just a photovoltaic diode connected to a sensitive microammeter. The meter scale may be calibrated either in terms of foot-candles or in camera shutter/iris settings.



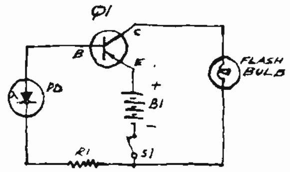
LIGHT METER

The *automatic light switch* consists of a photoresistive diode connected in series with a sensitive relay and a d.c. power source. As long as there is sufficient light on the diode, its resistance is kept low and it passes sufficient current to hold the relay closed. When darkness falls, the diode's resistance increases, reducing relay coil current and allowing the relay to drop out, closing the lamp contacts.

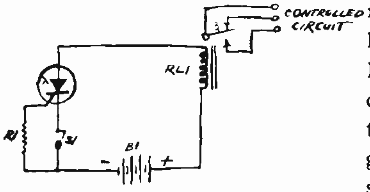


LIGHT SWITCH

Another photographic instrument circuit is a remote *slave flash.* A light-activated switch is connected in series



SLAVE FLASH



LOCK-IN RELAY

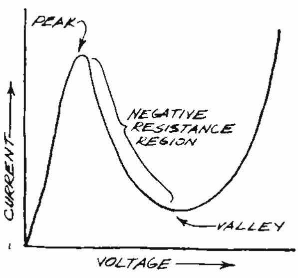
with a current limiting resistor (*R1*), a power source (*B1*), and a power transistor's base-emitter circuit. In operation, light from the main flash triggers the photodiode, causing it to fire and applying a heavy base current to the transistor. The transistor, in turn, conducts heavily, firing the flash bulb. The power switch, *S1*, must be open before a new bulb can be inserted.

A *lock-in relay* uses a Photran with its gate biased by means of *R1*. In operation, the relay remains open until light strikes the Photran's sensitive surface. When this happens, the Photran switches to a conducting state, closing the relay. The relay then remains closed until the power circuit is interrupted (by opening *S1*). This general type of circuit might be used as an automatic switch for, say, a darkroom, or in alarm applications.

TUNNEL DIODES

Sometimes called the *Esaki diode* in honor of its Japanese inventor, the tunnel diode is an extremely versatile device. It is capable of being used as a detector, amplifier, or oscillator, is extremely efficient and, in some types, is useful at frequencies up to 10,000 megacycles or more.

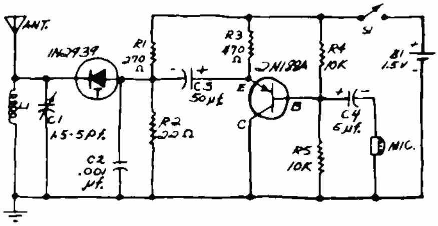
Manufactured from standard semiconductor materials such as germanium as well as from intermetallic compounds such as gallium arsenide, the tunnel diode is basically a *pn* junction, but with the junction depletion region made very thin. The result is that the device is essentially in a "reverse breakdown" condition even when a small forward bias is applied. As the bias is increased, there is an increase in current, up to a point. As the reverse breakdown condition is neutralized, the diode's current *decreases with increasing* voltage until a valley point is reached—afterwards, the tunnel diode behaves much like a conventional diode. A decrease in current with increasing voltage is the basic characteristic of a *negative resistance* (as distinguished from a "positive" resistance, in which current increases as applied voltage is increased). It is this characteristic (negative resistance) which makes the tunnel diode useful as an oscillator.



In a conventional semiconductor device, the current carriers move rather slowly, diffusing through the crystalline structure of the material. In a tunnel diode, the current carriers (electrons, for example) traverse the junction area at what appears to be the speed of light. In effect, when an electron enters the junction, another suddenly appears at the other side, much as if there were a "tunnel" through the junction area (hence the device's name).

A practical *FM wireless microphone* based upon a circuit suggested by GE, is shown below. The resistors are all half-watt units, while *C3* and *C4* are electrolytic capacitors, *C2* a small ceramic disc unit, and *C1* a tiny air variable capacitor. Coil *L1* consists of six turns of No. 16 wire, air-spaced 3/8" in diameter. The antenna is a 4 3/4" length of No. 14 wire, and the microphone is a Shure Brothers No. 420 or equivalent.

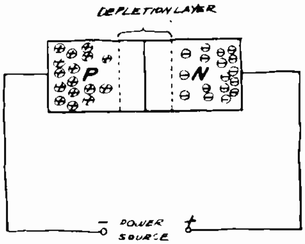
The tunnel diode serves as an oscillator in conjunction with tuned circuit *L1-C1*, with its d.c. operating voltage supplied by voltage divider *R1-R2*. The audio signal obtained from the microphone is amplified and superimposed on the d.c. voltage through coupling capacitor *C3*. This varies the tunnel diode's instantaneous supply voltage in accordance with the audio signal, frequency-modulating the r.f. signal developed by this device.



FM WIRELESS MICROPHONE

CAPACITOR DIODES

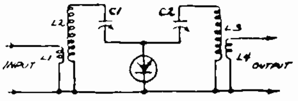
The application of reverse bias to a junction diode will cause the junction area to be depleted of current carriers (electrons and holes) and thus act as a high resistance, insulator or dielectric. There is still an electrical capacitance between the *p* and *n* areas, however. This characteristic of the semiconductor diode has led to the development and production of a variety of voltage-variable semiconductor capacitors. These devices are identified by a variety of names, including *varactor* (for *variable reactor*), *Semicap* and *Varicap*.



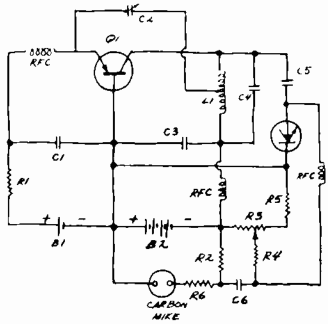
VOLTAGE-VARIABLE DIODES

The operation of a varactor is easily understood. If a semiconductor diode junction is reverse-biased, the central junction area is depleted and acts as an insulator (dielectric). There is always an interelectrode capacity between the *p* and *n* areas. As the reverse bias is increased, the depletion layer expands, reducing the interelectrode capacity. Conversely, as the reverse bias is decreased, the depletion layer shrinks, increasing capacity. Maximum capacity is obtained when the device is operated at zero bias.

Commercial varactors can be made of germanium or silicon and are generally specified in terms of *maximum working voltage*, *capacitance* (at a specific voltage), and typical "*Q*." The latter characteristic indicates the "quality" of the device and is obtained by dividing its reactance



FREQUENCY DOUBLER



FM WIRELESS MICROPHONE

(in ohms) by its equivalent series resistance (in ohms). A Q may range from less than 5 to 100 or more.

In practice, varactors are used for electrical tuning in circuits such as the basic *frequency doubler* shown on page 77 or the *FM wireless microphone* at left.

POWER DIODES

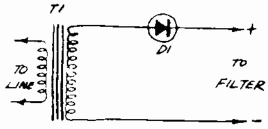
Power diodes are basically similar to small signal diodes. They are manufactured of the same materials, have similar characteristics, and, in general, are produced using the same construction techniques. The chief differences between power and small signal diodes, then, lies in their physical size and actual specifications. Power diodes have larger junction areas in order to pass heavier currents and, in some types, have thicker junctions to permit them to handle high voltages without breakdown. At the same time, the larger junctions mean greater interelectrode capacities and hence limited high frequency capabilities.

As do their smaller cousins, power diodes conduct heavily when biased in the forward direction and block current flow when biased in their reverse direction. Their forward and reverse resistances are likely to be lower than small signal types with, of course, correspondingly higher forward and "leakage" currents. Power diodes are rated and specified in the same general terms as are applied to small signal types—typically, maximum forward current, nominal reverse current, nominal reverse voltage, and peak inverse voltage (PIV).

Rectifier Diodes

Designed primarily for use in a.c.-to-d.c. power supplies, power rectifiers can be manufactured of selenium, germanium, or silicon. A few types are made using copper oxide, copper sulphide, and various magnesium compounds, but these have been largely supplanted by the former types. Since they are intended primarily for power supply use, some types may be specified in terms of *maximum a.c. input voltage, output d.c. volts* and *current* rather than in the more general terms mentioned above.

In a *half-wave rectifier* using a single diode, the PIV is twice the output d.c. voltage or 2.83 times the a.c. input voltage with a capacitive input filter under "no load" conditions; the nominal d.c. output is 1.41 times the r.m.s. (a.c.) input voltage. The ripple frequency (which must be



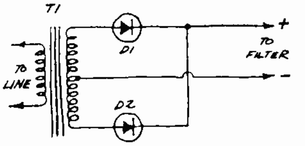
HALF-WAVE RECTIFIER

removed by the filter circuit used) is equal to the line frequency.

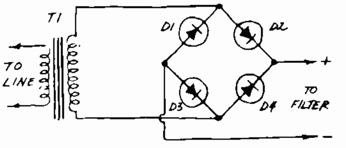
The *full-wave rectifier* requires a center-tapped source (such as the transformer secondary) and uses two diodes. Under the conditions described above, the PIV is twice the output d.c. voltage or 2.83 times the r.m.s. (a.c.) input voltage, while the nominal d.c. output is 1.41 times the a.c. voltage from half the secondary winding. The ripple frequency, in this case, is twice the line frequency.

A center-tapped source is not required for the *full-wave bridge* rectifier, but four diodes are used. Here, the PIV is equal to the d.c. output voltage and is 1.41 times the r.m.s. (a.c.) voltage supplied by the transformer's secondary winding.

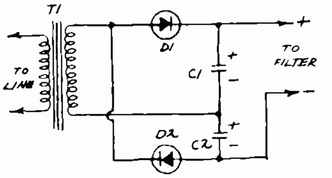
The *voltage doubler* supplies an output d.c. voltage which is twice the peak input voltage—or 2.83 times the r.m.s. (a.c.) input voltage. The PIV is equal to the d.c. output. In operation, diode *D1* conducts on one half-cycle, charging *C1* to the peak supply voltage. On the next half-cycle, *D2* conducts, charging *C2* to the peak supply voltage. The two capacitors (*C1* and *C2*) are discharged in series through the filter to the load.



FULL-WAVE RECTIFIER



BRIDGE RECTIFIER

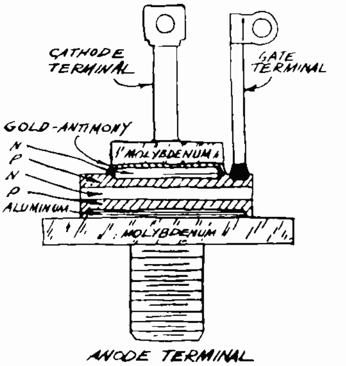


VOLTAGE DOUBLER

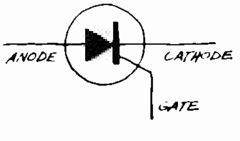
Silicon Controlled Rectifiers

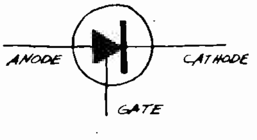
The *silicon controlled rectifier,* or SCR as it is commonly called, is a "big brother" version of the silicon controlled switch (SCS). It is a four-layer semiconductor device with an "all or nothing" characteristic. When forward-biased, it does not conduct until its breakover voltage is reached *unless* it is triggered by a control signal applied to its gate electrode; afterwards, it conducts heavily and will continue to conduct until its anode-cathode voltage is dropped to a low value. When reverse-biased, the SCR blocks current flow until its zener voltage is exceeded and junction breakdown occurs.

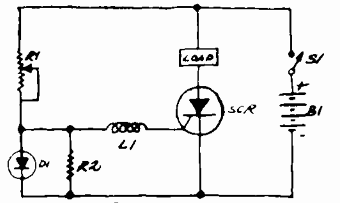
Most SCR's have the gate connection made to the third layer of the four *pn* layers making up the device. Those SCR's with a *cathode gate* are identified by the schematic symbol shown at left below while a few types are equipped with an *anode gate* (at right below) and are identified by a slightly different symbol.



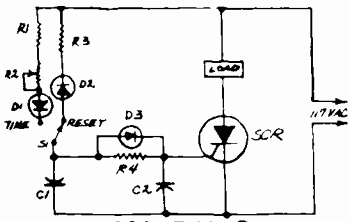
SILICON CONTROLLED RECTIFIER



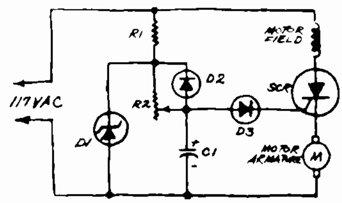




SCR REMOTE CONTROL



SCR TIMER



SCR MOTOR SPEED CONTROL

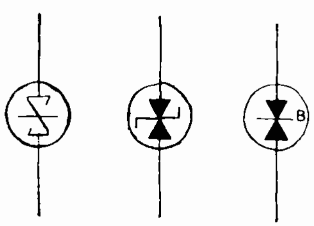
Commercial SCR's are sold in sizes with current ratings of less than 1 ampere to well over a hundred amperes, and with voltage ratings up to 500 volts or more. While standard SCR's can be turned "on" by the application of a trigger signal to their gate—and "off" only by dropping or reversing the anode-cathode voltage, there are several new types which can be turned "off" by the application of a reverse bias trigger to their gate.

A *remote control* SCR circuit is shown at the left. In this circuit the gate is biased just below its firing point by voltage divider *R1* and *R2*. Diode *D1* is included for temperature compensation. A radio signal from a nearby transmitter, picked up by antenna coil *L1*, "fires" the SCR, actuating the *Load*, which might be, as an example, a motor in a toy.

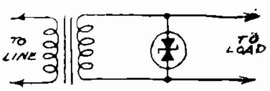
This *timer* circuit is designed for operation on a standard a.c. line. When the control switch, *S1*, is turned to its "TIME" position, *C1* is charged through *D1*, *R1* and *R2*. When sufficient voltage is built up across this capacitor, the SCR is triggered, supplying power to the load device. Potentiometer *R2* sets the time delay, which is a function of the *R1/R2/C1* time constant. The circuit is reset by turning *S1* to the "RESET" position, which discharges the capacitor and applies a reverse voltage to the gate. The SCR, of course, stops conducting on alternate half-cycles. Although a polarized capacitor is shown for *C1*, this normally would be a large-value metalized paper unit.

You can use an SCR to rectify line voltage and power a d.c. motor—while furnishing control over motor current in this *motor speed control* circuit. The motor speed adjustment control is *R2*, while the zener diode, *D1*, stabilizes the gate voltage. The point at which the SCR "fires" on alternate a.c. half-cycles is determined by its gate voltage. If *R2* is set for maximum voltage, the SCR conducts over virtually an entire half-cycle, supplying maximum power to the motor's field and armature windings. If *R2* is set for minimum voltage, the SCR conducts only during the last half of each alternate half-cycle, or for a quarter-cycle, supplying minimum power to the motor.

SURGE SUPPRESSORS

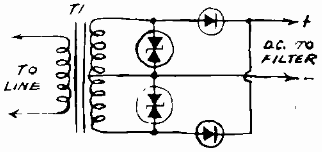


Electrical circuits, whether operated on a.c. or d.c. voltages, are often plagued by transient voltage peaks or surges, either externally or internally generated. Silicon and germanium semiconductor devices are especially sensitive to surge voltages, and a high-voltage transient or "spike" can destroy a semiconductor junction. Manufacturers have introduced special semiconductor devices to guard against and suppress transients. Most of these devices are made up by connecting a suitable pair of selenium zener diodes back-to-back and are identified by a variety of trade names, depending on the manufacturer, including *Voltrap, Thyrector, Klip-Sel,* and *Silgard.*



SURGE PROTECTION

Typical surge protector applications are illustrated here. A single unit is used in one circuit to protect the a.c. voltage supplied to a load by a transformer. A pair of units are frequently used in a full-wave rectifier to protect the rectifier diodes against transients. Circuit operation is similar in both cases. Under normal conditions, the surge suppressors act as open circuits, since one or the other of the two diode elements making up the device is always reverse-biased. If a transient voltage spike or surge occurs which exceeds the device's rating, the unit goes into zener breakdown, shorting out the surge.

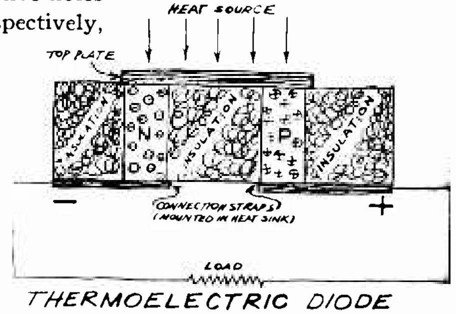


FULL WAVE SURGE PROTECTION

THERMOELECTRIC DIODES

Although not a "diode" in the classical sense, the thermoelectric diode is a thermocouple-type device with a variety of applications. It consists of *p*- and *n*-type semiconductors bonded together by copper or similar high-conductivity metal. Straps are connected to the opposite ends of the semiconductor bars for electrical connections and the two ends of the bars are thermally insulated.

If the connection straps are attached to an insulated heat sink and heat is applied to the sides of the semiconductors which are bonded together, the electrons and positive holes in the *n*-type and *p*-type semiconductors, respectively, undergo thermal diffusion from the high- to the low-temperature side, developing a potential difference. This voltage can be used as an effective *power source* for a standard electrical load as long as a temperature difference is maintained between the two sides of the device. Thus, the unit becomes a heat-to-electrical energy converter.



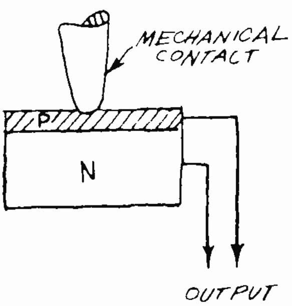
THERMOELECTRIC DIODE

The output voltage supplied by a single element is relatively small, and commercial thermoelectric generators generally are made up of a number of elements in a series-parallel arrangement to obtain usable voltages at fairly high currents. The *3M* Type 18A thermoelectric generator is a typical unit: it can supply up to 15 watts—3.5 volts at 4.3 amperes—while consuming 0.15 lb. of propane fuel per hour.

Essentially the same type of thermoelectric diode can be used in a different manner. If power is *applied to the device* by an external d.c. source, with the negative terminal of the power supply connected to the *p*-type semiconductor and the positive terminal connected to the *n*-type material, the top plate becomes cool and the lower connectors warm. In effect, the device absorbs heat at one end and releases it at the other and becomes a type of electronic *heat-pump*.

Commercial thermoelectric heat-pumps of this general type are used in the manufacture of motorless refrigerator and air-conditioning units and as "spot coolers" for high-power transistors, diodes, SCR's, and similar semiconductor devices. One firm identifies its line of thermoelectric cooling elements as *Frigistors*.

SPECIAL DIODES



PIEZOELECTRIC DIODE

While the diodes described on the preceding pages constitute the overwhelming majority of commercially available semiconductor diodes, there are a number of important special-purpose units. Most are experimental, but are expected to be useful in the very near future.

The *piezoelectric* diode is one that is currently under development. It consists of a *pn* junction to which a mechanical pressure contact is made. The junction's resistance (and hence its effective output) is proportional to the mechanical pressure exerted. Undoubtedly, piezoelectric diodes will have potential applications in microphones, hi-fi phono cartridges, and vibration pickups.

THE FUTURE

As we have seen, the semiconductor diode is one of the most versatile of simple electronic components. It has, today, more applications than the proverbial dog has fleas. If past performance is any criteria, we can expect many new applications in the future—and many new types of semiconductor diodes. Of the various experimental types now being tested, the semiconductor *laser*, the tunnel diode (and its first cousin, the "camel" diode), and the thermoelectric "diode" hold the greatest promise for startling future developments. But even the best of prophets can be wrong. A completely new type of semiconductor diode may even now be in the development stages in our nation's research laboratories!

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CHAPTER 4

SCIENCE FAIR PROJECTS

Each year tens of thousands of high school and junior college students enter "Science Fair" contests. Originated to encourage more interest in science at school levels, the "Science Fair" has gradually become a highly competitive event with prizes worth hundreds and even thousands of dollars. Electronics has always played a prominent role in "Science Fairs"—partially because of the space-age interest, and partially because of the visual effects that electronics projects offer to the public.

For this portion of the Fall 1965 ELECTRONIC EXPERIMENTER'S HANDBOOK, the Editors have selected three "Science Fair" projects that are sure winners. In each story all of the necessary construction details are presented to make the project operative, but only a minimum of background theory is included. This presentation is in keeping with the philosophy of "Science Fairs" in that the student must analyze the subject matter and then demonstrate his findings.

The "Repulsion Coil" project on page 88 demonstrates the principle of resonance using 60-cycle house current. Two visual effects offered by this project are a reciprocal resonant engine and a magnetic gun. The "Big TC" Tesla Coil (page 93) has been a "Science Fair" winner since its original appearance in the July 1964 issue of POPULAR ELECTRONICS. This article has been brought up to date and, as can be seen in our cover photo, the spark output greatly increased. Extra safety precautions have been incorporated in the revised circuit. A small Tesla coil using commonly available TV components is shown on page 99. This "Li'l TC" can be used to demonstrate brush discharges from high-frequency, high-voltage power supplies, or even to spin a near-weightless aluminum vane.

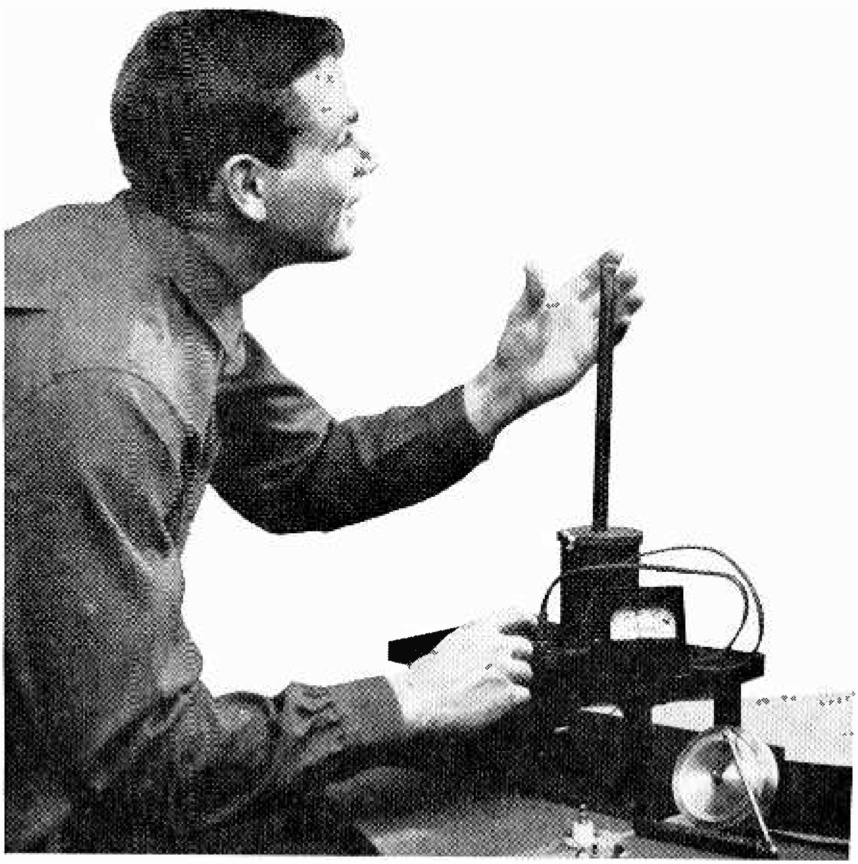
A 60-CYCLE REPULSION COIL RESONANCE ENGINE

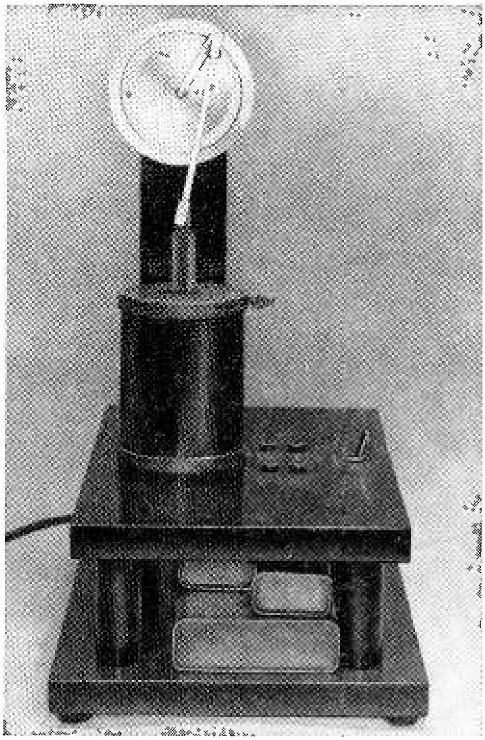
By WALTER B. FORD

Startle your friends with this dynamic demonstration of low-frequency resonance and other dramatic a.c. effects. This Science Fair project works on ordinary 60-cycle house current

NEARLY EVERY electronics experimenter is familiar with the process of adjusting a circuit to resonate at a specific radio frequency—you do this every time you tune in your favorite radio or TV station. Much more mysterious and surprising, however, are resonant circuits operating at the low 60-cycle frequency of our home lighting circuits. The repulsion coil—resonant engine described here reveals some of the secrets of this fascinating phase of electronics and provides a unit that can be used for a number of exciting experiments.

The values and dimensions given here are from the author's working model, and while they may be varied somewhat, changes of any kind are not recom-





Constructed on a black lacquer wooden base, the resonant-coil engine is an impressive-looking unit.

mended unless the experimenter understands what effect the changes will have on the operation of the unit. If, for example, capacitors of lower value are used, the stroke of the engine piston will change. This will mean that there will have to be a proportionate change in the length of the flywheel crank.

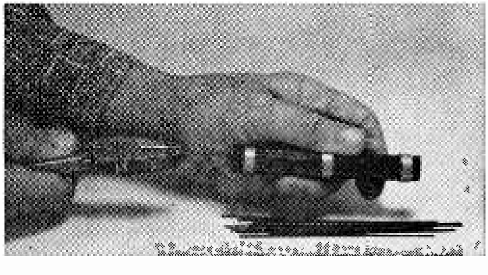
Making the Coil. The inductive part of the series-resonant *LC* circuit used in the unit is in coil *L1*. Begin by making up a coil form as shown in Fig. 1 (page 90). Although plain wood discs may be used for the ends, plywood, fiber, or Micarta is preferred, since there is less chance of breakage if the coil is accidentally dropped. The center tubing can be Micarta, Bakelite, or fiber, or can be made by drilling a ⅝" hole lengthwise in a piece of ¾" dowel rod. Whichever material is used, make sure the inside surface is smooth, sanding if necessary, so the engine piston will travel freely.

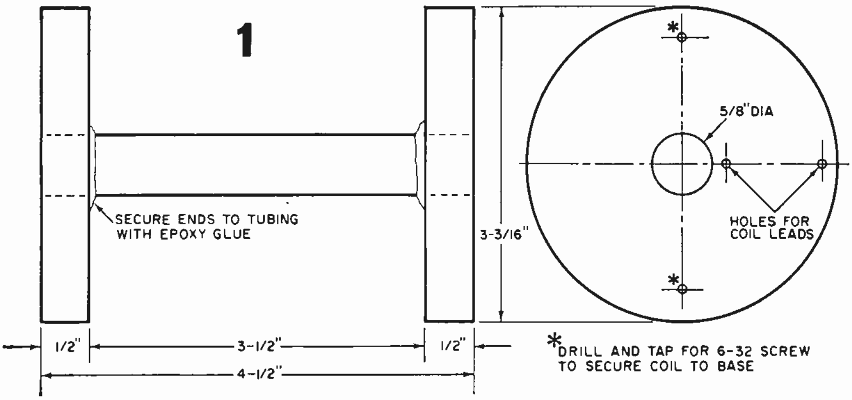
Complete the coil form by drilling holes in the end discs that make a snug fit around the center tubing, and gluing the ends and tubing together with epoxy glue. This step is important because there will be considerable pressure against the ends when the wire is in place on the coil. Drill 1/16" holes through one end of the coil form for the coil leads as indicated in Fig. 1. Drill and tap two holes for *6-32* machine screws in the same end of the form to hold the completed coil to its base (if wood is used, wood screws can be used and the threaded holes will not be needed). Wind the coil form with 2½ pounds of 24-gauge magnet wire. While it is not necessary to wind the coil perfectly, like thread on a spool, it should not be allowed to pile up at any one point.

Constructing the Cores. Uncoil enough 16- or 18-gauge soft iron wire to make the engine core, grip one end in a vise, grasp the opposite end with a pair of pliers, and pull until you can feel the wire stretch somewhat. This will straighten the wire. Cut the wire into 4¾" lengths and make forms to hold the bundle in cylinder form from pieces of thin-wall metal or plastic tubing. Holes (9/16") drilled in small pieces of wood or cardboard can also serve the purpose. Since the forms must be cut away after the core is glued, keep their outside dimensions down to a minimum.

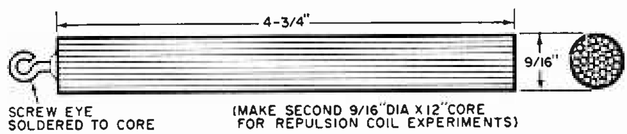
Bundle the 4¾" wires together and insert them in the forms. Press the end of a screw eye into the center of one end of the core, and cut off the ends of the wires forced out of the core at the opposite end. Withdraw the screw eye—it will be fastened permanently later. Apply epoxy glue to the areas of the core not covered by the forms holding the core wires and allow the glue to set. The type of epoxy glue that will set with artificial heat is preferred for this, since

Straighten the iron wire for the cores by stretching it as explained in text. Then cut and bundle the wires into cylindrical form as shown in Fig. 2.

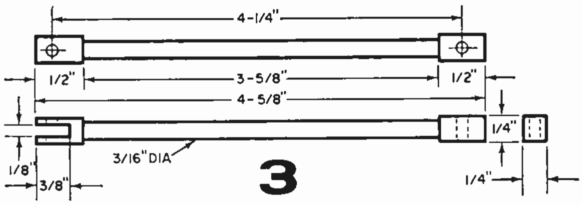




Coil form may be made of fiber, plywood or Micarta. End plates must be strong and firmly glued to center.

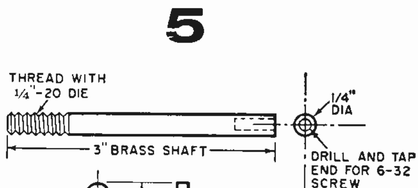


Both cores are made of #16- or #18-gauge soft iron wire. Straighten the wire as shown in the photograph on the bottom of the facing page.

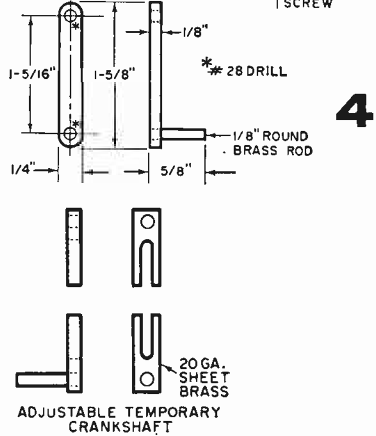


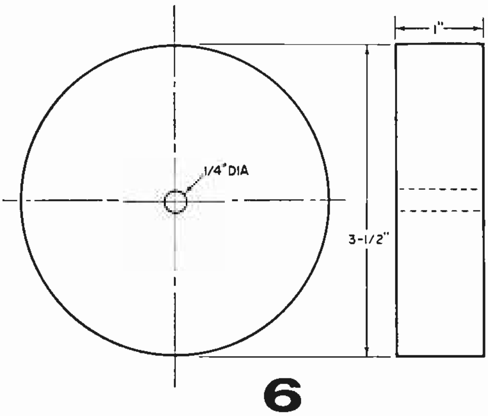
This arm couples the flywheel to the core, which acts as the piston. Prototype was cut from brass stock.

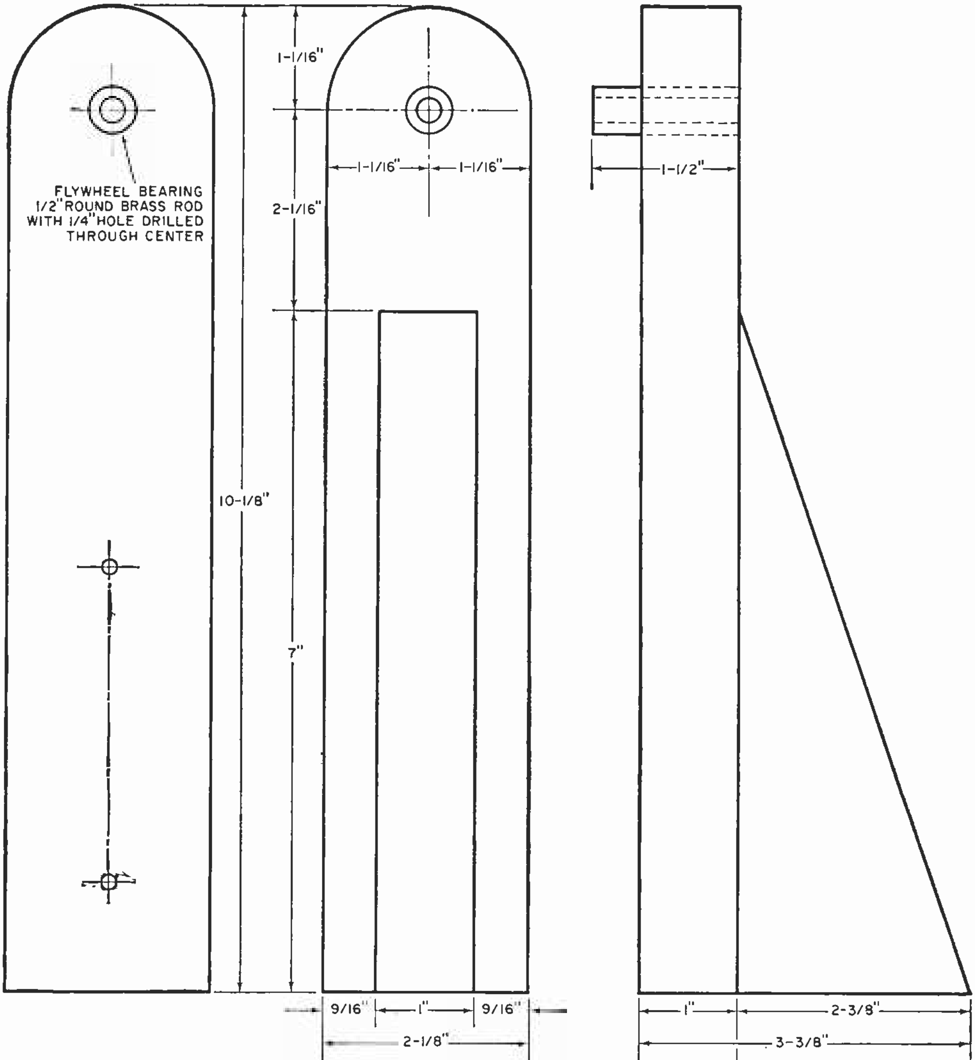
Several small parts must be fabricated to connect the arm to the flywheel. At right, below, are two possible ways of constructing the engine crankshaft.

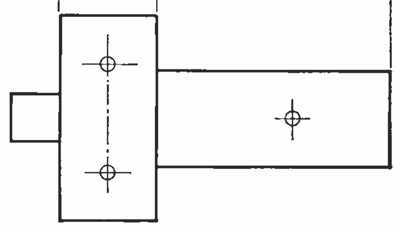


The flywheel weighs about 15 ounces. The author used aluminum, but plastic or brass would serve as well. War surplus stores or machine shops may have such flywheels for sale.







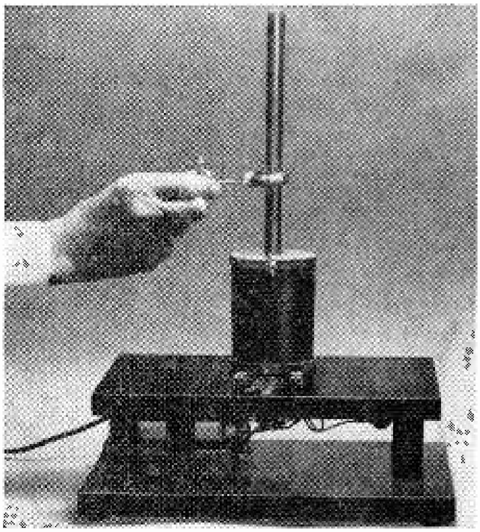


The size of the stand necessary to hold the flywheel for experiments will depend on the length of the shaft (Fig. 3) and diameter of the flywheel (Fig. 6).

7

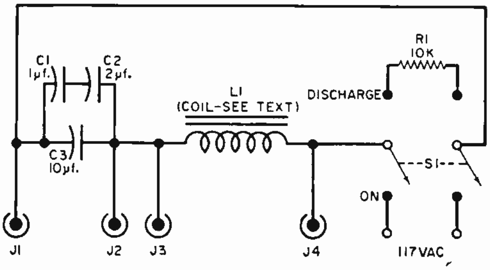
BILL OF MATERIALS

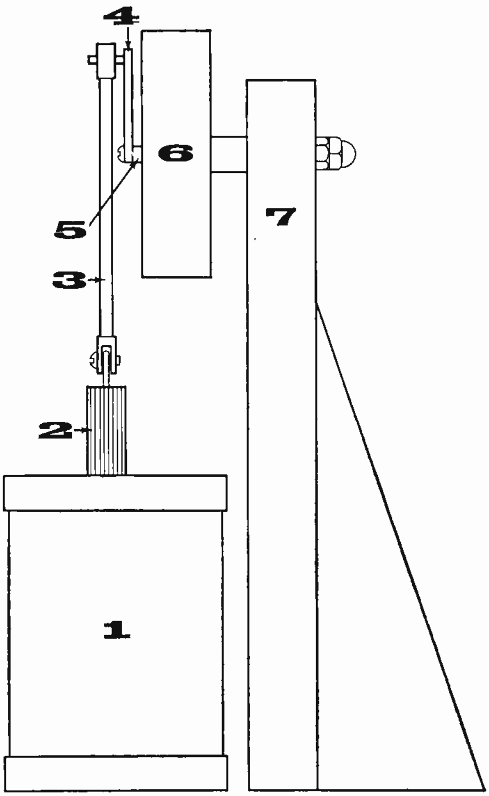
C1—1-µf., 600-volt non-electrolytic capacitor
C2—2-µf., 600-volt non-electrolytic capacitor
C3—10-µf., 600-volt non-electrolytic capacitor
J1, J2, J3, J4—Insulated pin jack
L1—See text
R1—10,000-ohm, 10-watt resistor
S1—D.p.d.t. (center-off) 10-amp toggle switch (motor start type)
1—2½-lb. spool of 24-gauge magnet wire, cotton- or enamel-covered
1—1-lb. spool, 16- or 18-gauge soft iron wire
2—3³⁄₁₆"-diameter, ⅜"-thick discs of fiber, Micarta, or wood
1—⅝"-i.d., 4¼"-long piece of fiber or Micarta tubing, or wood dowel
1—3½"-diameter, 1"-thick flywheel; aluminum, brass or plastic—see text
Misc.—Brass rods for crankshaft and connecting rod, wood for bracket and base of engine, brass bearing, wood screws, machine screws and nuts, wire, solder, a.c. line cord, epoxy glue, etc.



A small coil connected to a flashlight bulb illustrates transformer action of mutual inductance.

Permissible changes in certain component values are discussed in text. However, do not eliminate discharge function of the d.p.d.t. toggle switch.





This is how the various pieces for the resonant engine shown in detail on page 90 are assembled.

drying time is shortened and because surplus glue may be more easily pared off. After the glue has set, remove the forms and apply epoxy to the uncovered core areas. When this second application is dry, remove any rough spots on the core with a coarse file. Solder a screw eye in the hole that was made in the end of the core. The finished core should look like Fig. 2, on page 90.

For the repulsion coil experiments, make another core following exactly the same procedure outlined, but using 12″ iron wires and omitting the screw eye.

Parts for the Engine. The connecting rod (Fig. 3, page 90) is made with 3/16″ brass tubing soldered into pieces of 1/4″-square brass, the ends of which have been drilled and shaped as shown. This construction was used to "dress up" the prototype, and need not be duplicated exactly. A rod made from a single solid piece of brass will work as well.

The engine crankshaft is shown in two forms in Fig. 4. If you want to experiment with different values of capacitors, or longer or shorter piston travel with a corresponding change in speed, build the slotted version so you can adjust its length. The two parts are held together with a small machine screw and nut. Since this is made of lighter material, it is not recommended for permanent use. If all the values and measurements given for the engine are followed, make a solid crankshaft exactly like that shown.

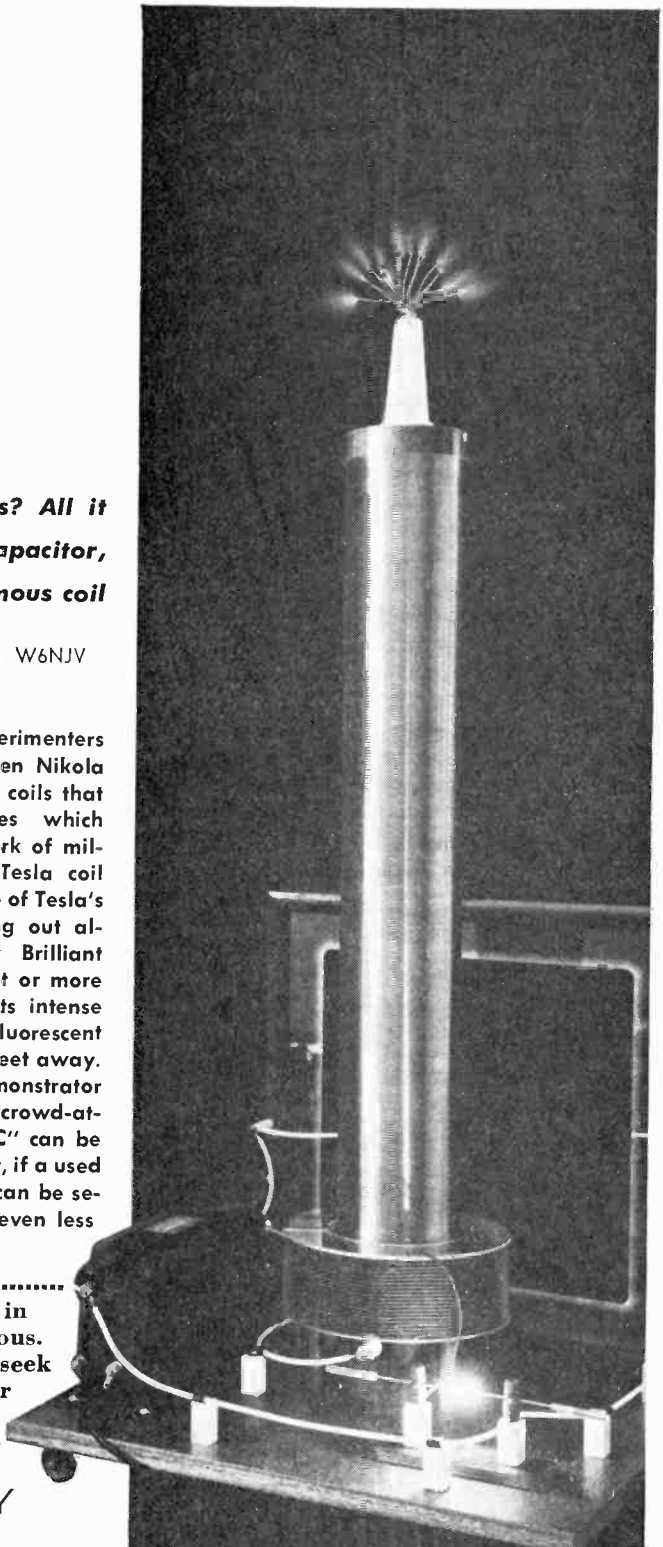
The engine flywheel is made of brass or aluminum, and is 1″ thick and 3½″ in diameter. It is supported by a 1/4″ brass shaft 3″ long (see Figs. 5 and 6, page

(*Continued on page* 141)

BIG TC

A quarter of a million volts? All it takes is a transformer, a capacitor, a spark gap, and Tesla's famous coil

By CHARLES CARINGELLA, W6NJV



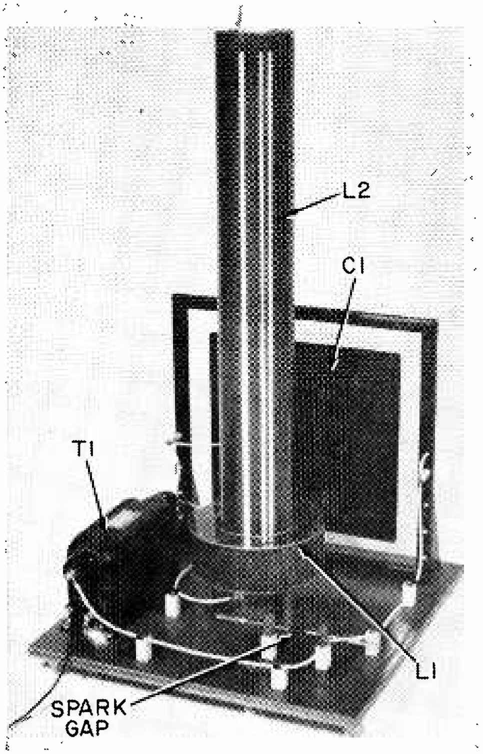
TESLA COILS have fascinated experimenters ever since the early 1900's when Nikola Tesla first experimented with giant coils that produced lightning-like discharges which would span his laboratory—the work of millions of volts of electricity. The Tesla coil described here is smaller than some of Tesla's designs, but it's capable of putting out almost a *quarter of a million volts!* Brilliant corona discharges as long as a foot or more provide a spectacular display of its intense electrical field, and neon and fluorescent lamps can be excited as far as five feet away.

Intended both as a dynamic demonstrator of electrical principles and as a crowd-attracting science fair project, "Big TC" can be put together for about $30. However, if a used transformer from a neon sign shop can be secured reasonably, the cost will be even less

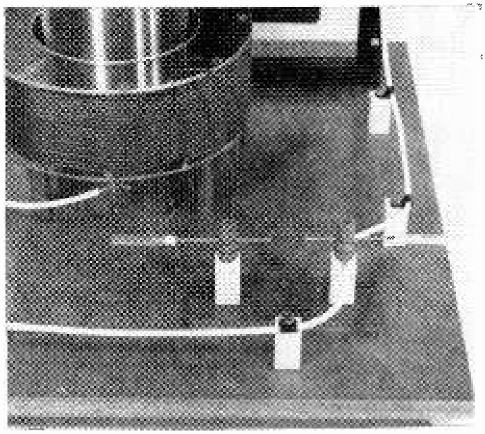
WARNING: The voltages used in this project are highly dangerous. Inexperienced persons should seek aid from an instructor or other expert before building it.

COVER STORY

BIG TC

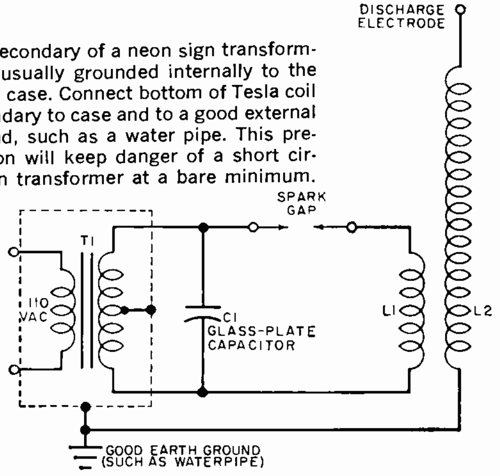


Mount L1-L2 in center of base, T1 and C1 at edges. A bigger base and greater component spacing will permit greater voltage output with less arcing.



Spark gap generates r.f. energy to excite coil. It consists of two copper rods mounted on standoffs.

The secondary of a neon sign transformer is usually grounded internally to the metal case. Connect bottom of Tesla coil secondary to case and to a good external ground, such as a water pipe. This precaution will keep danger of a short circuit in transformer at a bare minimum.



As shown in the schematic diagram above, *T1* steps the household line voltage up to 12,000 volts. The transformer is the type commonly used to operate neon signs. A high-voltage glass-plate capacitor, *C1*, is connected directly across the high-voltage secondary winding of *T1*. The capacitor serves as an energy storage device, charging up to *T1*'s secondary voltage and then discharging in response to the 60-cycle a.c. voltage.

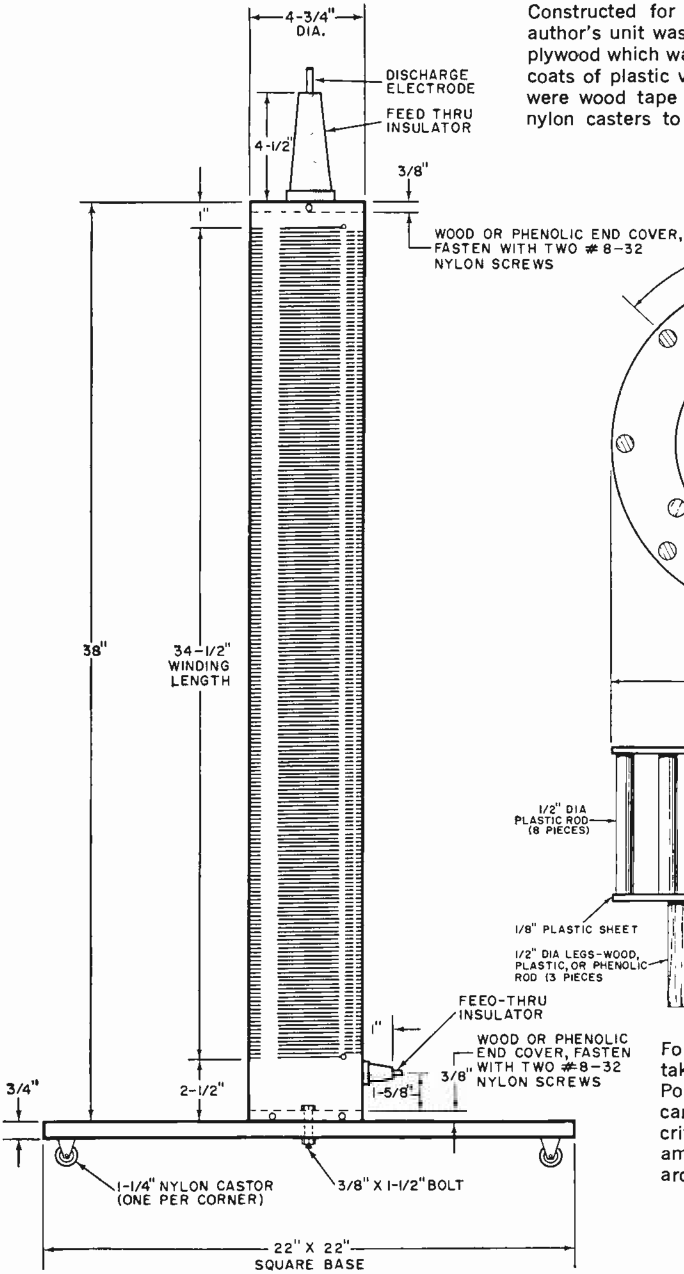
Discharging of *C1* is through the spark gap into coil *L1*. Each time the spark gap "fires," a high current flows through *L1*. The larger capacitor *C1* is made, the larger will be the current through *L1*. Discharges across the spark gap produce extremely jagged pulses of power which are very rich in r.f. harmonics. The energy—due to the values of the components used—is greatest in roughly the 100-kc. region.

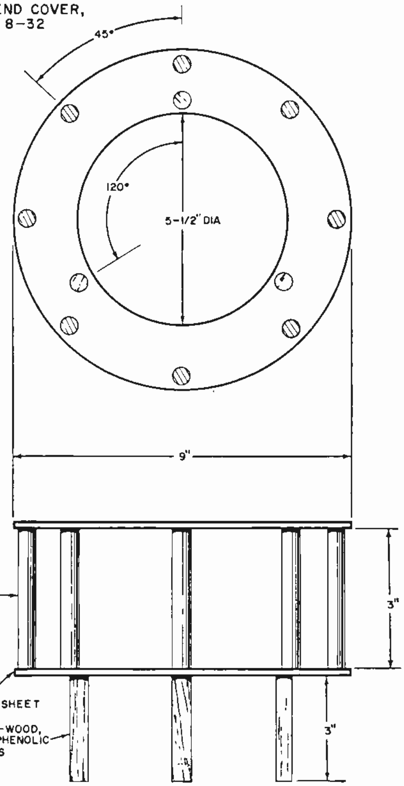
Windings *L1* and *L2* form a air-core step-up transformer, with *L1* the primary and *L2* the high-voltage secondary. The voltage at *L2* will be 75,000 to 250,000 volts depending on the size of *C1*.

Design and Layout. The prototype of "Big TC" was built on a plywood base measuring ¾" x 22" x 22", although a larger base would be desirable for high-voltage units to prevent arcing between *L2* and *T1* and *C1*. Mount *L2* in the center of the base and *T1* and *C1* as close to the edges as possible; if you plan to operate the unit at voltages exceeding 100,000 volts, make the base 3′ x 3′ for even greater separation between components.

Power transformer *T1* is the only

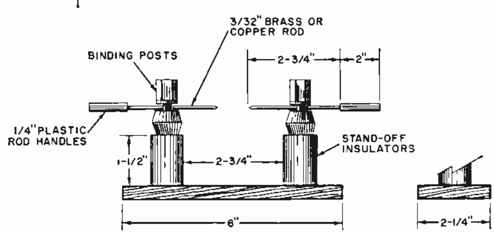
Constructed for classroom demonstration, the author's unit was mounted on mahogany veneer plywood which was sanded and covered with five coats of plastic varnish. Other finishing touches were wood tape veneer around the edges, and nylon casters to make the unit easy to move.



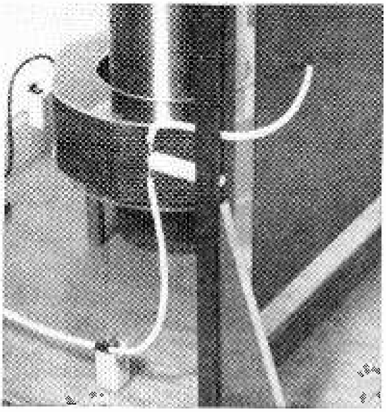


Form for L1 with center cut out to take base of L2 is shown above. Polystyrene was used, but wood or cardboard can be substituted. The critical dimension is the outside diameter; less than 9" will result in arcing between coils L1 and L2.

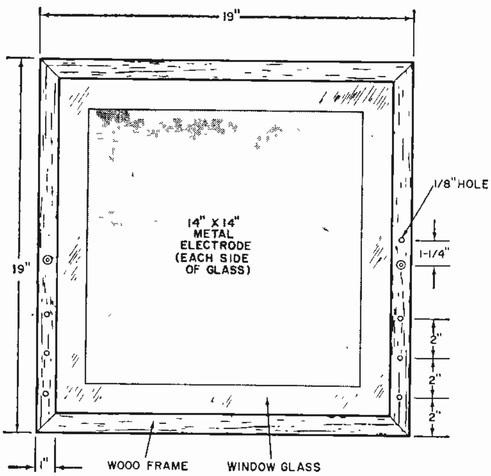
The various dimensions of the prototype coil are indicated in the drawing; none is particularly critical. Note that space has been left at each end of coil, and that stand-off insulators are used to bring out the ends. Nylon screws or glue must be used to fasten top end cover to avoid arcing. After winding coil, cover with many coats of acrylic plastic spray. Spray form first if cardboard is used. Details on spark gap are shown at right.

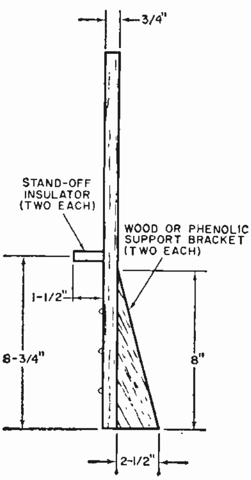


BIG TC



Leads are soldered directly to capacitor plates. Note use of stand-off insulators.





Glue metal plates to glass, leaving a generous margin of glass on all sides (see text). Epoxy glue, contact cement, or any other glue which will form a tight bond can be used. The wood frame protects the glass and makes mounting it possible.

high-cost component. A neon-sign unit rated at 12,000 volts a.c. at 30 ma., it sells for about $40 new, but used transformers are constantly being salvaged by sign shops, and can be picked up for $10 to $20. It is also possible to find neon signs in junk yards, in which case you can probably buy the transformer for practically nothing. The author used a GE unit, No. 51G473, known technically as a "luminous tube transformer." Measuring 9½" x 6" x 4", it has 2" feedthrough insulators at either end connecting to the high-voltage winding.

Primary coil *L1* and all connecting leads must be made with high-voltage wire, preferably supported away from the base on 1" ceramic standoff insulators. Test prod wire such as Belden Type 8899 is ideal—it has flexible rubber insulation with a puncture voltage rating of 20,000 volts.

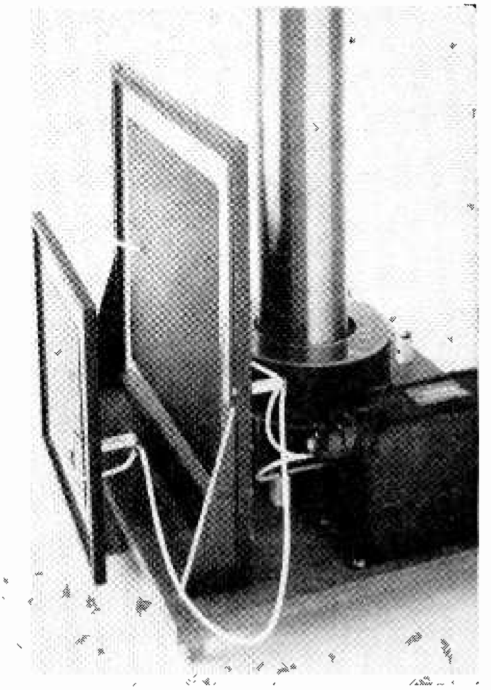
Winding the Coil. For the big coil (*L2*) a phenolic coil form* measuring 4¾" in outside diameter and 38" in length was used. Alternately, cardboard, wood or other insulating materials can be substituted. You can improve these latter types of coil forms by spraying on at least six coats of acrylic plastic spray before winding the wire on them.

The winding itself is done with No. 26 Formvar-insulated wire—two 1-lb. spools (splice them together and keep the solder joint as small as possible) will give you a 2000-turn, tightly spaced coil covering 34½" of the coil form. There should be extra space between the ends of the winding and the ends of the form—see the drawing on page 95.

The lower end of the coil is terminated at a 1" feedthrough insulator installed in the side of the form, the top end of the coil at a 4½" feedthrough mounted to the top end of the form. Make the end covers of wood or phenolic discs cut to the inside diameter of the coil form, and mount them in place with

---

*Tubing can be found in metropolitan areas at surplus houses and establishments which sell plastics (sheets, rods, etc.). Clear acrylic tubing (48" long, 4½" O.D.) can be ordered from Industrial Plastics Supply Co., 324 Canal St., New York, N. Y. 10013, for $13.85 including shipping charges and postage; address your order to the attention of Mr. Charles Roth.



This Mark II version of "Big TC" used a second outboard capacitor—increasing the capacity across the primary by 0.0014 uf. Estimated output of the Mark II model was about 130,000 volts. See page 96.

nylon screws (metal screws at the top end would produce corona discharges which could burn the coil form). Alternatively, the top coil cover can be cemented in place with epoxy cement if a sturdy coil form is used. The coil is attached to the base with a 3/8" bolt.

Winding the coil is not nearly as difficult as it appears—the author completed the task in about two hours. Spray the entire winding with acrylic plastic for added insulation, moisture protection, and to keep the windings in place. You can't overdo this step—the author used the contents of an entire aerosol spray can on the prototype, applying one thin layer at a time and letting it dry before adding another.

Building the Primary. As shown on page 93, the form for *L1* was made with polystyrene rods and sheeting. While the plastic has excellent insulating qualities and looks attractive, wood or even cardboard can be substituted. If plastic is used, it can be strongly "welded" together with acetone. Regardless of the material used, the form should have an outside diameter of at least 9" to avoid arc-over between *L1* and *L2*. The coil itself (*L1*) consists of 20 turns of heavy test prod wire.

Spark Gap. The spark gap is simply two ordinary binding posts mounted on stand-off insulators. In turn, these are mounted on a phenolic base measuring 3/8" x 2 1/4" x 6". The electrodes are brass and copper rods with a gap on the order of 1" between them. This distance will vary slightly, depending on the size of capacitor *C1*.

Fabricating the Capacitor. The capacitor consists of two 14" x 14" sheets of tin cemented to a 18 1/2"-square piece of window glass. Although aluminum foil can be used for the capacitor plates, tin was obtained from a sheet metal shop for this purpose so that connecting leads could be soldered directly to it. If you use aluminum foil, a fairly good connection can be had by making leads of 1/2"-wide aluminum foil strips and taping them down to the electrodes.

Glass is an excellent dielectric material for this application since it has an extremely high puncture voltage and a high dielectric constant. As you will note in the drawing on page 94, a border of glass is left around the capacitor plates—this should be at least 1 1/2" wide. The calculated capacity of *C1* is approximately 0.0027 μf.

Testing and Operation. Caution! Adjustments to the Tesla coil, and specifically to the spark gap, should be made *only* when the unit is *off*. Although the output voltage of the Tesla coil may be on the order of 150,000 volts, the current capacity is only hundreds of microamps. This current can inflict a nasty shock and r.f. burns, however.

Use EXTREME CAUTION around the neon sign transformer. It delivers 12,000 volts at 30 ma., and this voltage could be lethal under certain conditions.

Again, be sure the plug is out when you make adjustments.

To adjust the spark gap, first open it to about 1½″; it will not fire at this point. Gradually move the electrodes together—unplugging the unit each time you adjust the gap—until the point is reached where the gap "fires."

The author's original version of "Big TC" produced an output voltage of about 100,000 volts with the single plate glass capacitor described above. To increase the output of "Big TC," it is only necessary to increase the capacity across the primary by adding one or more plate glass capacitors in parallel with *C1*. With two capacitors (both the same size as detailed on page 94), the author's prototype produced over 150,000 volts output; and with three capacitors in parallel, the output exceeded 200,000 volts. However, at such high voltage there was a tendency for insulation breakdown between coil *L2* and capacitor *C1*. This breakdown could have been overcome by making the mounting base larger and increasing the spacing between components.

The author's Mark II version of "Big TC" compromised by adding a second capacitor with half the plate area of *C1*. Except for size, this new capacitor was fabricated in exactly the same way and had a measured capacitance of 0.0014 μf. The new capacitor was attached to the base board with a 6″ x 9″ piece of ⅜″-thick phenolic board. Four retaining screws held the board to the underside of the base board and four more screws affixed the phenolic to the wooden frame of the outboard capacitor. With this second capacitor (see cover photograph), the voltage output was estimated to be in the neighborhood of 130,000 volts.

The output of your Tesla coil can be estimated by drawing an arc to a metallic object attached to a long wooden handle. Slowly increase the distance between the object and the discharge terminal until the arcing stops: a 6″ arc represents 100,000 volts, a 14″ arc about 200,000 volts, and a 21″ arc some 300,000 volts. More amazing than figures, however, are the brilliant, spectacular phenomena exhibited by high-voltage, high-frequency electricity. -30-

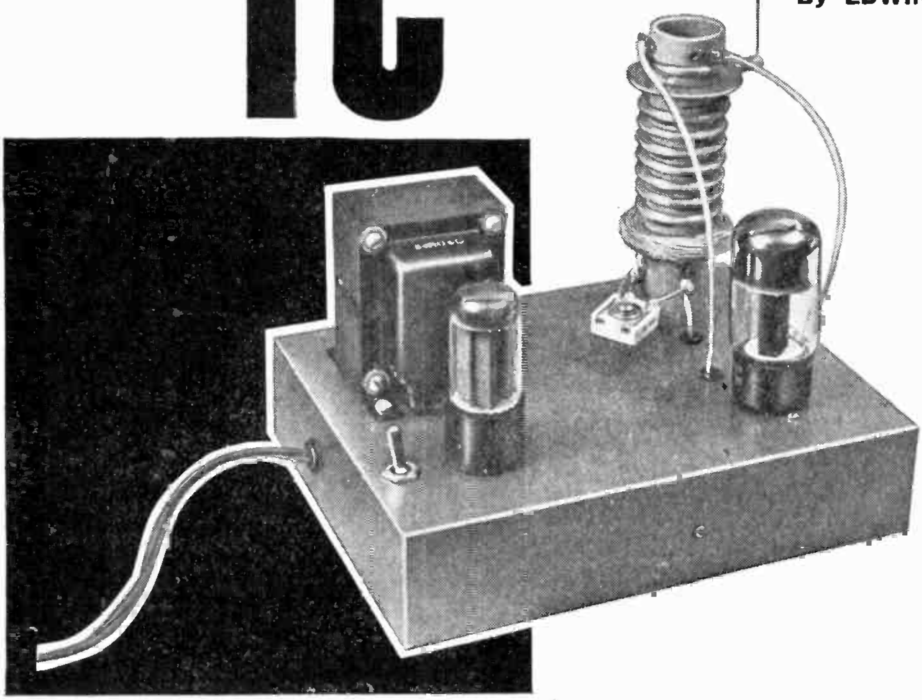
Li'l TC

IF you have read the preceding article on "Big TC," you will have learned that a Tesla coil is simply a radio-frequency step-up transformer carried to extreme limits. While a coil that can generate 150,000-200,000 volts is exciting and very dramatic, many of the same visual effects can be demonstrated on a smaller scale with "Li'l TC." In fact, "Li'l TC" is much safer, easier to build, and less expensive.

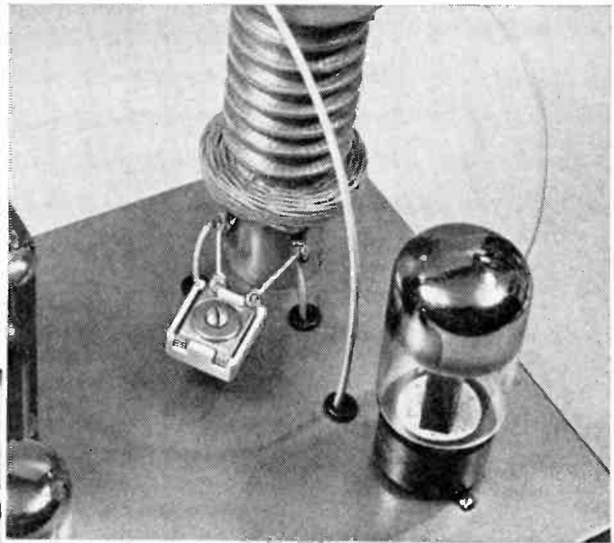
The only item many experimenters will have to buy in order to build "Li'l TC" is the r.f. coil. This coil is manufactured by the J. W. Miller Co. for use in generating the high voltages required in large-screen TV receivers. It is an item that is not stocked by many parts stores, although most of them can obtain it for you within 48 hours. If you have trouble finding the coil, it can be ordered from Allied Radio Corp., 100 N. Western Ave., Chicago 80, Ill., as their stock number 61G102 at a price of $8.82 plus postage. An experienced project builder may not find it necessary to buy one of these coils, but may be able to

A potent "little brother" to "Big TC," this Tesla coil version is inexpensive, easy to build, and it can put out 30,000 volts!

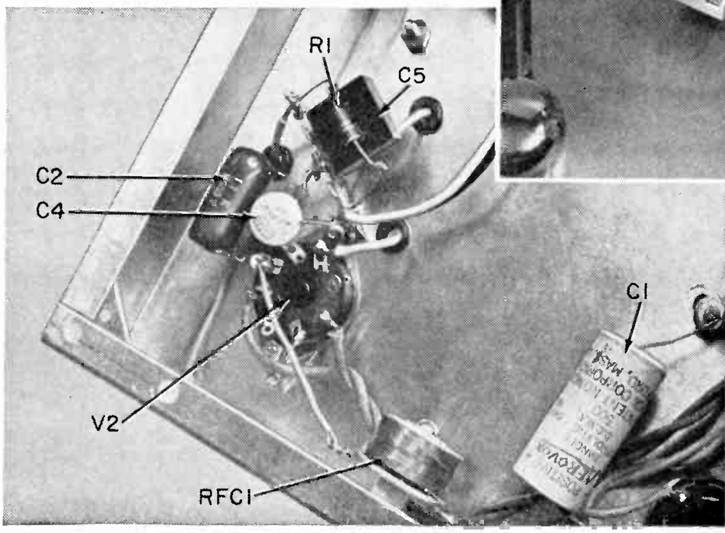
By EDWIN N. KAUFMAN



Li'l TC



Tuning capacitor C3 is attached to the h.v. coil with two bus-bar leads so that it will be suspended in mid-air away from the coil and metal chassis. Use an insulated alignment tool to rotate the setscrew adjustment.



Most of the parts are grouped around the base of tube V2. Leads to the h.v. coil pass through grommeted holes to the terminal connections on the Miller coil form.

construct "Li'l TC" using a high-voltage transformer from a large-screen old-style TV receiver.

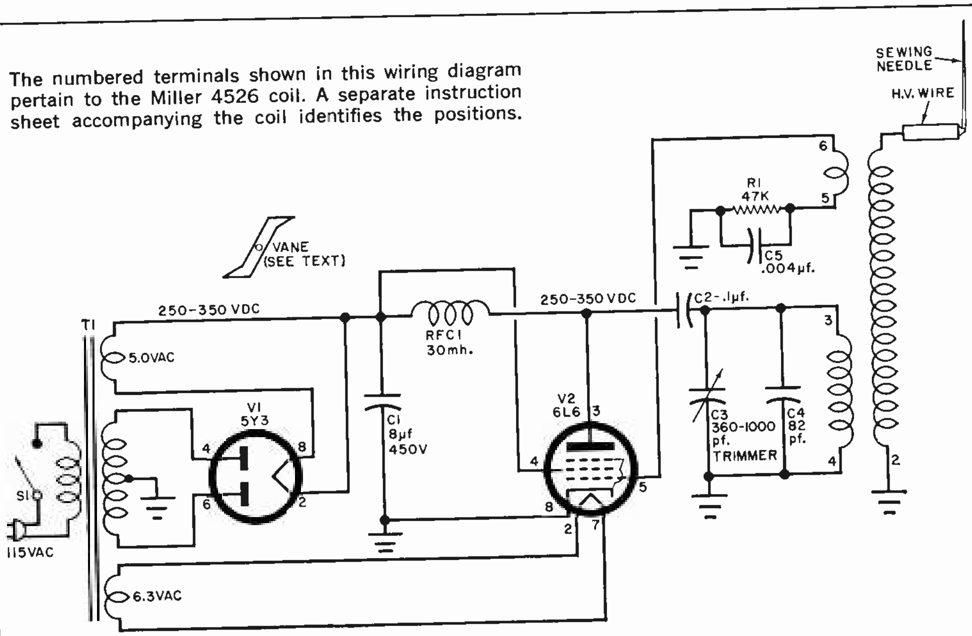
Construction. The mechanical layout is not critical, and the design shown in the photographs need not be followed exactly. It is convenient to place the r.f. coil off in one corner of the chassis and to drop the connecting leads to *V2* through grommeted holes in the chassis deck. The high-voltage output lead of the coil is shortened and a sewing needle soldered to the end to show "point discharge" effects.

The power supply is of conventional design and the B-plus applied to the plate of *V2* can range from 250 to 500 volts. However, 250 - 350 volts is more than ample for an output of between 12,000 and 15,000 volts. The output will also vary according to the type of tube used at *V2*. When you open the coil box, you will see that a 6Y6 is recommended by the manufacturer. However, noticeably improved effects were obtained by the author by substituting a 6L6. A 6V6 or another equivalent power pentode would do in a pinch.

Capacitor *C3* is used to tune the primary of the h.v. coil. For convenience, two bus-bar leads about 1″ in length were soldered to the capacitor and used to support it in mid-air. The remaining components are scattered around below the chassis deck.

Firing Up Li'l TC. When used in a TV receiver, the high voltage generated by this coil/oscillator arrangement is rectified and filtered. It is then considerably more dangerous than the unfiltered r.f. generated by Li'l TC. Nevertheless, Li'l TC should be treated with respect, for the voltage can puncture the skin of a finger, although high-frequency voltages usually tend to flow relatively harmlessly along the skin's surface.

The numbered terminals shown in this wiring diagram pertain to the Miller 4526 coil. A separate instruction sheet accompanying the coil identifies the positions.



PARTS LIST

C1—8.0-µf., 450-volt electrolytic capacitor
C2—0.1-µf., 600-volt molded capacitor
C3—360-1000 pf. trimmer capacitor
C4—82-pf., 1.6-kv. ceramic capacitor—see text
C5—0.004-uf., 600-volt mica capacitor
R1—47,000-ohm, ½-watt resistor
RFC1—30-mh., 100-ma. r.f. choke (J. W. Miller 692 or equivalent)
S1—S.p.s.t. toggle switch
T1—Power transformer: primary, 117 volts a.c.; secondaries, 500 volts, CT, 5 volts at 2 amperes, and 6.3 volts at 2.5 amperes (Thordarson 24R09U or equivalent)
V1—5Y3 tube
V2—6L6 tube—see text
1—High-voltage coil (J. W. Miller 4526—see text)
1—Metal chassis (Premier ACH-404 or equivalent)
Misc.—Tube sockets, wire, solder, etc.

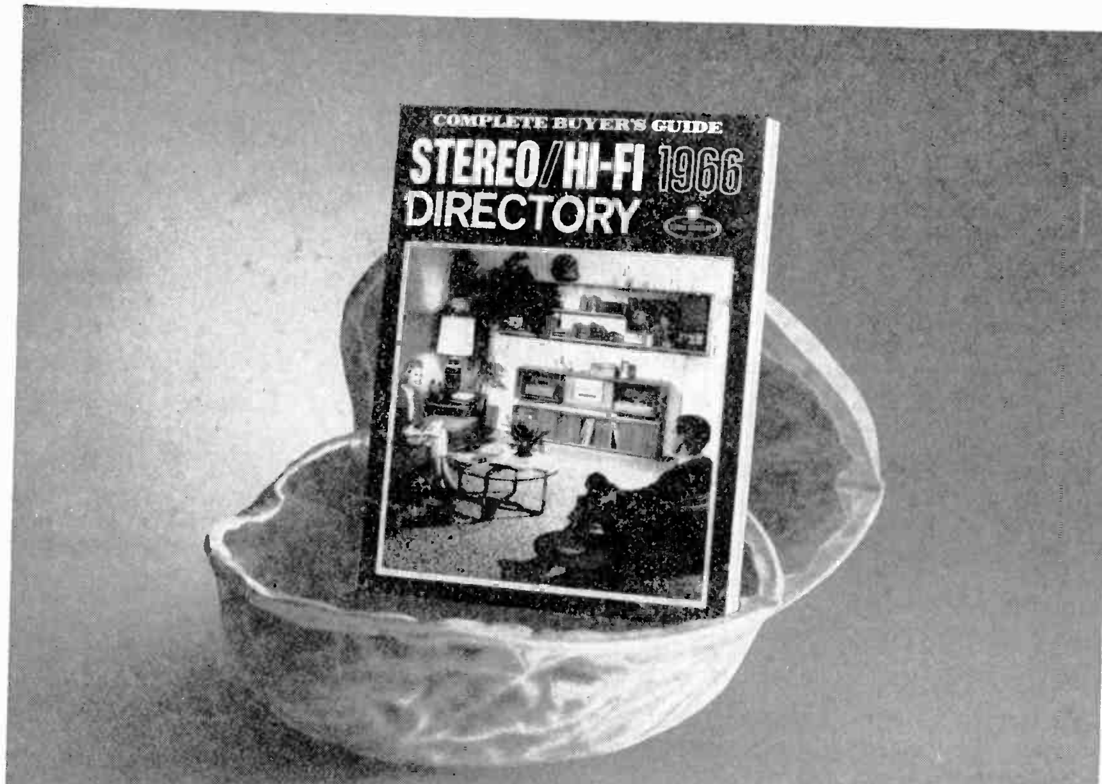
After double-checking your wiring, turn on the a.c. power and permit the two tubes to warm up. Take an insulated screwdriver—something like a long alignment tool—and adjust *C3* for a brush discharge from the needle point. If you do not have enough range in *C3* to tune through the maximum discharge, change the value of *C4*—add more capacitance at *C4* if the plates of *C3* are tightly meshed; use less if *C3*'s are too loose. You can set *C3* for maximum discharge by listening to the sound of the brush effect—tune for a clean high-pitched hiss and not a sputtering sound.

The brush discharge from Li'l TC will be about 1″ in height and can be seen best in a dimly lighted room. Actually, a brush corona will appear at any sharp edge on the output lead, so be careful to round out the soldered connections between the eye of the needle and the shortened h.v. lead.

Ionic Propulsion Vane. Probably the most impressive demonstration of a Tesla coil is the ionic propulsion vane. You can make one for Li'l TC by cutting out the general pattern shown in the diagram above.

Make the over-all length of the vane about 1″ to 1½″. Cut the vane from aluminum foil and puncture the center so that the vane is balanced. Use one of your wife's extra beads as a bearing by slipping it on the upright needle. Then drop the vane over the needle so that it rests on the bead and can rotate freely. Put a piece of cork or rubber on the tip of the needle to stop the vane from picking up so much speed that it spins right off the needle.

The photograph on the first page of this article is a two-second time exposure (slightly enlarged) showing what the brush corona discharge and rotating vane should look like. —30—



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CHAPTER

5 COMMUNICATIONS SWL CB HAM

Projects included in this chapter of the ELECTRONIC EXPERIMENTER'S HANDBOOK are aimed at the 6-meter ham with a Technician Class license. In case you are not already aware of it, Technician Class hams can operate in the 50-mc. band and above. The license requires passing the regular theory examination but only a 5-wpm code sending and receiving ability. It is issued for a 5-year period—unlike the Novice license (1 year)—and can be renewed.

A companion unit to the 6-meter receiver (ELECTRONIC EXPERIMENTER'S HANDBOOK, 1964 Edition) is the 6-meter transmitter on page 111. If you want to improve receiver sensitivity, the small outboard r.f. preamplifier (page 121) may be your cup of tea. Also intended for the Technician (or General Class ham) is the solid-state converter (page 104). This converter has extraordinary sensitivity and can be broad-banded to cover 1.5 megacycles.

Two valuable projects round off this chapter: a speech filter with fully adjustable controls (page 107), and some excellent ideas on how to pep up AM receiver sensitivity (page 116).

TRANSISTORIZED 6-METER CONVERTER

By ROY C. HEJHALL, K7QWR

Build a sensitive converter using inexpensive mesa transistors

GOOD PERFORMANCE can be obtained on six meters with a transistorized converter that uses inexpensive transistors and is easy to construct. The converter described in this article incorporates three Motorola 2N963 *pnp* mesa transistors which can be purchased for about the same price as a set of tubes for a vacuum-tube converter. The total parts cost (including the transistors and the 43-mc. crystal) is under $20 if all new components are employed. Sensitivity of the unit is about 1 microvolt for a 10-db signal-to-noise ratio.

The Circuit. The converter consists of an r.f. amplifier, a mixer, and an oscillator. The r.f. amplifier stage is a neutralized common-emitter circuit. The mixer is also common-emitter, and base injection of the oscillator signal is used for simplicity. The crystal oscillator is a Colpitts type using a third-overtone crystal to generate the required 43-mc. oscillator signal directly. The intermediate frequency is 7 to 11 mc., which allows a 40-meter receiver with bandspread to be employed for the low end of six meters. Input impedance of the converter is 50 ohms.

Power requirements are 9 volts d.c. at about 8 ma. Either a power supply or a 9-volt transistor radio battery can be used to power the converter. The power supply leads are filtered to reduce spurious responses.

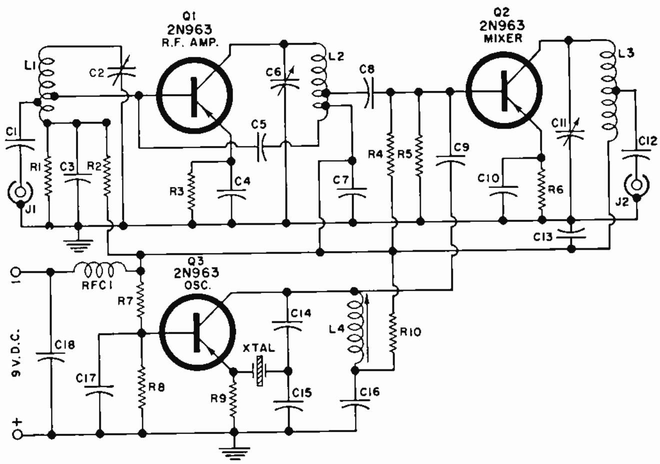
Construction. The converter was constructed on a copper chassis, which was cut and formed as shown in the photos, so that the completed converter could be enclosed in a gray LMB 5¼" x 3" x 2⅛" chassis box. Copper was selected for the chassis only for ease in soldering components directly to it; an aluminum chassis could have been used with equal success.

Each end of the chassis was slotted for BNC coaxial connectors; the connectors serve as input and output signal jacks and also clamp the chassis to the box. Care must be given to vertical placement of the chassis in the box, since the crystal above and coil forms below the chassis leave little clearance when the box is assembled. Two banana jacks were mounted in the box for power supply leads.

The usual precautions in VHF wiring, such as short leads and minimum chassis current paths, should be observed. The photograph of the bottom of the chassis can be used as a guide for layout. It is suggested that the general layout of the r.f. stage, including the shield between base and collector, be followed. Minor changes will be insignificant, but a radically different layout might affect neutralization.

There are no special precautions to be taken in the construction of the mixer and oscillator stages. The r.f. stage shield should also function to shield local oscillator signals from the r.f. stage input.

The coils are wound on ¼"-diameter coil forms. The oscillator coil is slug-tuned; the other coils have no slugs. Another version of the converter has been built by the author using no coil forms in the r.f. stage input and output



The 3-db bandwidth of this converter is approximately 1600 kc. Alignment should be set up on about 50.5 mc. to put the most sensitive part of the bandwidth in the low end of the 6-meter band. Good results can still be obtained up around 51.5 mc.

circuits, since the #20 wire used is rigid enough to support itself.

Building the converter on such a small chassis did cause some crowding of components, and a slightly larger chassis and box could be used, particularly if you want to power the converter with an internal battery.

Alignment and Testing. Before attempting alignment, a check for correct d.c. operating conditions should be made. About the simplest check is to measure total current drain; it shoud be about 8 ma.

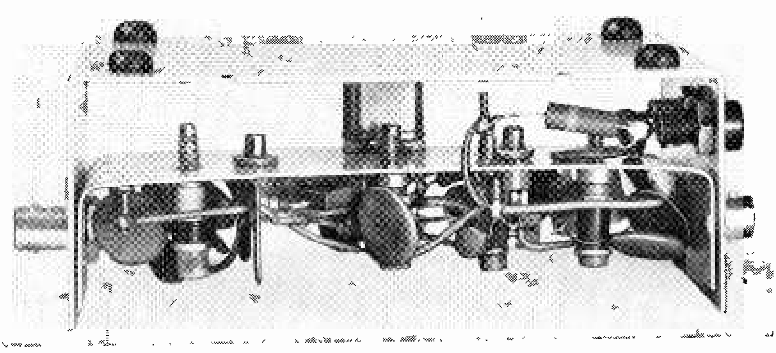
The first step in the alignment procedure is to tune the r.f. input and output circuits and the mixer output circuit to approximate resonance, using a grid-dip meter. This can be done with the power to the converter off. Couple the grid-dip meter to *L1* and tune *C2* for resonance at 50 mc. In the same manner, couple to *L2* and tune *C6* for resonance at 50 mc. Then couple to *L3* and tune *C11* for resonance at 7 mc. In each case, a definite dip should be obtained if the circuits are operating properly.

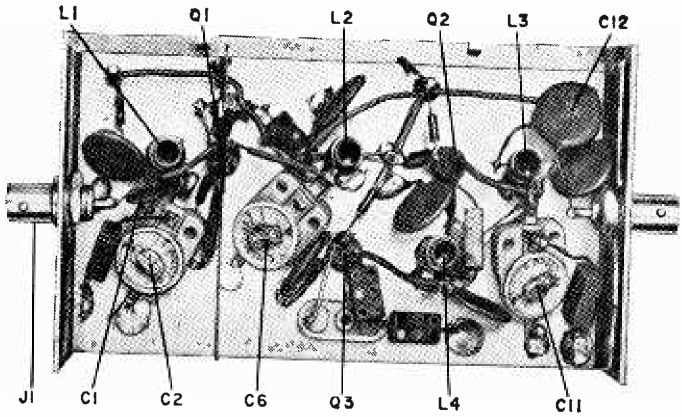
The next step is to adjust the oscillator coil (*L4*) slug. Set the slug about mid-range in the coil. Connect an r.f. signal generator to the converter input jack and connect the converter output to the antenna terminals of any receiver which will tune to 7 mc. Then connect a 9-volt d.c. power source to the converter. Apply a 50-mc. modulated signal to the converter and locate the signal with the receiver tuned to 7 mc. If the oscillator is detuned too far, it may not oscillate; so if the signal cannot be located at first, continue to search for it while slowly moving the oscillator slug. Once the signal is located, adjust the slug for maximum audio output in the receiver.

Now, with the 50-mc. signal still applied to the converter input, tune *C2*, *C6*, and *C11* for maximum signal output.

If the converter is constructed in a box, placing the cover on the box has a

A piece of copper is bent to form a sub-chassis and mounted as shown. Power for the converter goes through the tip jacks on the right-hand side of the box. If you have not already noticed, the converter is upside down in this illustration.





This under-chassis view of the converter shows the location of the major components. A shield extends across the socket of transistor Q1 to prevent coupling between L1 and L2. The crystal socket is just visible below Q3. Output jack J2 is unlabeled, but is located at the right of the chassis.

slight effect on alignment. Therefore, holes should be drilled in the box to allow the final peaking of *C2*, *C6*, and *C11* to be done with the box assembled.

If no grid-dip meter is available, it is possible to skip the first alignment step by tuning *C2*, *C6*, and *C11* all about mid-range, and using a strong signal from the signal generator until the signal is located with the receiver. Once the signal has been located, the remainder of the alignment is carried out as described.

If no signal generator is available, tuning *C2*, *C6*, and *C11* to approximate resonance with a grid-dip meter should be done first, as before. Then the converter input is connected to a 6-meter antenna and the remainder of the alignment procedure performed as previously described, except that on-the-air signals are used in place of the signal generator.

Aligment can be performed at any frequency in the 6-meter band where maximum sensitivity is desired. The 3-db bandwidth of the converter is 1.6 mc., and if the alignment is done at 50.5 mc., the converter will provide optimum performance from 50.0 to 51.5 mc.

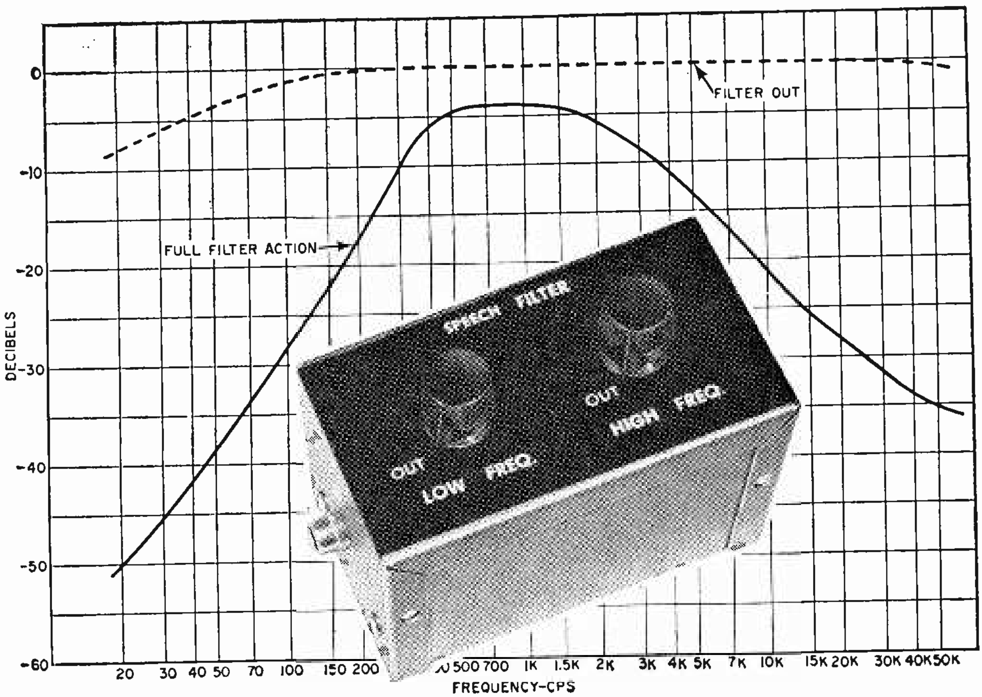
Once proper alignment has been completed, it probably will never have to be done again, since transistor characteristics normally do not change with age and the life expectancy of the transistors is greater than that of the person constructing the converter. Also, the circuit operates at room temperature, so there is no heat present to harm the other components.

Some spurious responses may be encountered from strong TV or FM broadcast stations mixing with oscillator harmonics. The best cure for this is to place a trap for the offending station or a 6-meter low-pass filter ahead of the converter.

The author wishes to express his thanks to Frank Davis, K7VKH, for his valuable assistance throughout this project. —30—

PARTS LIST

C1—0.003-µf. disc ceramic capacitor
C2, C6—5-80 pf. mica compression or ceramic trimmer capacitor
C3, C7—0.1-µf. disc ceramic capacitor
C4—0.01-µf. disc ceramic capacitor
C5—18-pf. mica capacitor
C8—0.001-µf. disc ceramic capacitor
C9—5-pf. mica capacitor
C10—0.05-µf. ceramic capacitor
C11—25-280 pf. mica compression or ceramic trimmer capacitor
C12, C13, C16, C17, C18—0.02-µf. ceramic capacitor
C14—12-pf. mica capacitor
C15—82-pf. mica capacitor
J1, J2—BNC coax connector
L1—5 turns of #20 enamel-covered wire, ¼" diameter, close-wound; tapped 1 turn and 2 turns from cold end (0.15 µh.)
L2—8 turns of #20 enamel-covered wire, ¼"-diameter, close-wound, tapped 2 turns and 4½ turns from cold end (0.19 µh.)
L3—26 turns of #28 enamel-covered wire, ¼"-diameter, close-wound, center-tapped (2.3 µh.)
L4—10 turns of #26 enamel-covered wire, ¼"-diameter, close-wound, slug-tuned (0.55 to 0.85 µh.)
Q1, Q2, Q3—2N963 transistor
R1—5100 ohms
R2—8200 ohms
R3—1200 ohms
R4—11,000 ohms
R5—10,000 ohms
R6—2000 ohms
R7—12,000 ohms
R8—2200 ohms
R9—470 ohms
R10—1000 ohms
(R1–R10: all resistors ¼ watt)
RFC1—18-µh. r.f. choke
Xtal—43-mc. third-overtone crystal



An Adjustable Speech Filter

Cut out noise and increase intelligibility with this all-purpose amateur, CB, hi-fi, and recording filter

By DANIEL MEYER

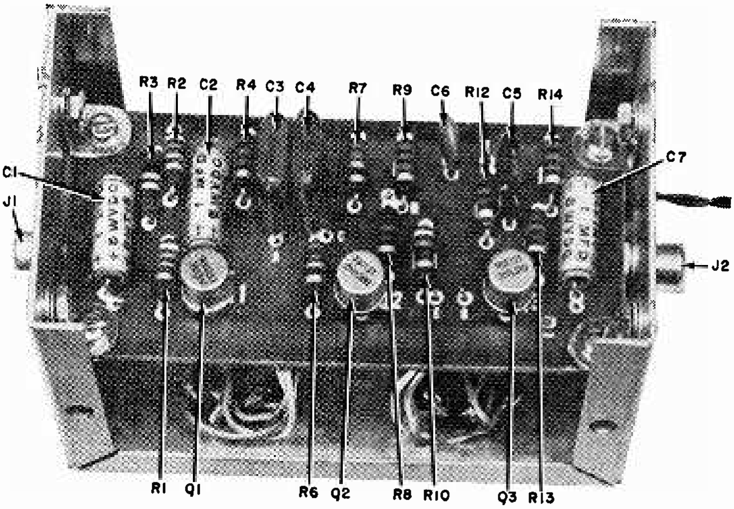
WOULD YOU LIKE to have a speech filter to use with your CB receiver that could be adjusted to give the best reception for various signals and noise conditions? A filter that can also be used with your transmitter to get more modulation in the 300 to 3000 cycle range where it will do the most good? A versatile unit which can also be used with your hi-fi system to clear up the noise on old recordings or weak FM signals? If so, here is a simple three-transistor circuit that will do these jobs and more.

Two feedback-type filters are used to produce the high and low frequency attenuation. The circuit has zero unity gain and may therefore be used at any point in a system that has a signal level of one volt or less. In addition, the amount of high or low frequency filtering may be adjusted and either filter may be switched out of the circuit to give a flat response.

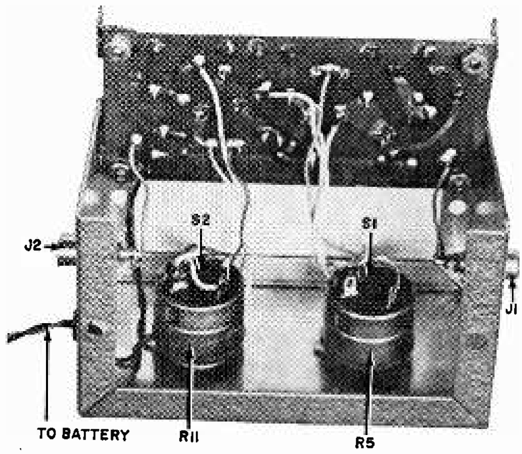
How It Works. Transistor *Q1* is an emitter follower which gives the filter a high input impedance and also provides a low impedance driving source for transistor *Q2*. Capacitor *C2* and resistor *R3* form a feedback loop around transistor *Q1* that reduces the loading effect of the bias resistors *R1* and *R2* on the input of the filter.

Transistor *Q2*, with its associated resistors and capacitors, acts as a variable, *high-pass*, active filter. Potentiometer *R5* varies the cutoff frequency of the filter from approximately 100 to 400 cycles. In the "out" position of *R5*, switch *S1* closes and shorts out the filter.

Transistor *Q3*, with its associated components, is a variable, *low-pass*, ac-



Refer to the schematic diagram on the facing page to locate the components in photo above.



Potentiometers, switches and jacks are wired before the board is installed in cabinet.

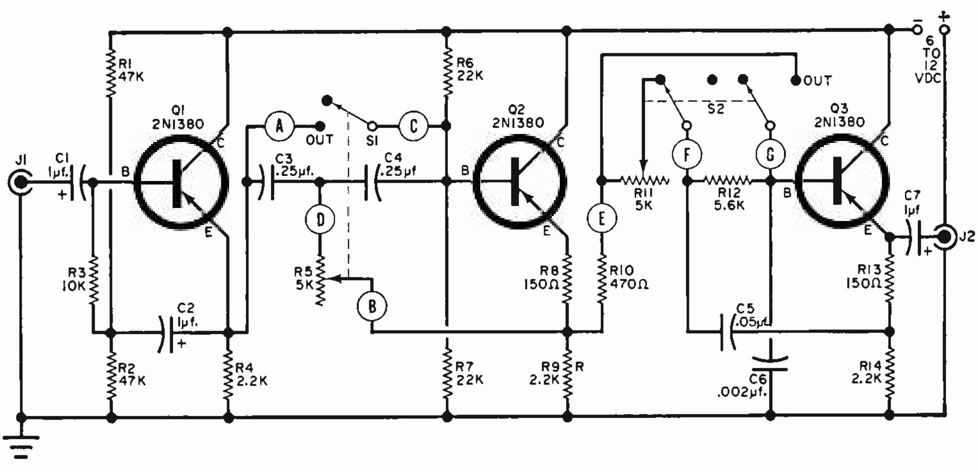
tive filter. Potentiometer *R11* is used to vary the cutoff frequency of the filter from approximately 3000 to 6000 cycles. In the "out" position of *R11*, the normally closed pole of switch *S2* opens and breaks the signal connection to *R11*, while the normally open pole of the switch closes and shunts the signal around the filter.

The input impedance of the filter is about 50,000 ohms and the output impedance on the order of 1000 ohms. The circuit draws 6 ma. at 12 volts d.c. or 3 ma. at 6 volts d.c.

Constructing the Filter. The filter is built on a printed-circuit board to simplify construction and make for compactness. Install the parts on the board in the positions indicated, and solder to the etched copper pattern on the reverse side of the board. Use rosin core solder throughout, and use an iron rated at less than 50 watts. Solder the connections as quickly as possible to avoid prolonged heating of the laminate.

Next, drill the holes for the connectors and the controls. Mark the hole positions with a punch, then use a 1/16" drill to make pilot holes. Now drill out the connector holes to 1/4" and the control mounting holes to 3/8". Place a block of wood under the metal during the drilling operation.

Cut the shafts of potentiometers *R5* and *R11* to a length of 3/8" from the mounting bushing. Mount *R5*, *R11*, *J1* and *J2* on the case. Use lock washers between the controls and the case to



PARTS LIST

C1, C2, C7—1-μf., 6-volt electrolytic capacitor
C3, C4—0.25-μf., 75-volt capacitor
C5—0.05-μf., 75-volt capacitor
C6—0.002-μf., 75-volt capacitor
J1, J2—Phono jack
Q1, Q2, Q3—2N1380 transistor
R1, R2—47,000 ohms
R3—10,000 ohms
R4, R9, R14—2200 ohms
R6, R7—22,000 ohms
R8, R13—150 ohms
R10—470 ohms
R12—5600 ohms
(R1 through R12: All ½-watt fixed resistors)
R5, R11—5000-ohm potentiometer with d.p.d.t. switch, log taper (Centralab B-12 with KR-3 switch)
S1, S2—D.p.d.t. switch mounted on rear of R5, R11
4—Mounting brackets (Cambridge Thermionic Corp. 1963 or equivalent)
1—2¼"x2¼"x4" aluminum case (Bud CU-2103 or equivalent)
1—Circuit board (the author used an etched-circuit board (No. 101) which is available with three transistor sockets for $1.25 from Demco, Box 16041, San Antonio, Texas 78216)

prevent slipping while using the unit.

Now wire the controls (low-frequency filter *R5*, high-frequency filter *R11*, and jacks *J1* and *J2*). Follow the schematic diagram and photographs. The wires from these controls are connected to the coded points on the board corresponding to similar points on the schematic. Fasten the board to the brackets, and mount the entire assembly in the case.

Testing. Before applying voltage to the filter, check carefully for shorts or incorrect connections. Now connect the points marked plus and minus to a 6-to-12 volt battery or power supply. Note that the positive lead is grounded and common to both the input and the output.

Do not attempt to connect the filter in an automotive electrical system if the car has a negative ground. If the filter has to be used with a mobile system, strap a 6-volt dry cell to the rear of the filter box for a power supply. This will also help keep ignition noise out of the filter and eliminate any possibility of short-circuiting the electrical system.

The input and output connections may be made to the filter at any point in the circuit having a signal level of less than one volt. The best place to connect into a receiver would be at the volume control. Simply disconnect the wire from the center terminal (wiper) of the volume control and connect the input of the filter to this terminal. The wire is then connected to the filter output.

On a transmitter, the filter can be used with a crystal microphone, but volume will be reduced due to the loading effect of the 50,000-ohm input impedance of the filter on the high-impedance crystal. In a hi-fi system, the filter can be installed between the preamplifier and the power amplifier units.

Using the Filter. Turn the control knobs to the position that will clear up the maximum amount of noise without affecting the intelligibility of the speech or distorting the music any more than necessary. For communications work, especially under noisy conditions, you will find that the narrower bandpass settings are the most desirable. If conditions on the band improve, you may want to set the filter for a wider response, but let the noise on the band dictate this. Should noise conditions clear up completely, or if you want an absolutely flat response, you can easily switch the filter completely out of the circuit by rotating the controls fully counterclockwise until the switches engage. The response will now be an essentially flat $\pm$ 1 db from 10 to 50,000 cycles. The filter itself has less than one per cent total harmonic distortion in its bandpass for any given setting of the controls.

The device can also be used for many special effects in tape recording, where it functions almost in an opposite manner to a reverberation unit or echo chamber. You can usually connect the filter into the tape recorder's recording preamplifier right at the record level controls. (Naturally, for stereo effects you will require two filters.) With the filter in the circuit, and the controls rotated clockwise, you will notice a marked decrease of high and low frequencies. Since all the high-fidelity manufacturers are trying to open up the frequency response, you may well wonder how such a filter can be considered beneficial. Speech recorded through the filter will easily simulate telephone conversations, or communications radio reception. Other applications are certain to suggest themselves upon experimentation.

In a mobile installation, you will find this filter an ideal adjunct to your electronic equipment, be it broadcast, Citizens Band or amateur radio. Static noise is largely a high frequency function, and as you can sharply attenuate high frequencies with this filter, you can reduce static.

If you follow the diagrams, photographs and instructions, you will have no trouble putting the filter together and getting it to work properly. After you have used it for a while to silence static, or break through local noise with your transmitter, you'll probably find it indispensable. —30—

THE COMPANION 6-METER TRANSMITTER

Just two tubes and a power supply give you a 6-meter phone transmitter that's hard to beat for simplicity

By **CHARLES GREEN,** W3IKH

WANT TO KNOW how you can put a high-quality 6-watt, 6-meter phone signal on the air at a rock-bottom price? It's easy—just build this beautifully simple three-tube (counting the rectifier) "Companion Transmitter." Although this attractive little rig was designed to complement the "Simple Superhet for 6" which appeared in the April, 1963, issue of POPULAR ELECTRONICS and the 1964 ELECTRONIC EXPERIMENTER'S HANDBOOK, it can be used with any 6-meter receiving setup.

Designed for easy construction, the Companion Transmitter incorporates two 6CX8's, combination triode-pentodes (*V1b* and *V2b* have internally connected suppressor grids) ordinarily used in TV receivers. In the r.f. section, the triode portion of one 6CX8 (*V1a*) functions as a crystal overtone oscillator using standard FT-243 8-9 mc. crystals to produce an output in the 25-mc. region.

The pentode section of the 6CX8 (*V1b*) in the r.f. section is both a doubler and final amplifier; this type of circuit was chosen as it does not require neutralization. The plate circuit pi-network matches the r.f. output to an antenna of 50 to 72 ohms impedance.

As shown in the schematic on page 113, a second 6CX8 does duty as a speech amplifier-modulator. The mike input signal from *J4* is amplified by *V2a* and fed through *C15* to the grid of *V2b*. The signal is further amplified by *V2b* which modulates the r.f. output by means of the inductance of *T1* which is common to the plate circuits of both *V1b* and *V2b*. Only the primary winding of *T1* is used.

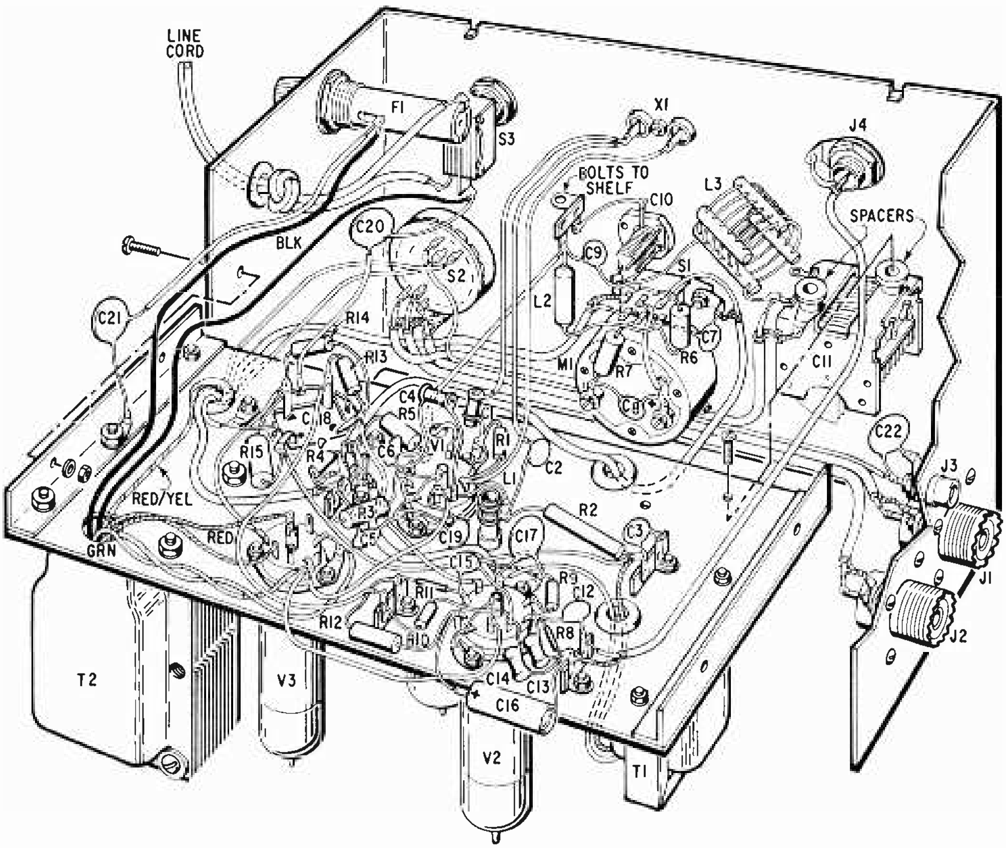
Metering of the final is provided by *M1*, connected to measure either grid or plate current using switch *S1*. Rotary switch *S2* is a d.p.d.t. type which switches the antenna and receiver and transmitter B-plus supplies when going from receive to transmit. A 6X4 rectifier (*V3*) and the *RC* filter circuits of *C18* and *R13*, *R14*, *R15* deliver the required B-plus voltages to the transmitter circuits.

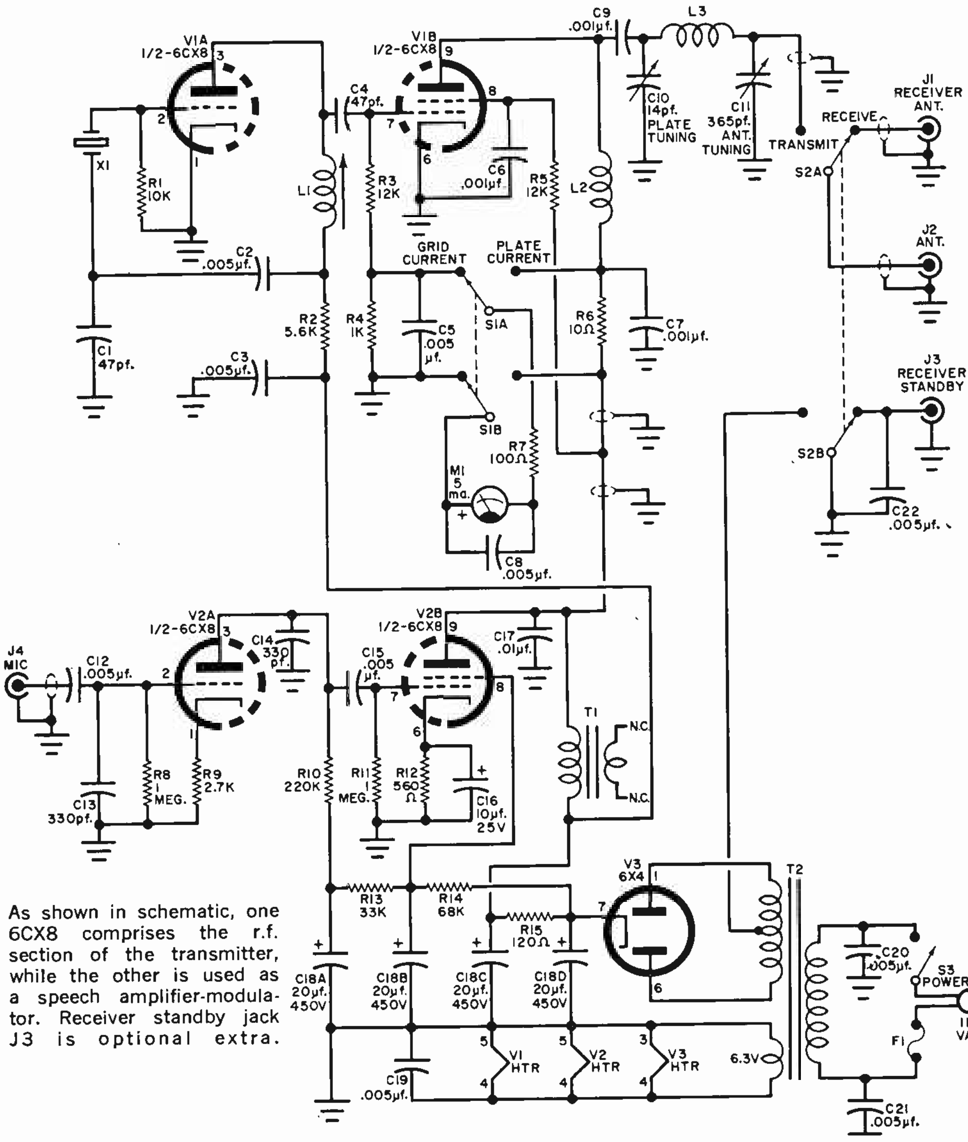
Layout and Construction. To simplify construction, the bulk of the transmitter is built on a 4½" x 8" piece of aluminum. As shown in the photographs and pictorial diagram, this piece of aluminum is mounted 2" from the bottom of a 4½" x 6" x 8" utility box with aluminum angle stock. It will pay you to follow the layout shown as closely as possible, as lead length and component placement are relatively critical at 6 meters. Grouping the components on the chassis before you cut the mounting holes will help you determine the best layout.

Antenna tuning capacitor *C11* is mounted on the top of the chassis shelf with two ⅜" spacers to clear its Bakelite end plates. Bend up the unused lugs. Mount a single-lug terminal strip under one of the mounting screws of the filter capacitor (*C18*) on the chassis top to connect *C9* and *L2* to the plate lead from *V1b*. Drill a hole for this lead, and position it so it does not touch the chassis. Position *C9* annd *L2* at least ½" away from *V1*'s envelope, and make their leads as short as possible. The shielded wire to meter switch *S1* should be positioned against the front panel, away from pi-network coil *L3*.

The leads going from *J1*, *J2*, *J3*, and from the junction of *C11*-*L3* to transmit switch *S2* should be positioned over the top of the back of meter *M1* and taped together. All of the leads except that going from *J3* are made of RG-58/U coaxial cable. The secondary leads of *T1* are not used, and should be cut short

Layout is shown in pictorial below. For approximate spacing, see right photo on page 114.





As shown in schematic, one 6CX8 comprises the r.f. section of the transmitter, while the other is used as a speech amplifier-modulator. Receiver standby jack J3 is optional extra.

and taped. In completing the Companion Transmitter, make sure the meter switch is labeled correctly: "G" for grid drive and "P" for plate current. Drill a 3/8" hole in the top of the box for adjusting grid drive coil *L1*, and cut a row or two of holes in the back of the box cover for ventilation.

Testing and Adjustment. Insert the tubes in their sockets and a good active crystal in the front panel crystal socket. Place the cover on the transmitter, install a 52-ohm dummy load at jack *J2* and let the unit warm up for a minute or two. Set switch *S1* to measure grid current, and insert a plastic alignment screwdriver through the access hole in the cover onto the adjustment slug of coil *L1*.

Depress transmit switch *S2* and adjust the grid current to 2 ma. This adjustment should be made as quickly as possible to prevent damage to the tube. If the grid current adjustment cannot be

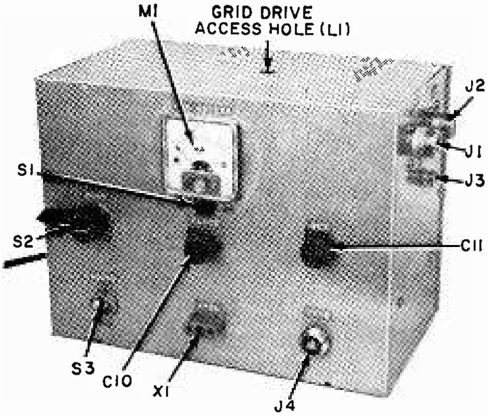
PARTS LIST

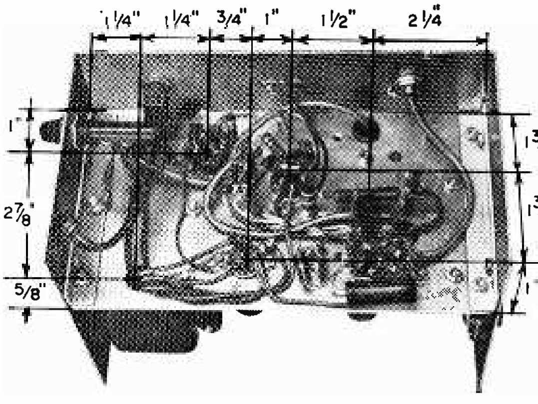
C1, C4—47-pf., 600-volt ceramic tubular capacitor
C2, C3, C5, C8, C12, C15, C19, C20, C21, C22—0.005-μf., 1000-volt ceramic disc capacitor
C6, C7, C9—0.001-μf., 1000-volt ceramic disc capacitor
C10—14-pf. miniature variable capacitor (E. F. Johnson Type 160-107 or equivalent)
C11—365-pf. variable capacitor (Lafayette 32-G-1103 or equivalent)
C13, C14—330-pf., 1000-volt ceramic tubular or mica capacitor
C16—10-μf., 25-volt electrolytic capacitor
C17—0.01-μf., 1000-volt ceramic disc capacitor
C18—Four-section electrolytic capacitor, 20 μf., 450 volts per section
F1—1-amp type 3AG fuse in panel-mounting fuse holder
J1, J2—Chassis-mounting coax receptacle (Amphenol 83-1R or equivalent)
J3—Phono pin jack, single-hole mounting
J4—Microphone connector, male, chassis-mounting (Amphenol 75-PC1M or equivalent)
L1—3.3-μh. to 4.1-μh., miniature adjustable r.f. coil (J. W. Miller Part No. 20A336RBI)
L2—7-μh. r.f. choke (Ohmite Z-50 or equivalent)
L3—6 turns of B&W "Miniductor" Type 3010 with 3/8" leads (coil size 11/16" x 3/4" dia.)
M1—5-ma. d.c. panel meter
R1—10,000-ohm, 1/2-watt resistor
R2—5600-ohm, 2-watt resistor
R3, R5—12,000-ohm, 1-watt resistor
R4—1000-ohm, 1/2-watt resistor
R6—10-ohm, 1/2-watt resistor
R7—100-ohm, 1/2-watt resistor
R8, R11—1-megohm, 1/2-watt resistor
R9—2700-ohm, 1/2-watt resistor
R10—220,000-ohm, 1/2-watt resistor
R12—560-ohm, 1-watt resistor
R13—33,000-ohm, 1-watt resistor
R14—68,000-ohm, 1-watt resistor
R15—120-ohm, 1-watt resistor
S1—D.p.d.t. slide switch
S2—D.p.d.t. rotary switch, non-shorting (Mallory Type 3222J)
S3—S.p.s.t. toggle switch
T1—Audio output transformer; primary, 10,000 ohms, secondary 4 ohms (Stancor A-3879 or equivalent)
T2—Power transformer; primary, 117 volts; secondaries, 460 volts CT @ 50 ma., 6.3 volts @ 2.5 amp (Thordarson 24R11-U)
V1, V2—6CX8 vacuum tube
V3—6X4 vacuum tube
X1—8.+mc. transmitting crystal
1—4 1/2" x 6" x 8" aluminum utility box (LMB 146 or equivalent)
1—4 1/2" x 8" aluminum plate for chassis shelf
2—9-pin miniature tube socket
1—7-pin miniature tube socket
1—Xtal socket for FT-243 crystal holders
Misc.—Aluminum angle stock, terminal strips, RG-58/U cable, shielded audio cable, hookup wire, hardware, solder lugs, grommets, etc.

made, change the crystal for a more active one. Set the transmit switch to standby position and move the meter switch to indicate plate current. Rotate the antenna tuning control to the maximum counterclockwise position (full capacity) and depress the transmit switch. Tune the plate for maximum current dip, then adjust the antenna and plate controls alternately until the current is 22 ma. The last adjustment should be made with the plate tuning control. At this point, the transmitter is fully loaded.

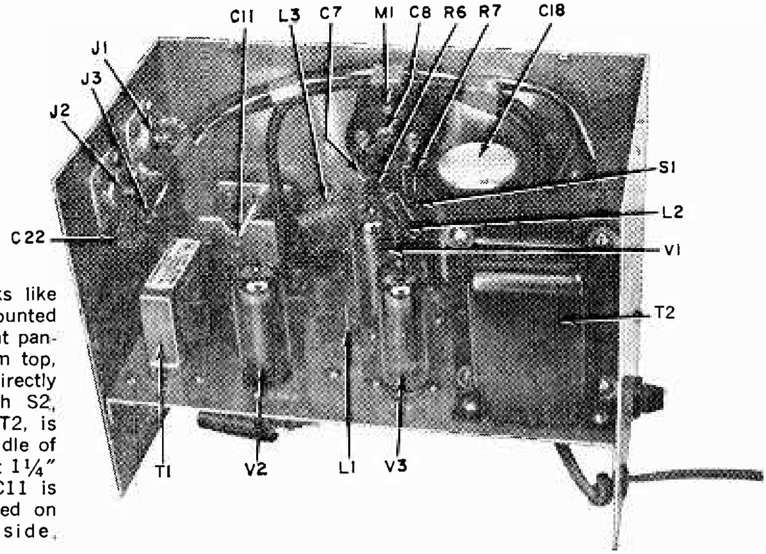
Check the grid current again, and reset *L1* if necessary for a 2-ma. reading. These tune-up procedures should also be used for on-the-air operation with an antenna connected in place of the dummy load.

Your receiver can be used to check modulation with a high-output crystal mike connected to *J4*. The radiation from the dummy load should be sufficient for this test. In the interests of economy and simplicity, the speech amplifier-modulator of the Companion





The dimensions above show approximate component spacing.



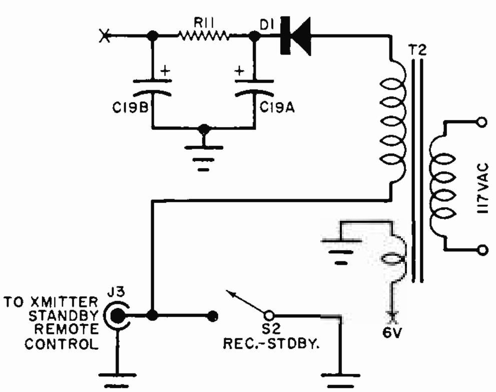
Top of rig looks like this, with M1 mounted at center of front panel and ½" from top, S1 and C10 directly below it. Switch S2, hidden behind T2, is mounted in middle of panel and about 1¼" in from side; C11 is similarly mounted on the opposite side.

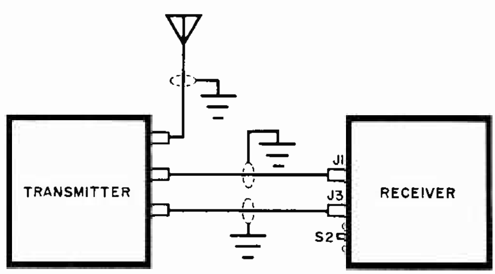
Transmitter was limited to a single tube. For this reason, a high-output mike must be used for a good percentage of modulation. Strongly recommended is the Astatic Model 150 recorder mike which has an output of —44 db. It is readily available and sells for under $4.00.

"Simple Superhet" Conversion. If you plan to use the "Simple Superhet for 6" as the station receiver, a few simple modifications will give you improved reception and single-switch operation.

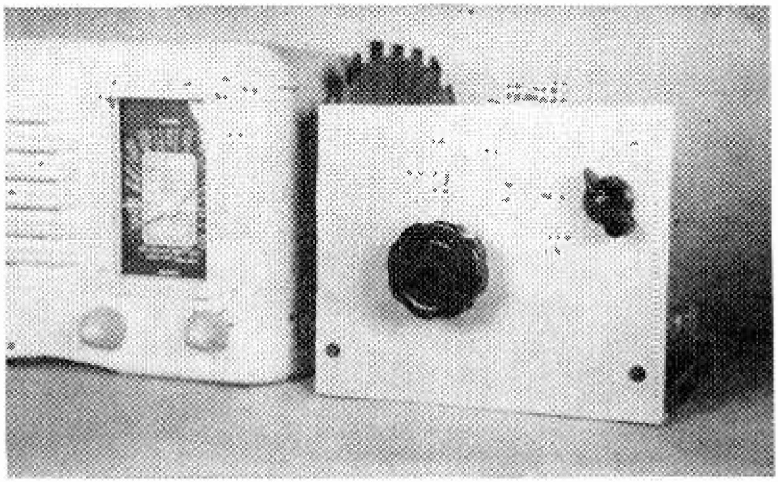
A remote control jack and standby switch (*J3* and *S2* in the drawing below) are installed on the side of the receiver cabinet. The ground lead of the receiver transformer is then connected as shown. This arrangement permits transmitter switch *S2* to control the receiver. More B-plus for the receiver can be obtained by replacing the selenium rectifier (see the April, 1963, issue) with a 400-PIV, 450-ma. silicon unit.

The most-used portion of the 6-meter band, 50-51 mc., can be made to cover more of the receiver dial by connecting a 10-pf., 600-volt ceramic tubular capacitor between the stators of *C1* and *C2*. Readjust the bandset capacitor *C2* and calibrate the receiver as described in the original article. —30—





Receiver is modified as shown at left to permit single switch operation of station. Connections between the units are for antenna and power switching.



SOUP UP THAT AM BROADCAST RECEIVER

By **F. J. BAUER, Jr.,** W6FPO

Want to improve the sensitivity of your small receiver? Here are several ideas that really work

IF BROADCAST BAND DX'ing is your cup of tea, you are aware of the shortcomings of the "All-American 5" and the built-in loop antenna. As the loop is not just a signal catcher but also a part of the first tuned circuit of the receiver, you can't tamper with it without altering receiver alignment.

Simple Coupler. Will a coupler and long-wire antenna improve your reception? They certainly will, and here's a quick-and-dirty test to prove the point. String up a good antenna, the longer (at least 50 to 100 feet) and higher the better. Connect one end of this wire to a four- or five-turn coil of wire that you wind around your hand. The other end of the coil goes to a good water-pipe ground (see Fig. 1, on page 120). Now tune in a weak station and bring the coil of wire closer to the loop antenna on the receiver. See? The signal strength increases, and the weak station comes in strong. The next step is to build something more permament.

A Better Coupler. A better antenna coupler tunes the antenna to the frequency of the station you want to hear. It consists of an adjustable ferrite coil with a series capacitor that can be switched in or out of the circuit (Fig. 2). With the capacitor in the circuit, the upper half of the broadcast band is covered, and with the capacitor out of the circuit, the lower half is covered. You can adjust the ferrite coil to obtain optimum results.

Still Better. A more elaborate, more flexible coupler will work with any antenna length (Fig. 3). The author utilized parts available in the junk box, using coil *L2* for maximum coupling to the receiver. This coil was salvaged from an old receiver as was capacitor *C1*, made by paralleling the three sections of an old tuning capacitor.

Adjusting the Couplers. The first thing to do is determine the amount of "coupling" that will best suit your own

(*Continued on page* 120)

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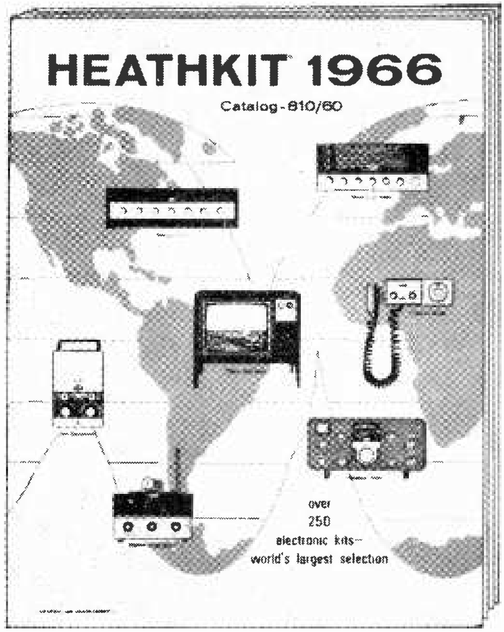

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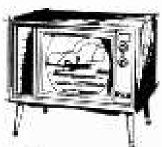

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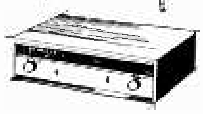

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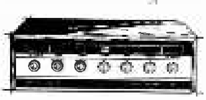

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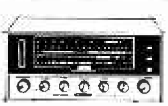

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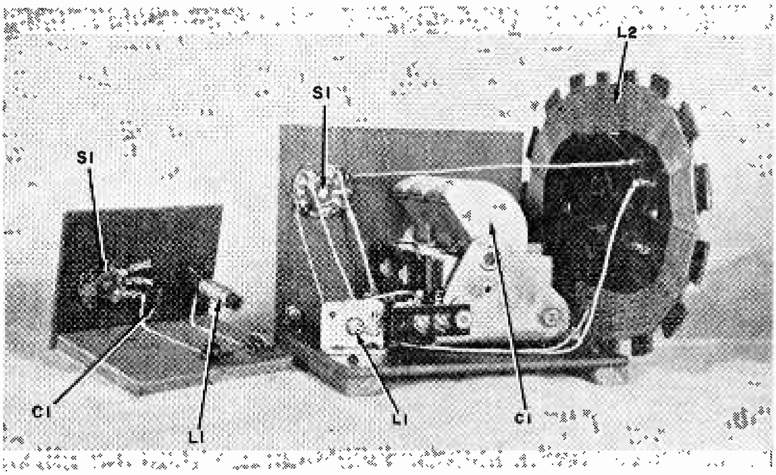


Looking at the backs of the two couplers diagrammed in Figs. 2 and 3, it's obvious that there isn't any complex wiring to be done. Use point-to-point wiring throughout, build panels of Masonite, woodscrap.

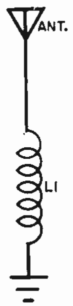


Fig. 1. Simple coupler consists of four or five turns of wire connected to a long (50′-100′) antenna and good ground. To use, place coil near receiver's antenna.

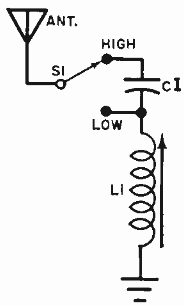


Fig. 2. Better coupler has s.p.d.t. switch to insert or remove 100-pf. capacitor C1. Ferrite antenna coil L1 fine-tunes antenna.

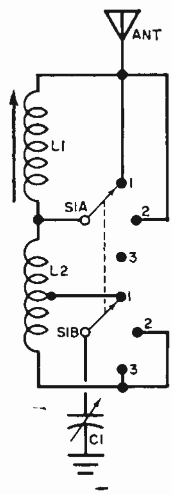


Fig. 3. This coupler is more flexible. A double-pole, 3-position switch selects portion of band to be heard, .001-μf. capacitor C1 fine-tunes.

system. ("Coupling" refers to the placement of your antenna coupler with relation to your receiver antenna coil.) There are two ways to do this. If you have a VTVM, connect it to the a.v.c. bus in your receiver. Now move the coupler closer to your antenna coil as you observe the meter. The voltage will increase—to a point—and then start to fall off. The best location for the coupler is where it was at that highest voltage point.

A simpler way to achieve maximum coupling efficiency is to place the antenna wire near a fluorescent fixture and couple for maximum noise in the receiver loudspeaker. In either case, do not increase the coupling beyond the optimum point, for over-coupling serves only to introduce interference with no increase in gain.

Using the Couplers. To use the coupler shown in Fig. 2, first select the switch position (capacitor *C1*—a 100-pf. unit in this coupler—in or out) that corresponds with the frequency you want to hear, and then adjust the slug in *L1* for best reception. Coil *L1* in Figs. 2 and 3 is an Olson Radio No. L-75.

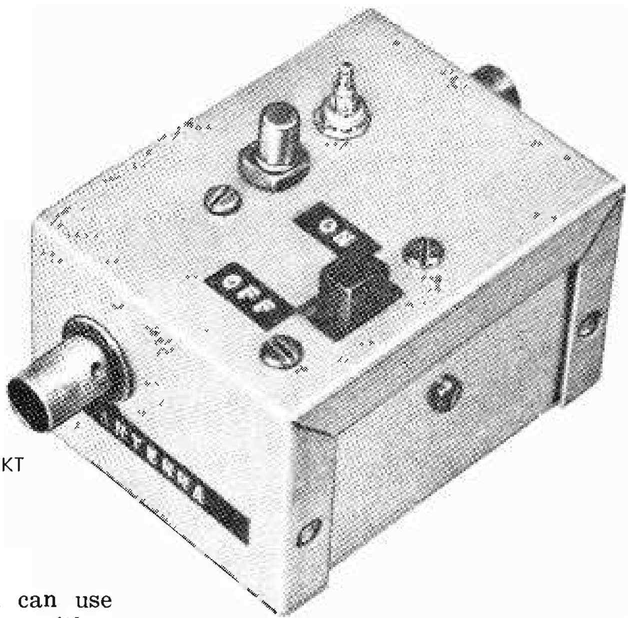
To use the coupler shown in Fig. 3, tune in a station near 540 kc., with the plates of capacitor *C1* (.001 μf.) fully meshed, and adjust the slug in coil *L1* for maximum volume. Then you can use switch *S1* to rough-tune the coupler, and capacitor *C1* to fine-tune. The switch positions and frequency ranges are as follows:

Switch Position	*Frequency*
1	540- 870 kc.
2 *(center tap)*	740-1200 kc.
3	1100-1650 kc.

An outdoor antenna will improve any "All-American 5." An antenna coupler will permit you to use an outdoor antenna with your receiver. —30—

THE 6 METER 7 AND 2 PREAMP

A high-gain, low-noise transistor preamp for 6—for just $7 and 2 hours of labor



By **JOSEPH TARTAS,** W2YKT

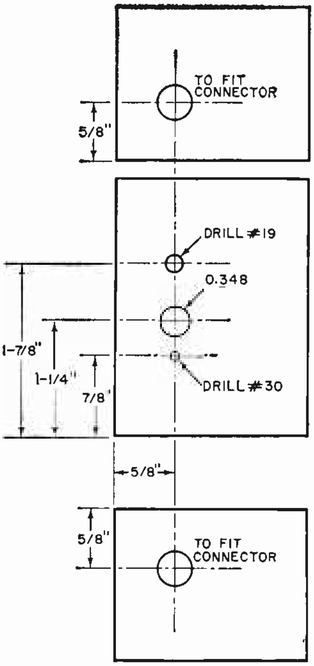
IF YOU work 6 meters and can use more r.f. gain on receive along with a reduction in signal-to-noise ratio (and who can't?), the "6 Meter 7 and 2 Preamp" is for you. Heart of this little one-evening project is a new low-noise germanium transistor, the 2N2188, made by Texas Instruments. At 50 mc., the preamp has a measured 6 db noise figure, which represents a maximum sensitivity (the smallest signal it can receive) of about 1.5 μv. Inserted between the antenna and receiver input, it can boost signal level by at least 12 to 15 db.

Other advantages of the preamp are that it is compact and self-powered—at a battery drain of 4 ma., the battery should last for nearly its shelf life. Although the unit was designed for 50-ohm input and output, it will work well at impedances up to 300 ohms without much deterioration in performance. Lastly, the total cost is only about $7.00.

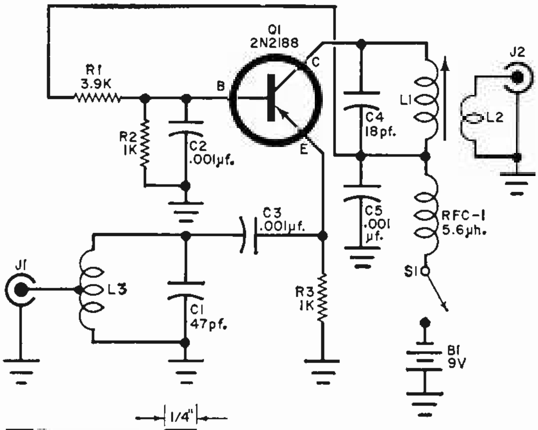
The 6-meter preamp is housed in a small 1⅝" x 2⅛" x 2¾" Minibox, and straight-line, minimum length leads are employed. Carefully follow the layout as shown in the photos. Drill holes in the box for mounting r.f. connectors *J1* and *J2* (use the type you presently employ for convenience), the on-off switch *S1*, the transistor socket, and the output coil form (*L1* and *L2*).

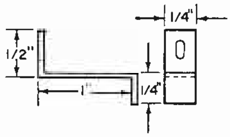
The Coils. Wind input coil *L3* with #14 wire; consisting of five turns with an i.d. of ⅜", it should have an approximate length of ½". Support it by soldering the center turn directly to the center conductor of the input r.f. connector. The grounded end is connected to a lug held to the chassis with a screw and bolt. The same lug also serves as a ground for the 47-pf. capacitor (*C1*) and resistors *R2* and *R3*.

The output coil is wound with the three-turn secondary (*L2*) at the cold



DIMENSIONS SHOWN FOR CU-3000A MINIBOX



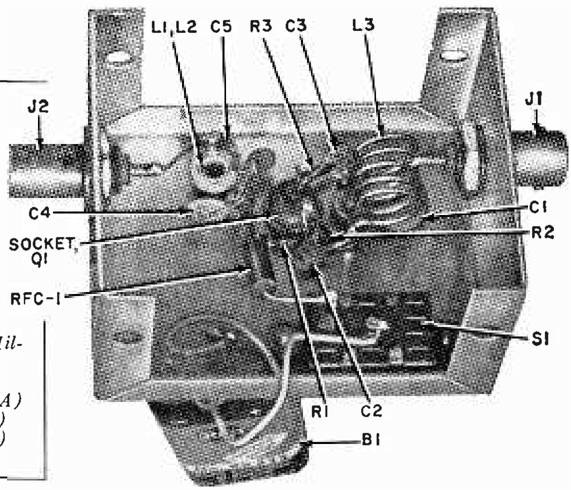


BATTERY RETAINER

Follow "straight-line" layout shown here. Leads must be kept short for good results. Advanced experimenters might try an Amperex 2N2495 for less noise at lower cost.

PARTS LIST

B1—9-volt transistor battery
C1—47-pf. ceramic disc capacitor
C2, C3, C5—0.001-µf. ceramic disc capacitor
C4—18-pf. ceramic disc capacitor
J1, J2—R.f. connector
L1, L2—8 turns and 3 turns, respectively, of #24 wire wound on Cambridge Thermionic slug-tuned coil form PLST/2C4L/P
L3—5 turns of #14 wire, i.d. 3/8", length 1/2"
Q1—2N2188 transistor (Texas Instruments)
R1—3900-ohm, 1/2-watt resistor
R2, R3—1000-ohm, 1/2-watt resistor
RFC-1—5.6-µh. miniature r.f. choke (J. W. Miller 9330-18 or similar)
S1—S.p.s.t. slide switch
1—1 5/8" x 2 1/8" x 2 3/4" Minibox (Bud CU-3000A)
1—Transistor socket (Elco 3304 or equivalent)
1—Battery clip (Cinch-Jones 5D or equivalent)



end of the primary (the end of the coil form closest to the box top). The primary (*L1*) has eight turns. Wind the coils in the same direction, connecting the top leads to *Q1*'s collector and to *J2*, respectively. Both are wound on the slug-tuned, .2"-o.d. (coil winding area) coil form given in the Parts List. As specified, this form comes with terminals and slug designed for VHF applications. It is available from suppliers in large cities, or from most parts suppliers on special order. Another source is Newark Electronics Corp., 223 West Madison St., Chicago 6, Ill.

Tuning the Preamp. To peak the preamp, simply insert the transistor in the socket—after checking first to make sure battery polarity is correct—and tune the output coil for maximum noise or signal level in the middle of the band. If necessary, the input coil can also be peaked by squeezing the turns together or gently pulling them apart. Since the bandwidth of the preamp is about 2.5 mc., adjustment is not critical. For best results, you may want to peak the unit in the middle of the portion of the 6-meter amateur band most used in your own area. -30-

CHAPTER

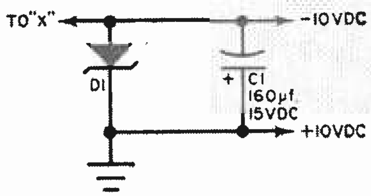
6 TEST EQUIPMENT PROJECTS

Because of the commercial availability of test equipment—either in kit form or prewired—projects for the home constructor must be instruments he can't buy. This is the philosophy used in selecting projects for the Fall Edition of the 1965 ELECTRONIC EXPERIMENTER'S HANDBOOK.

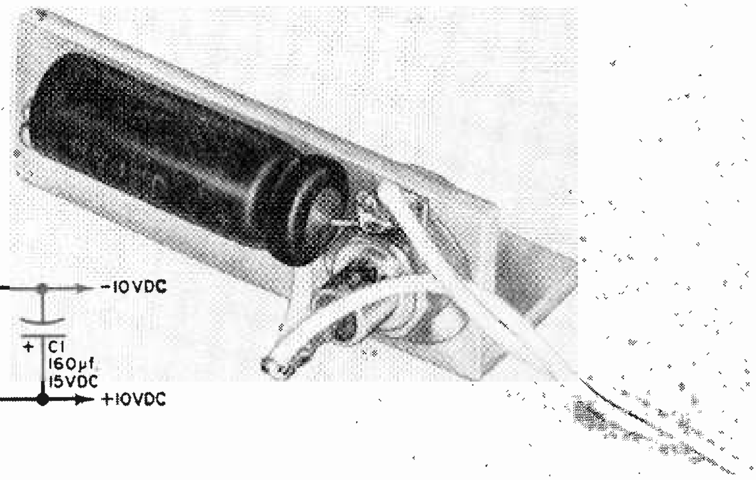
The "Field-Effect Transistor Voltmeter" (page 127) is one of the first—if not the very first—construction project to take advantage of the unusual characteristics of the field-effect transistor. This device is simple to build and calibrate, and has an input resistance comparable to that of a VTVM. The "SCR Tester" (page 126) is a companion piece to the "Automatic Diode Checker" (in the 1963 Edition of the ELECTRONIC EXPERIMENTER'S HANDBOOK). It could also be labeled "automatic" since it checks operating characteristics of the gate as well as checking for opens and shorts.

This chapter is rounded off with several short items and some of the best "Tips and Techniques" from past issues of POPULAR ELECTRONICS.

Hybrid Circuit for



Schematic for zener diode version is shown above. Current increases through diode as load current goes up. Diode can safely handle one ampere.



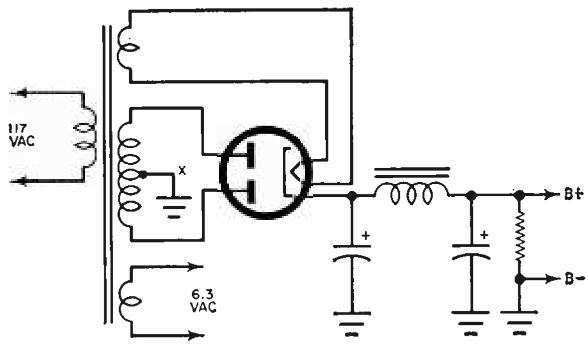
Good heat sink is prime requirement of zener regulator above. No insulation is required between diode, bracket. Capacitor connects to standoff.

Put that high-voltage bench supply to work powering your transistor projects— a simple addition gives you a handy low-voltage tap

By **ROY E. PAFENBERG,** W4WKM

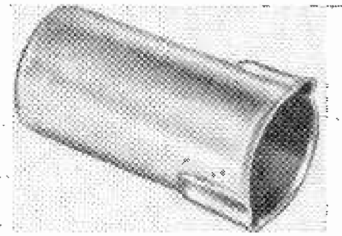
AN A.C.-OPERATED power supply furnishing a range of commonly used voltages is a "must" for experimental electronics work. These "bench supplies" range from very elaborate commercial units to those built on open chassis from junk box parts. Most such supplies were designed for use with vacuum tube circuits, but with the popularity of transistors on the upswing, they have limited application.

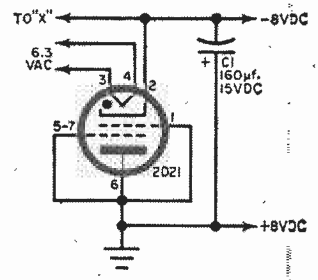
One answer to this problem can be found in the assemblies shown here. Either of the units will convert a conventional B-plus supply to furnish suit-



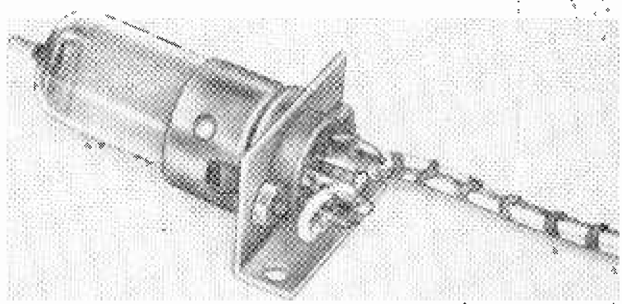
Typical supply is shown in schematic (right). Attach regulator at "X." Disconnect tap, connect to low-voltage regulator input, and then ground the regulator.

Transistor Power





Schematic diagram of 2D21 regulator. Higher voltages can be obtained by adding additional tubes, but increase voltage rating of C1 appropriately as well.



Tube regulator is assembled on bracket of bent-up aluminum sheet scrap. This mounts under supply chassis. Capacitor C1 is not shown in photograph.

able low-voltage outputs for transistor work. A peculiarity of this conversion is that the current that may be drawn from the low-voltage tap is limited to a value somewhat less than the combined bleeder—high-voltage output current. This is no drawback with tube or tube-and-transistor equipment, however, and another bleeder can always be added to the high-voltage end of the supply if you need more current while using the low-voltage tap exclusively.

How It Works. If you insert a resistor in series with the transformer center-tap in a conventional power supply, a voltage (determined by the current in the circuit) will be developed across the resistor. This is how negative bias voltages have been obtained for years. When you insert a *zener diode* in series with the center tap, the rectified voltage across it causes the diode to conduct, and the voltage drop remains constant over a wide range of bleeder and external load current of the B-plus output. While the voltage of the diode is subtracted from the output, it is negligible when considered as a percentage of the output.

The second version of this circuit uses a cold-cathode, gas-filled 2D21 thyratron. As the voltage drop of a gas tube is fairly independent of current variation, a well-regulated voltage is developed. The 2D21 is inexpensive, which adds to the appeal of this version.

Building the Regulators. Construction details are shown for assemblies designed for installation under the chassis of the supply. In the diode version, ¾-inch aluminum angle stock is used to mount diode *D1* and capacitor *C1*. A standoff insulator is used for one end of the capacitor. No insulation is required for the diode stud, as in the usual grounded bias supply. The aluminum provides a good heat sink for the diode, which is an International Rectifier 10-watt, 10-volt unit. You can substitute at will, but do not exceed the diode current ratings.

In the 2D21 version, bend up a small bracket from scrap aluminum for the tube socket. You can, if you wish, increase the voltage output of the 2D21 circuit by adding additional tubes in series, but be sure to increase the working voltage rating of the capacitor if you make such a change. —30—

SCR TESTER

By T. E. HOPKINS

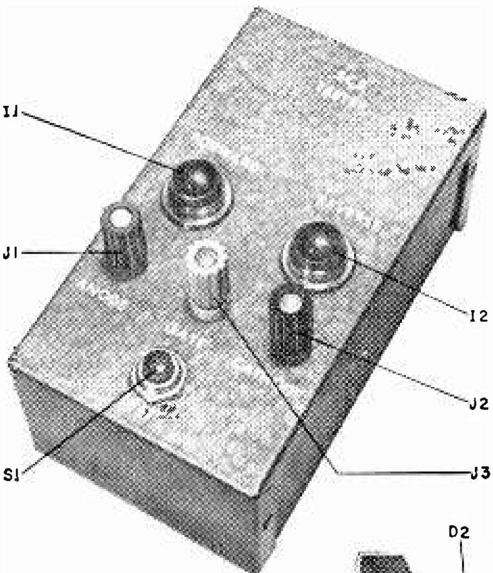
There's no easy way of testing an SCR but this handy gadget solves the problem

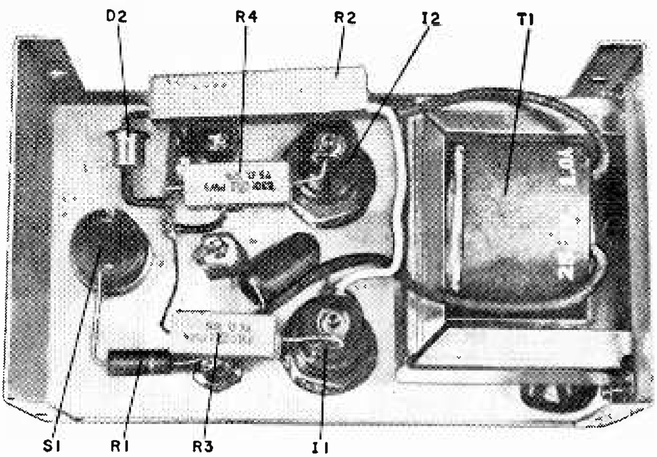
INCREASING commercial and domestic use of silicon controlled rectifiers (SCR's) in such popular devices as light dimmers, for power tool speed control, etc., has created a need for a simple, quick, and reliable method of checking the condition of those suspected of being faulty.

An SCR is a four-layer semiconductor device with two main conducting terminals and a gate terminal. It contains junctions that are intended to block all current in a reverse direction, block current flow in the forward direction under normal or ungated conditions, and allow forward current flow when the gate is energized or triggered. Thus, it is possible for an SCR to break down in either the forward or reverse direction or both. It is also possible for the gate connection to become either shorted or open. Therefore, it is *not* possible to determine the condition of an SCR by simple ohmmeter tests as may be done with a rectifier or even, to some extent, with a transistor.

The device described in this article will test both forward and reverse breakdown and gate operation. Transformer *T1* provides a 25-volt, r.m.s. source of a.c. to the circuit. This voltage is alternately applied in the forward and reverse directions across the anode-cathode connections of the SCR. If initial breakdown is present in either direction, current will flow in that particular direction and the current will be detected by either the "Forward" or "Reverse" lamps.

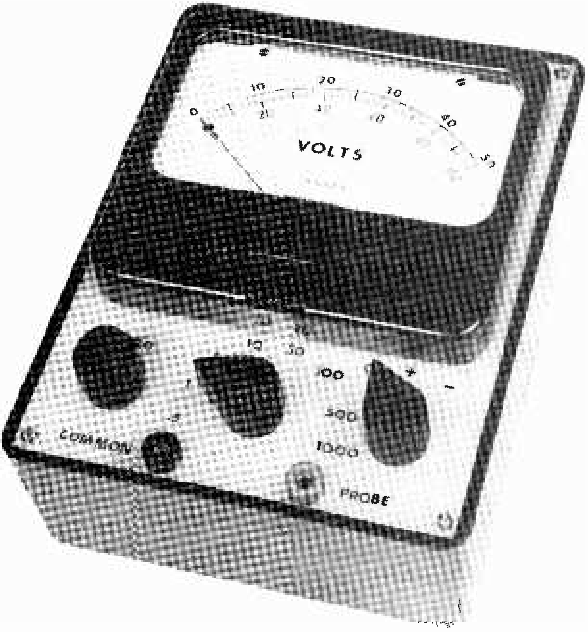
(*Continued on page* 139)





All of the components can be readily fitted into a convenient aluminum box. The wire from switch S1 to center binding post J3 ("Gate") may not seem visible, but it's really there. Numerous inexpensive 24-25 transformers are available as substitutes for the filament transformer called out in Parts List on page 139.

ADVANCED EXPERIMENTER'S CORNER



FIELD-EFFECT TRANSISTOR VOLTMETER

Extraordinarily high input impedance, portability and accuracy, with a single transistor

By **JEFF H. TAYLOR,** Texas Instruments, Inc.

THE field-effect transistor has steadily gained in popularity due to its ability to act like a vacuum tube. With increased popularity, the price of such transistors has fallen and is now within the budget range of most experimenters. The 2N2498 is currently being sold for $12.75, and the new 2N3330 for $10.82. The transistor voltmeter described in this article is similar in many respects to a VTVM, but uses, instead of a vacuum tube, a single unipolar field-effect transistor—the 2N2498.

The unipolar transistor—unlike its bipolar brothers—exhibits extremely high input impedance and some of the other characteristics that might be attributed to a vacuum tube, specifically a pentode. Because of these characteristics, a voltmeter can be designed with a single transistor and a bare minimum of parts. As the specifications on the next page show, the field-effect transistor voltmeter is small, lightweight, and has a battery life equal to the shelf life of the mercury cells used to power it.

Technically, the voltmeter uses a field-effect transistor in a source-follower configuration (similar in many respects to the familiar cathode-follower arrangement used with vacuum tubes). The voltage gain of the final circuit is less than unity, and varies with changes of the small-signal common-source forward transfer admittance and other circuit impedances.

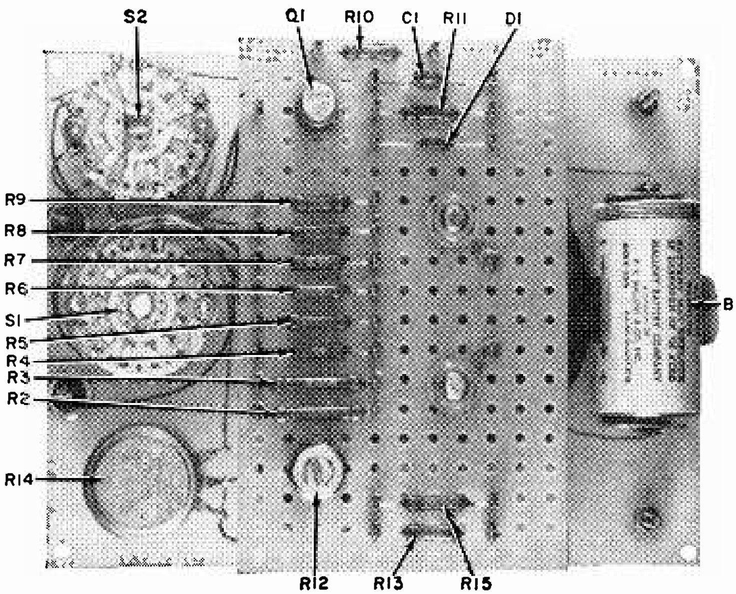
Circuit Theory. The basic voltmeter circuit is shown in the small diagram in the upper right-hand corner of the next page. To analyze it, assume that a zero potential is established between points *A* and *B* and that current will flow through the transistor and resistor R_s. This places point *C* negative with respect to point *B*. Combination resistors R_a and R_b can be adjusted to provide a potential at point *D* equal to the potential at point *C*. The meter will now indicate zero. If a negative potential is applied to the input (*A-B*), the current through the transistor and resistor R_s will increase and point *C* will become more negative—causing a meter reading proportional to the potential difference between points *A* and *B*.

The input resistance of this circuit can be extraordinarily high since it is determined by the *gate-to-channel* leakage of the field-effect transistor. ("Channel" refers to the conducting path between the "source" and the "drain.") Obviously, this circuit will not work in actual practice since the open gate would permit static potentials at point *A* to cause the meter needle to wander. A practical version of this basic circuit is shown in the large schematic diagram and construction photograph.

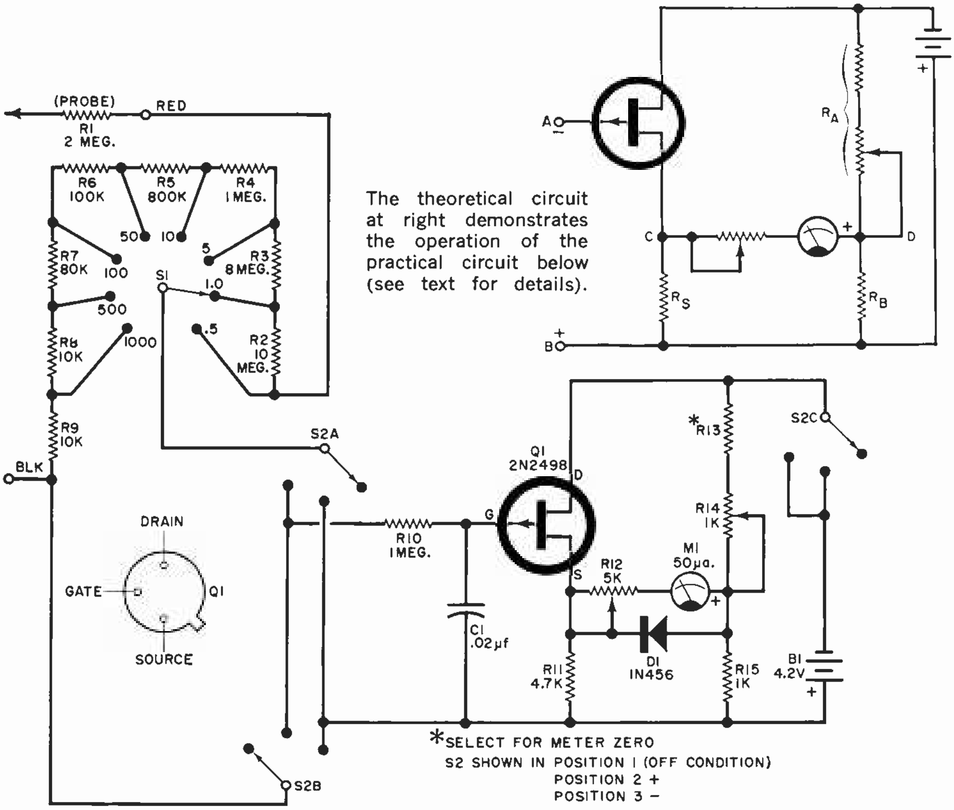
A Practical Circuit. Through a rather modest arrangement of switches and resistors, a single field-effect transistor voltmeter can be built possessing the detailed specifications outlined at the bottom of page 129. The input impedance of this voltmeter is determined by the series combination of resistors *R1* through *R9*. To provide protection from transient overload or stray a.c. voltage injection, the filter consisting of *C1* and *R10* has been introduced. Diode *D1* has been wired across the meter so that the movement current can be limited to about 1½ times the full-scale deflection value. Although this circuit was designed using the 2N2498 field-effect transistor, the 2N3330 will perform equally well, and so will the 2N2497, 2N2499, 2N3329 and 2N2500.

Since the over-all accuracy of the

(*Continued on page* 140)



The voltmeter is mounted in a black Bakelite meter box available at most radio supply houses. The circuit components are mounted on a piece of perforated phenolic board which is attached to the back of meter M1 with nuts on the meter input terminals. Although layout is not critical, care should be taken to insure that leakage paths do not develop in input circuit.



The theoretical circuit at right demonstrates the operation of the practical circuit below (see text for details).

PARTS LIST

B1—4.2-volt mercury battery (Mallory TR233 or equivalent)
C1—0.02-μf., 200-volt capacitor
D1—1N456 silicon diode
M1—0-50 microampere meter (Simpson Model 29 or equivalent)
Q1—2N2498 field-effect transistor (Texas Instruments)
R1—2-megohm (or 1.8- or 2.2-megohm), ½-watt resistor, 10%
R2—10 megohms, R3—8.0 megohms: 1-watt resistors, 1% (Aerovox CPX-1 or equiv.)
R4—1.0 megohm, R5—800,000 ohms, R6—100,000 ohms, R7—80,000 ohms, R8, R9—10,000 ohms: ½-watt resistors, 1% (Aerovox CPSX½ or equiv.)
R10—1.0-megohm, ½-watt resistor, 10%
R11—4700-ohm, ½-watt resistor, 10%
R12—5000-ohm potentiometer with lock
R13—1000- to 5000-ohm resistor—see text
R14—1000-ohm potentiometer
R15—1000-ohm, ½-watt resistor, 10%
S1—1-pole, 8-position rotary switch (Centralab PA-1001 or equivalent)
S2—3-pole, 3-position rotary switch (Centralab PA-1007 or equivalent)
1—Battery holder (Keystone #173 or equivalent)
2—Banana jacks, one red, one black
1—Black plastic multimeter case (approx. 6 13/16" x 5 9/32" x 2 5/16") or similar
Misc.—Set of test leads with banana plugs, knob for zero control, perforated phenolic board

SPECIFICATIONS

Accuracy Determined by meter movement used. Accuracy of instrument shown is within ±2% of full scale.
Battery Life Essentially shelf life.
Input Impedance 22 megohms on any range (including 2-megohm probe).
Power Consumption Approximately 5 mw.
Power Supply 4.3-volt mercury battery.
Voltage Range 0.5 volt to 1000 volts. Eight ranges selected with front panel switch. Full-scale readings of: 0.5, 1.0, 5.0, 10, 50, 100, 500, and 1000 volts.
Warm-Up Time Zero.
Weight Approximately 2¼ lb. with battery.

NOW...GET THE FINEST *STEREO TEST RECORD* ever produced for just...$4.98

Featuring Tests Never Before Available To The Hobbyist

UNIQUE FEATURES OF HiFi/STEREO REVIEW'S MODEL 211 STEREO TEST RECORD

- Warble tones to minimize the distorting effects of room acoustics when making frequency-response checks.
- White-noise signals to allow the stereo channels to be matched in level and in tonal characteristics.
- Four specially designed tests to check distortion in stereo cartridges.
- Open-air recording of moving snare drums to minimize reverberation when checking stereo spread.

Why We Make the Model 211 Available Now

Although there are many stereo test records on the market today, most critical checks on existing test records have to be made with expensive test equipment.

Realizing this, HiFi/STEREO REVIEW decided to produce a record that allows you to check your stereo rig, accurately and completely, just by listening! A record that would be precise enough for technicians to use in the laboratory—and versatile enough for you to use in your home.

The result: the HiFi/STEREO REVIEW Model 211 Stereo Test Record!

Stereo Checks That Can Be Made With the Model 211

✓ Frequency response — a direct check of eighteen sections of the frequency spectrum, from 20 to 20,000 cps.

✓ Pickup tracking — the most sensitive tests ever available to the amateur for checking cartridge, stylus, and tone arm.

✓ Hum and rumble — foolproof tests that help you evaluate the actual audible levels of rumble and hum in your system.

✓ Flutter—a test to check whether your turntable's flutter is low, moderate, or high.

✓ Channel balance — two white-noise signals that allow you to match your system's stereo channels for level and tonal characteristics.

✓ Separation—an ingenious means of checking the stereo separation at seven different parts of the musical spectrum—from mid-bass to high treble.

ALSO: ✓ Stereo Spread
Speaker Phasing
Channel Identification

PLUS SUPER FIDELITY MUSIC!

The non-test side of this record consists of music recorded directly on the master disc, without going through the usual tape process. It's a superb demonstration of flawless recording technique. A demonstration that will amaze and entertain you and your friends.

All Tests Can Be Made By Ear

HiFi/STEREO REVIEW's Model 211 Stereo Test Record will give you immediate answers to all of the questions you have about your stereo system. It's the most complete test record of its kind—contains the widest range of check-points ever included on one test disc! And you need no expensive test equipment. All checks can be made by ear!

Note to professionals: The Model 211 can be used as a highly efficient design and measurement tool. Recorded levels, frequencies, etc. have been controlled to very close tolerances — affording accurate numerical evaluation when used with test instruments.

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The Model 211 Stereo Test Record is a disc that has set the new standard for stereo test recording. There is an overwhelming demand for this record and orders will be filled by POPULAR ELECTRONICS promptly upon receipt. At the low price of $4.98, this is a value you won't want to miss. Make sure you fill in and mail the coupon together with your check ($4.98 per record) today.

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Stereo Test Record N
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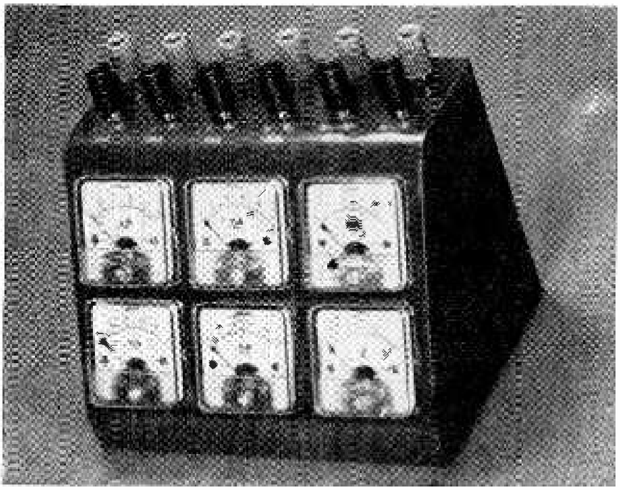
Please send me ________ test records at $4.98 each. My check (or money order) for $________ is enclosed. I understand that you will pay the postage. (Orders from outside the U.S.A. add 50c to partially defray postage and handling costs.)

Name ________________________
(Please Print)

Address ________________________

City ____________ Zone ______ State ________

Sorry—No charges or C.O.D. orders! EEH-65



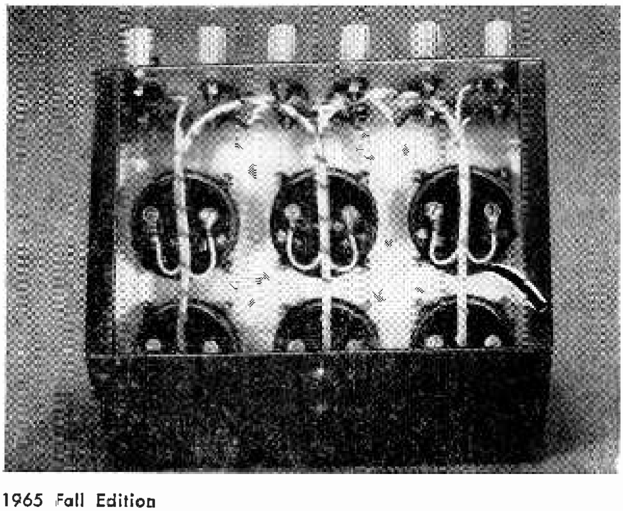
MULTIPLE METER TEST SET

"CONNECT A VOLTMETER across the power supply and prepare to meter the input to the amplifier. Adjust the value of the *Q2* bias resistor for a base to emitter voltage of −0.1 volt, making sure that the collector current does not exceed 12 ma." At about this point, you curse the writer of the instructions as a bloated plutocrat—he and all his test equipment vs. your lonely VOM.

Anyone who constructs electronics equipment as a hobby is well aware of the measurement problems involved. Voltage readings are not too difficult to take, but measurement of current at a number of points in the circuit is a different matter. Invariably the circuit must be opened, a meter inserted, a reading taken, the circuit closed up and the meter moved to the next point.

The compact little instrument shown here is a convenient answer to the problem of how to make several simultaneous measurements. Its cost is surprisingly low since use is made of imported meters—the author obtained his from Lafayette Radio via mail order. Besides a 0-15 volt d.c. meter, the cabinet holds one 0-50 μa. (d.c.), one 0-1 ma., one 0-5 ma., one 0-50 ma., and one 0-100 ma. meter. The cabinet is a Premier ASPC-1202 with a sloping front.

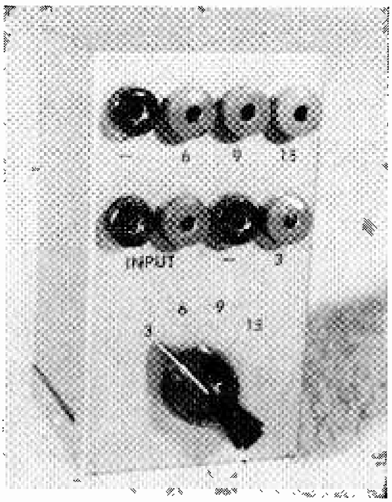
—*Roy E. Pafenberg*



Mount the six meters in a logical pattern so that the scales increase from left to right and top to bottom. Bring the meter leads out to insulated terminals or binding posts on the top ledge of the cabinet. Use color-coded terminals so that red indicates the plus meter lead and black the minus lead.

MULTI-OUTPUT ZENER VOLTAGE REGULATOR

By HAROLD REED



THIS simple voltage regulator will provide regulated outputs at most commonly used values for semiconductor circuits—nominally 3, 6, 9 and 15 volts. By using a special switching arrangement, only two low-cost zener diodes and three resistors are required. Any suitable d.c. source adjusted to 17 volts can be used for the input.

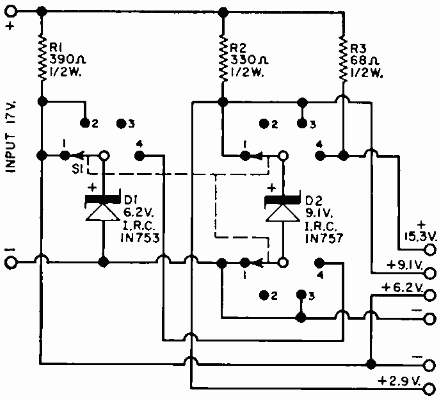
If a d.c. supply is not on hand, the constructor can build an a.c. rectifier especially for the regulator. Good regulation is obtained even with a simple half-wave diode supply.

How It Works. The schematic shows that the two zener diodes (*D1* and *D2*, 6.2- and 9.1-volt units respectively) are switched into four different circuit configurations.

With the switch in the first position, both diodes are used. The regulated output is the difference potential of the diodes, which is 2.9 volts. The second switch step provides a 6.2-volt regulated output. Here, only *D1* is used. On the third switch step, only *D2* is used and a 9.1-volt regulated output is available. In the fourth position, the two diodes are connected in series, giving a 15.3-volt regulated output.

The zener diodes are rated at 400 milliwatts. These diodes are also available with ratings from 250 milliwatts up to 10 watts at various voltages. Thus, a regulator of this type can be constructed to handle considerably larger currents and with many different combinations of regulated outputs.

The device is housed in a 4" x 2¼" x 2¼" aluminum box with identifying decals on the front panel. Parts placement and internal wiring are not critical. If a slightly larger box is used, a completely self-contained unit can be made by incorporating a power supply using germanium or silicon diodes.



Multiple outputs are available from this small regulator. Note that the 2.9-volt circuit has a separate negative terminal.

Testing the Unit. The regulator was tested with one of the simplest types of power supplies consisting of a half-wave rectifier and a capacitor-resistor filter.

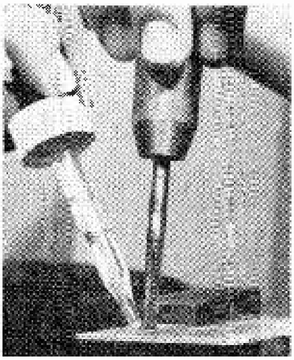
With a regulated output of 6.2 volts, starting with zero load current, the output remained steady as the load current was increased. When the load current reached 24 ma., the output dropped 0.3 volt. The 9.1-volt output held steady from zero load current up to 20 ma., when it also went down only 0.3 volt. Output from the 15.3-volt terminal dropped 0.5 volt between zero and 22 ma. load current. Likewise, the 2.9-volt output held steady and went down only 0.2 volt when the load current reached 10 ma.

In these tests, zero load current represented no load at all connected across the output terminals.

The Best of TIPS & TECHNIQUES

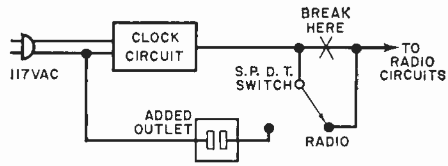
TETRACHLORIDE TAPPING TIP

If you use oil as a lubricant when tapping holes in metal, you may find that after a short time the oil gums, binds the tap, and the tap breaks off. To prevent this sort of tragedy, try using carbon tetrachloride as a tap lubricant. Because of its high rate of evaporation, neither gumming nor binding will occur, and you'll have a cleaner job. The carbon tet can be stored in an old medicine dropper bottle which will also serve as a convenient dispenser. However, make sure that the room is well-ventilated while you're using the carbon tet. *—Robert K. Dye*



CLOCK RADIO SERVES AS TV TIMER

A few slight modifications to your clock radio will enable it to turn your TV set on automatically at a definite time. Add an outlet to your radio and wire it according

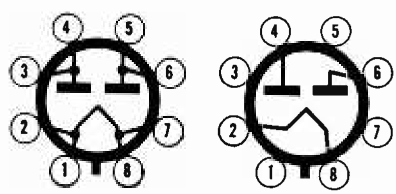


to the diagram. The s.p.d.t. switch can be mounted near the outlet. Locate the wire from the clock switch to the radio circuits and wire the added components as shown. When the TV set is plugged into the new outlet, it will be controlled by the clock mechanism if the switch is in the TV position. If the clock radio is equipped with a "sleep switch," you can use this to shut the set off automatically.

—*Fred Blechman, K6UGT*

SUBSTITUTING RECTIFIER TUBES

Be wary about replacing a rectifier tube such as a 5U4 with a 5DJ4 or similar tube. While at first glance the tube pin numbers and specifications may seem similar, many manufacturers utilize unused socket terminals as convenient tie points for components



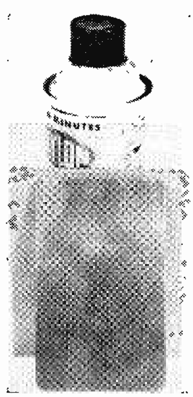
PINS 1,3,5, AND 7 MAY BE USED AS TIE POINTS

that may not even be a part of the rectifier circuit. The 5DJ4 has internal connections to tube pins that are not normally used in the 5U4. For example, if your set has a 5U4 rectifier socket with pin 5 as a ground, you'll have real trouble substituting a 5DJ4!

—*Carleton A. Phillips*

NEAT LAYOUT FOR PRINTED-CIRCUIT BOARDS

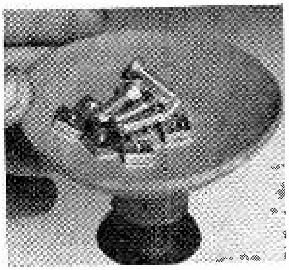
You'll find it easier to keep components on a printed-circuit board aligned and neatly arranged if you try this simple tip. Instead of laying out the board with penciled guide lines (they tend to erase themselves while you work), place a piece of perforated board over the copper laminated board, and spray with acrylic paint from a height of at least two feet. This will give you a grid of small dots on the circuit board to use as component centers and guides for the copper runs. After laying out the resist tapes, quickly slosh the board with lacquer thinner to remove the paint; if you work fast, the tapes will not be affected. If you use the resistive ink method, the dots can be removed with an ordinary ink eraser.



—*Donald E. Lancaster*

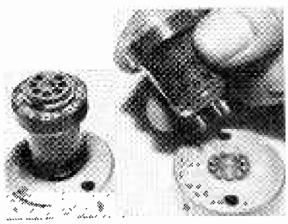
HANDY HOLDER FOR HARDWARE

If you attach a large and small rubber suction cup back to back, the result is a handy stick-on hardware holder. Fill the hole in the larger cup with epoxy cement, and insert the screw lug of the smaller. The hardware holder can then be attached to TV cabinets, tool box lids or other supports, and used for small parts, nuts, bolts or washers.



—*John A. Comstock*

STORING ADAPTER SOCKETS

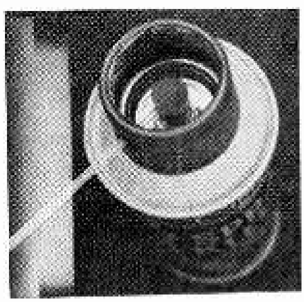


To keep your adapter sockets handy and safe, there's no better place to put them than in your tube pin straighteners. The adapter socket pins will be protected, and the sockets themselves will be ready for use at all times.

—*Clyde C. Cook*

CAP AEROSOL "WILDCATS" TO AVOID MESSY ACCIDENTS

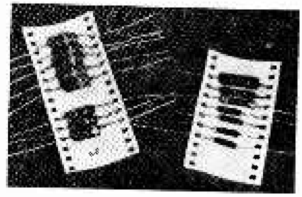
Don't discard the protective cap on the next can of aerosol tuner cleaner you buy—it can keep the contents of the can from being accidentally released, particularly when the can is carried from job to job. As slipping the cover on and off and attaching and detaching the extender for each job would be a nuisance, you can neatly trim out the top of the plastic cover with a small knife. Then drill or punch a hole on the side of the cap for the spray extender tube. When the can is empty, the modified cap can be transferred to a new can.



—*Elmer C. Carlson*

"FILM" STORAGE FOR SMALL PARTS

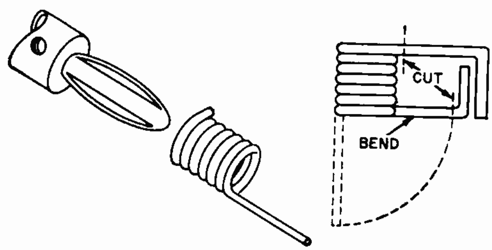
Small parts, such as resistors, capacitors and diodes, often become tangled and hard to locate when they are stored haphazardly in boxes. An easy way to keep them in order is to slip their leads through the perforations of 35-mm. film strips as shown. The film strips, together with the components, can then be neatly filed or tacked to a convenient shelf for easy access.



—*Art Blaske*

SNAP-TYPE CLOTHESPIN MAKES BANANA PLUG ADAPTER

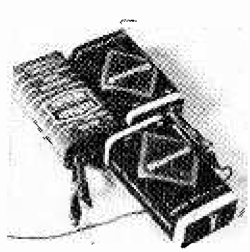
There's probably a bunch of banana-plug-to-pin-jack adapters in your home—in the family clothespin bag. To make an adapter, take the spring off a snap-type clothespin and cut the arms of the spring as shown here. The straight end of the spring can



be soldered to a printed-circuit board, giving you a banana jack, or you can insert the end in a pin jack and use leads terminated in banana plugs. —*R. D. Holen*

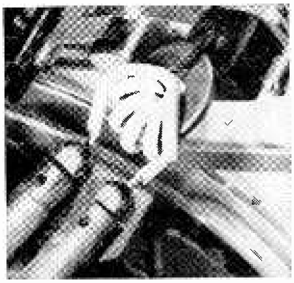
QUICK SERIES CONNECTION OF DRY CELLS FOR EXPERIMENTS

When you need some multiple of 9 volts d.c. for an experimental hookup, the quickest way to get it is to plug two or more 9-volt transistor batteries together, as shown. Make the output connection to the two terminals left exposed on the directly connected dry cell bank. Incidentally, you can use connectors taken from discarded cells for the wire ends to make connection and disconnection easy. —*Patrick Snyder*



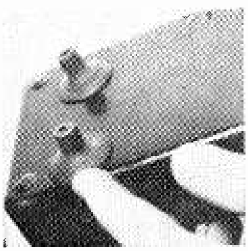
DEGAUSS YOUR TAPE RECORDER HEADS

When your tape recorder begins to sound "muddy," it's a good indication that the heads are in need of degaussing (or demagnetizing). There are commercial degaussers available, but it's easy to make one. Saw a 1/8" slot in a 1/2" flat iron washer and wind six or eight turns of #14 or #16 insulated wire on the washer. Connect the wire ends to your soldering gun (after you remove the soldering element), and you'll be able to degauss both the heads and guides. The tool can also be used to erase small sections of recorded tapes, such as unwanted switch pops, or words.



—*R. K. Dye*

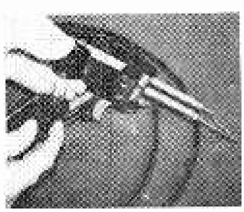
RUBBER FEET FROM SUCTION CUPS



You can make some dandy rubber feet for your instruments from simple suction cups. Rubber cement will hold them in place, or, if you like, a small hole can be drilled in each suction cup and a bolt used to attach it to the cabinet. The suction cups are resilient and provide good shock protection. —*John A. Comstock*

LIGHT FLASHER MAKES LOW-HEAT SOLDERING GUN

Ever need a particularly low heat for soldering miniature or transistor circuits? If you connect your soldering gun through an ordinary Christmas tree light flasher, it will cycle the gun on and off, keeping the heat at a low but usable level. You can get a 100-watt flasher from your local hardware or electrical appliance store. Just plug the flasher unit into the bench outlet, and the soldering gun into the flasher.



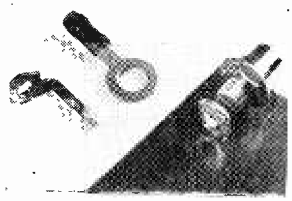
—*John Lias Wilson*

CAMERA TRIPOD PINCH-HITS AS MIKE STAND

A floor stand for a microphone is not often listed as standard equipment for a home tape recordist. For easy recording of noise-free tapes, however, it is almost a necessity. If you own a camera tripod, you can attach your microphone to the tripod's swivel head with a simple clamp or bracket, and derive all the benefits of a good mike stand. —*Glen F. Stillwell*

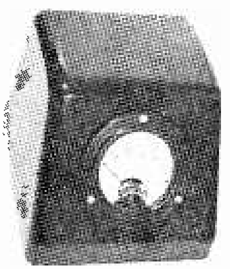
EASY WAY TO MOUNT PHONO JACK ON P-C BOARD

Here's how to mount a phono jack at right angles to a printed circuit board with a minimum of fuss. You'll need a crimp-on closed-eye-terminal for a ¼" stud and a Cinch-Jones Y-142 adapter (available for about three cents from any distributor). Cut the terminal just at the ferrule so you have a ⅛" tab projecting from the original eye. Flatten the Y adapter. Now mount the terminal and adapter near the edge of the board facing each other and about 7/16" apart. Insert the phono jack, tighten the nut, and solder the connections. The resulting mount is compact, neat, and rugged. —*Don Lancaster*



PLASTIC CASES HOLD METERS OR SPEAKERS

Discarded plastic TV booster or antenna rotor control cases of the type shown in the photo make excellent mounts for meters or for a miniature speaker. Strip the parts and chassis from the case, and, if you're lucky, the meter or speaker will fit in the hole left by the dial without further modifications. If necessary, enlarge the mounting hole with a hacksaw blade, and drill holes for mounting screws around the perimeter. —*Carleton A. Phillips*



SCR Tester

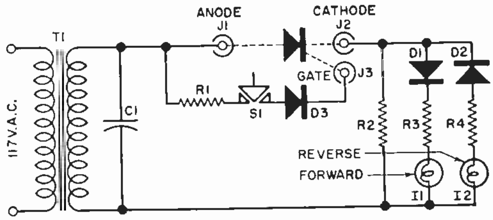
(Continued from page 124)

Thus, lighting of the "Forward" lamp as soon as the SCR is connected into the circuit indicates failure of the forward blocking junction. Lighting of the "Reverse" lamp at any time indicates breakdown of the reverse blocking junction. If neither lamp lights when the SCR is connected into the circuit, the "Test" push button is operated, applying a source voltage to the gate.

The "Forward" lamp should light under these circumstances if the SCR is good. If this lamp does not light when the button is depressed, the gate is either open or shorted.

This tester applies about 35 peak volts to the SCR anode so that higher voltage capabilities of the unit are not indicated. With very small SCR's, heat sinking may be necessary.

The device can also be used to test ordinary rectifiers by connecting them across the "Anode" and "Cathode" terminal posts. With the rectifier properly connected, a good one will light the "Forward" indicator lamp, an open one will keep both lamps off, and a shorted one will make both lamps come on. -30-



PARTS LIST

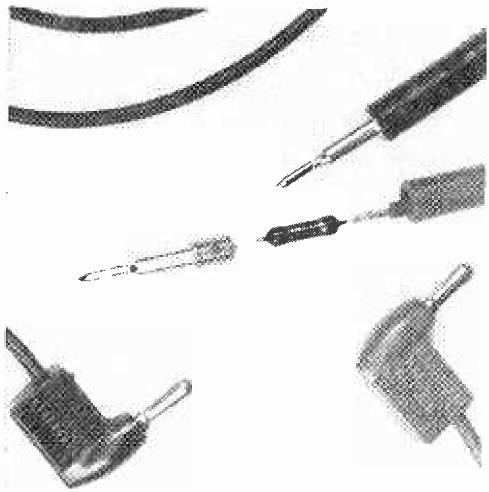
C1—0.05-µf., 200-volt capacitor
D1, D2, D3—100-volt, 1.6-amp. silicon rectifier (1N1218)
I1—#47 indicator lamp (Dialco 81410-112—green—or equivalent)
I2—#47 indicator lamp (Dialco 81410-111—red—or equivalent)
J1, J2, J3—Binding post (Johnson 111-101, 111-102, 111-103, or equivalent)
R1—100-ohm, 1-watt resistor
R2—50-ohm, 10-watt resistor
R3, R4,—75-ohm, 5-watt resistor
S1—Normally open push-button switch
T1—Filament transformer, 25.2 volts @ 1 amp. secondary (Stancor P-6469 or equivalent)

Transistor Voltmeter

(*Continued from page* 129)

voltmeter is largely determined by the input resistor string, resistors *R2* through *R9* should be stable and preferably have an accuracy of ±1.0%. Of course, if you have access to a bridge, standard ±5% resistors can be measured and very close values selected on this basis.

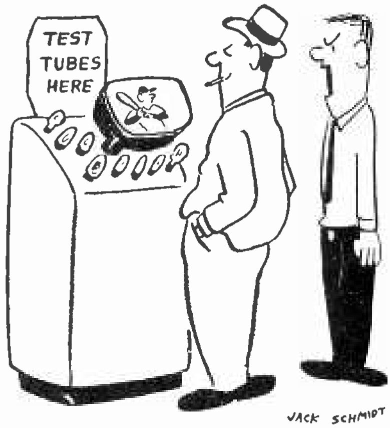
Resistor *R13* must be selected so that potentiometer *R14* will adjust near its center position to set meter *M1* to a zero deflection. The value of *R13* may vary from 1000 to 5000 ohms, but once set it will need no further adjustment.



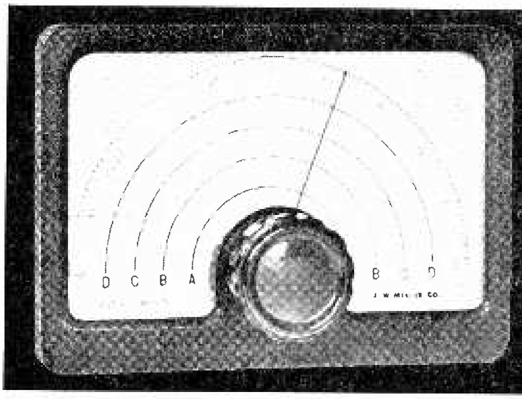
Solder resistor R1 to pin of probe and slip it inside red handle. Probes need not be reversed to reverse polarity; this is accomplished through S2.

Construction and Calibration. The voltmeter can be built on a single piece of phenolic board and attached to the back of meter *M1* through the meter input terminals. Except for the resistor in the probe, all of the resistors can be mounted to the board with Vector terminals and soldered in place. The layout should approximate that in the photo to eliminate the possibility of leakage paths in the input part of the circuit.

The final accuracy of the voltmeter depends on the values of resistors *R2* through *R9* as well as a calibrating voltage source. Ideally, a digital voltmeter of known accuracy and a variable d.c. voltage source should be used. However, initial calibration with several 1.34-volt mercury batteries may be used to set the 0-5 volt scale. Full-scale sensitivity is adjusted by varying potentiometer *R12* and locking it into position once satisfactory calibration has been established. —30—



"One at a time, Mister!"



Resonance Engine

(*Continued from page 92*)

90). Although the weight of the flywheel should not be too critical, some experimenting may be in order. The author's was made of aluminum and weighed about 15 ounces. Drill and tap one end of the flywheel shaft for a *6-32* machine screw and thread the opposite end with a ¼″-20 die.

The flywheel shaft bearing—a 1½″ brass rod ½″ in diameter with a ¼″ hole drilled through the center—is mounted in the bracket shown in Fig. 7 and in the assembly drawing. The bracket is made with a stiffening buttress so that it will stand up under the vibration of the engine. In the author's unit, the bracket was mounted to the coil platform by tapping three small pieces of brass rod and cementing them into holes drilled into the bottom of the bracket. Wing bolts thread into the holes from the bottom of the coil platform, making it easy to disassemble the engine for other experiments. In any case, drill a ½″ hole in the bracket at the height shown in Fig. 7, and cement the bearing in it with epoxy glue.

Mounting Stand. Make a double-deck stand as shown in the photos and secure the capacitors, *C1*, *C2*, *C3*, to the lower section. Mount the d.p.d.t. toggle switch, *S1*, and four pin jacks, *J1*, *J2*, *J3*, *J4*, on the upper deck of the stand in front of the coil position. Drill holes in the upper deck for coil leads, coil mounting screws, bracket mounting screws, and for the engine piston. The piston hole should be large enough to provide ample clearance.

Mount all of the parts on the stand as shown in the assembly view on page 92. Solder the end of the flywheel shaft to the end of the crankshaft where the two join together. To hold the long 12″ core in place for repulsion coil experiments, drill and tap the top disc for a setscrew that extends from the outer rim into the center hole.

Connect the parts as shown in the schematic diagram on page 92. You will note that the diagram shows a "discharge" position for *S1*. This is a safety device to discharge the capacitors after the unit has been in use. Label *S1*'s positions (*S1* is a center-off type) "On," "Off," and "Discharge."

Testing the Engine. When the assembly and wiring are done, spin the flywheel by hand to make certain there is no undue friction. Use light oil on all bearings and piston surface. With everything ready to go, plug the unit in, turn the switch on, and give the flywheel a turn in either direction. The flywheel will pick up speed and be on its way. Like most single-cylinder reciprocating engines, your engine will require an initial start, unless the crank is turned to its upper position, slightly off center.

Theory. How does the resonant engine operate? One of the laws governing a series-resonant circuit is that when the reactance of the capacitor equals the reactance of the coil, the maximum amount of current will flow in the circuit. The reactance of the capacitors is fixed; the reactance of the coil depends on the piston core's position.

When the piston core is slightly above its lowest point of travel, or the same distance below its upper point of travel, the reactance of the coil equals that of the capacitor, and the circuit is resonant. In operation, the piston is drawn toward one of the resonant positions, but the flywheel carries it beyond that point and the circuit drops sharply out of resonance. From there on, the piston is carried by the momentum of the flywheel to the next resonant position.

The value of the capacitance needed for the resonant engine is 10.6 μf. As shown in the schematic, the author got this value by connecting 1- and 2-μf. units in series, and then connecting them in parallel with a 10-μf. unit. Other combinations can, of course, be used to arrive at 10.6 μf.

Other Experiments. Want to make a step-down transformer? Wind a 40-turn coil of wire and connect it to a flashlight bulb. Position the long core in the engine coil, tighten the setscrew, and slowly bring the flashlight bulb and coil down over the core. An interesting variation is to try the same thing with the capacitor shorted out by means of a jumper across the two capacitor pin jacks. The increased brilliancy of the bulb with the capacitor in the circuit shows how much more efficiently a.c. circuits operate at resonance.

Another intriguing experiment using the transformer principle is the repulsion coil. Secure a piece of ⅝″-i.d. aluminum tubing 2″ long. Place the tubing over the long core, turn the switch on, and it will shoot skyward. Adjust the center core to get maximum upward thrust if necessary.

The transformer principle involved here is that of mutual induction where a varying current flowing in a coil induces a current in another coil placed in the same magnetic field, such as the primary and secondary of a transformer. The induced current is always in an opposite direction to the original current; thus, the magnetic fields set up by the two currents will be in opposition. The aluminum tubing acts like the secondary of a transformer, and, since it is free to move, opposing magnetic fields send it flying.

A similar piece of aluminum tubing 3″ long can be made to oscillate up and down the center core for approximately 8″ by adjusting the core to proper height. The height is critical—1/16″ either way may prevent it from oscillating.

If you have an a.c. voltmeter with a maximum range of at least 500 volts, it can reveal some startling facts about series resonant circuits. Connect the meter to *J3-J4* across the coil and adjust the long center core until the meter gives a maximum reading. Change the voltmeter to the capacitor jacks *J1-J2* and note the reading. Readjust the center core until the coil and capacitor voltmeter readings are the same. The circuit is now at resonance; about 400 volts should be indicated across each unit.

In a series resonant circuit such as this, the maximum current will flow at resonance. At 60 cycles, the reactance of the capacitor bank comes to about 250 ohms; and at resonance, the reactance of the coil will also be 250 ohms. However, at resonance, these reactances cancel one another—the current flow is limited only by the small resistance in the circuit. It is this current flow in combination with the reactances of the coil and capacitor—which may be said to build up the voltage by "handing it back and forth"—that accounts for the exceptionally high counter electromotive voltages. -30-

Shotgun Sound Snooper

(Continued from page 64)

cluster with a *6-32* x 3/8" machine screw and bolt. Install the front bracket the same way, and slide the horizontal support bar between the brackets, aligning the holes in the bar with the lower ones in the brackets. Bolt the horizontal bar in place along with the angle bracket for mounting the microphone to the pan head of a camera tripod. Now fit the microphone enclosure over the tubes; it can be taped on if necessary with a strip of masking or metalized Mylar tape around the enclosure and the rear support bracket. The Mylar tape is not necessary, but looks better.

The Amplifier. Weak or distant sounds naturally require a high-gain amplifier. Tube type amplifiers, because of their inherent hum at high gain settings, definitely are not recommended. The five-transistor Lafayette PK-544 is an ideal choice for this purpose, and the cost is low. The high-impedance microphone cartridge is matched to the low-impedance amplifier input with a transformer. As 8-11 ohm output transformer is an integral part of the PK-544. The high-impedance output shown in the schematic on page 64 is optional; *T2*, *S2*, and *J3* may be omitted if low-impedance output will suffice.

The PK-544, *R1*, *S1* (part of *R1*) *T2*, *S2*, and *J1*, *J2*, and *J3* are mounted in half of a 2 1/8" x 3" x 5 1/4" aluminum box (LMB #136). As a matter of convenience, the authors first mounted input transformer *T1* to the board of the PK-544 amplifier. To do this, you bend off the mounting tabs of the transformer. Then apply quick-drying cement to the bottom of *T1* and to an open area on the amplifier board near the input leads. Mount transformer *T1* in this area.

When the cement is dry, remove the PK-544 input leads where they fasten to the board. Referring to the schematic, trim the low-impedance leads of *T1* and solder them to the board where the original input leads were attached. The high-impedance primary of *T1* is later connected to *J1*.

As shown in the photo on page 64, the PK-544 is mounted with four *4-40* x 5/8" machine screws and extra nuts to the top of the box. Tighten the screws with nuts, then use eight more nuts, four above and four below, to mount the board so it is well away from the metal box. Mounting holes are already drilled in the PK-544; disregard the mounting hardware that comes with it.

Drill holes in the front of the box for mounting the three jacks, controls *R1-S1*, and transformer *T2*. Drill a hole in the bottom of the box for the battery mounting bracket which is made of a piece of scrap aluminum. Referring again to the photo and schematic on page 64, mount and wire the remaining components, cutting any excess leads. In general, it's a good idea to follow the arrangement shown to avoid possible feedback problems.

The bottom section of the box is fastened to the horizontal support bar of the tubular pickup unit by means of two *6-32* 3/8" screws and matching nuts. Place the top section of the box with the mounted amplifier components onto the bottom section, fasten with the screws provided, and the completed unit is ready to use.

Operation. Operation of the "Shotgun Sound Snooper" is simple—just connect a pair of headphones and turn on the amplifier, adjusting the volume control carefully to avoid painful sound volume. Earplugs or single phones are not suitable for critical listening. For best results, use good-quality dual headphones.

The tubular mike must be aimed toward the location from which sound pickup is desired—sight along the tops of the tubes and turn the volume up gradually. Picking up weak distant sounds amidst other distracting sounds becomes much like trying to listen to a newscast in a room filled with noisy people. It becomes necessary to mentally "tune out" the unwanted sound in order to concentrate on the news.

Wind has the effect of carrying sound, so straight-on reception is not always possible. Under windy conditions, the unit should be panned until the best reception is achieved as determined by ear. Noisy winds can spoil listening—especially if the tube ends cannot be sheltered a bit—but moderate wind noise can be cut down by draping the mike with a cloth.

If you enjoy experimenting, you'll find the "Shotgun Sound Snooper" a unique, fascinating project. Endless variations are possible, of course—in tube length and diameter, in the microphone cartridge, the amplifier, etc. Just as endless are the applications you'll find for the microphone. Construction is easy, and the cost is reasonable. Don't delay! -30-

Build Panic Alarm

(*Continued from page* 13)

behind a $2\frac{1}{4}''$ cutout, and a scrap of perforated sheet metal stock is painted red and used as the speaker grille. A matching $2\frac{1}{4}''$ round hole is cut in the panel to allow the bulb of the 25-watt lamp to protrude. The balance of the components are mounted on a $2\frac{7}{16}''$ x $6\frac{1}{2}''$ piece of Vector perforated breadboard stock, which is secured to the bottom of the cabinet using $\frac{1}{2}''$-long, $\frac{3}{8}''$-diameter, internally threaded brass stand-off posts.

Although assembly is not especially crowded, care must be exercised in the placement of components to insure adequate clearance for the 25-watt lamp and the speaker. The writer used brass eyelets for component connection; push-in terminals may be used if desired, however. A socket was not used for the 25-watt lamp in the writer's model. Instead, the lamp was inserted in position with the base against the perforated board, eyelets were installed in the board and #16 solid copper wire used to secure the lamp base and make the required connections. Since brass—instead of the more common aluminum—is used in the base of the red-frosted lamp, soldering the lamp in place provides a simple and effective method of mounting.

Testing and Adjustment. Check your work carefully, using an ohmmeter to test for continuity and the absence of shorts. Be sure that no portion of the circuit is shorted to the metal cabinet. When you're satisfied that the wiring is correct, apply power to the unit. The 25-watt lamp should glow at approximately half brilliance and the 50C5 heater should light. A voltmeter connected across capacitor *C5a* should measure approximately 150 volts d.c. Now brace yourself and push the panic button. Relay *K1* should close and a *very* loud rising and falling audio tone should be heard from the speaker. Lamp *I1* should flicker at a rate corresponding to the warble of the tone and lamp *I2* should appear to glow continuously.

The time constants of the two neon lamp oscillators have been selected for optimum results. However, you may want to change the frequency of the output tone or the rate of warble. To increase the rate of warble, reduce the value of resistor *R2*; to decrease the rate of warble, increase the value of this resistor. Reduce the value of resistor *R3* to increase the frequency of the output tone, and increase the value of this resistor to reduce the frequency. You will note some interaction between the two oscillator circuits, and trial and error adjustment of the resistor values may be required to obtain exactly the effect you desire.

When the alarm functions to your satisfaction, button up the project. Decals will serve to give it a commercial appearance, and a very light coat of clear spray lacquer will protect the decals after they have been applied.

Furnishing application instructions for the panic alarm would be gilding the lily. Analyze the moods of your boss, and when the prognosis is favorable, introduce the panic alarm. —30—

Build the Bi-Coupler

(*Continued from page 43*)

The area at the top, sides, and rear of each speaker should be padded, but anything beyond this is a matter of taste. The top is screwed into place through the sides, fronts, and rear partition—don't use glue here, as you may want to make the speaker change for which this enclosure was planned.

The final touches are up to you. The author's Bi-Coupler was wrapped in grille cloth and wood trim was added at top and bottom as shown in the photos.

Hooking-Up. Assuming your speakers are 8-ohm units, you can connect them in parallel to match your amplifier's 4-ohm output, or in series for a 16-ohm output. For stereo, of course, each speaker goes to its individual 8-ohm output. Again, for optimum separation, you may want another speaker for stereo, but you can settle back and enjoy your first Bi-Coupler until your system grows its second one. -30-

For Greater Safety

(*Continued from page* 16)

inadvertently leaving the emergency switch on. Figure 2, page 16, shows the necessary changes for a four-light flashing switch.

The most convenient way to connect the leads from the emergency switch to the turn-signal switch leads is to strip the free ends about 3/8″, fan out the strands, and insert the lead into the socket half of the proper bullet connector. Then reassemble the connector, making sure no bare wire is left exposed.

To keep from distorting the connectors, light gauge wire (#22 or #24) should be used on the emergency switch. Since these leads will probably be less than a foot long, no appreciable voltage drop will be introduced. To make the job even easier, it's a good idea to prewire the switch with the proper length leads for the mounting location chosen, then mount the switch.

The author's car, a 1962 Ford, already had cutouts in the lower face of the instrument panel for mounting accessory controls. These were concealed by an aluminum trim panel, making it easy to bore a hole for a three-pole rotary switch. To give the installation more of a built-in look, a matching replacement knob was purchased and the switch shaft turned down to fit into it.

No matter how simple or elaborate your installation, the important thing is the large amount of safety that can be bought with a light-flashing switch costing literally pennies. -30-

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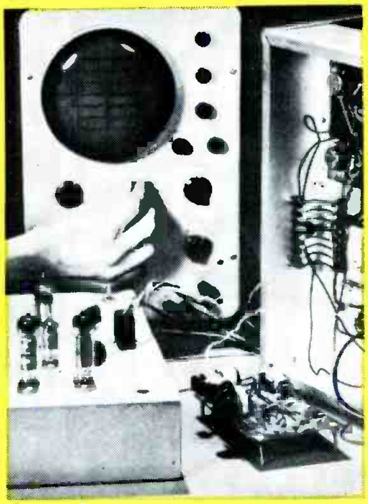

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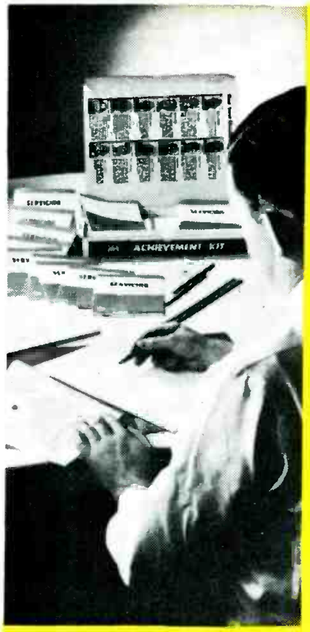

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