1969 POPULAR ELECTRONICS

ELECTRONIC EXPERIMENTER'S HANDBOOK

SPRING EDITION

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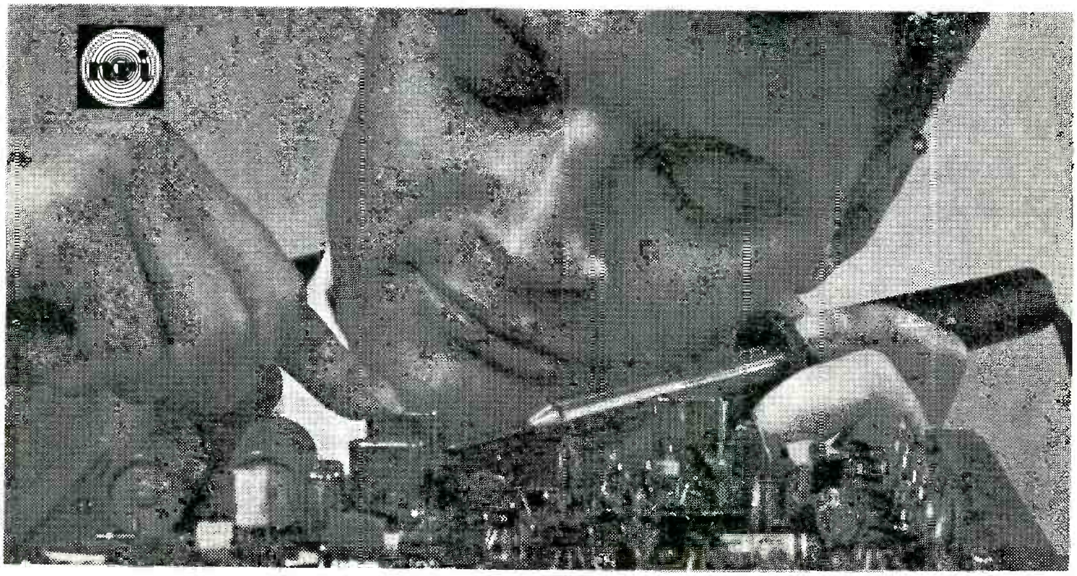

SPRING EDITION 1969 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

Why do experimenters experiment?

The answer to this disarming question is surprisingly complex. Some experimenters are simply using up their spare hours while others are born innovators. Some want to cut corners (financially) on the basis of "building-their-own" and there are those who avidly build and experiment in hopes of uncovering possible errors in published material. On the other hand, many use their hobby to learn more about electronics in the desire to improve their job or career opportunities.

The ELECTRONIC EXPERIMENTER'S HANDBOOK is unique in that it can be truthfully said that in each issue there is material for just about every experimenter. In the pages that follow are articles of import to the household gadgeteer, technician, hi-fi enthusiast, science fair contestant, communicator, hobbyist beginner, etc.

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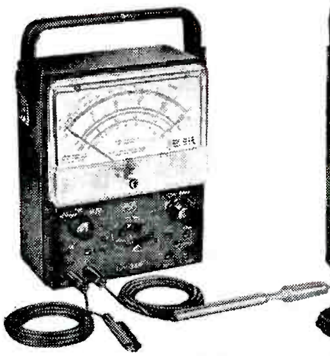

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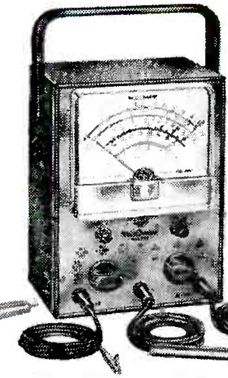

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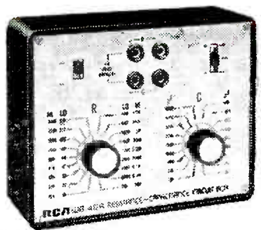

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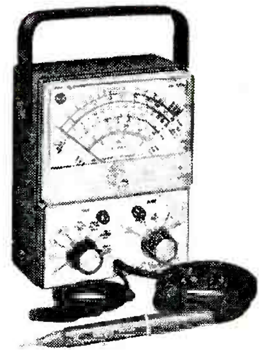
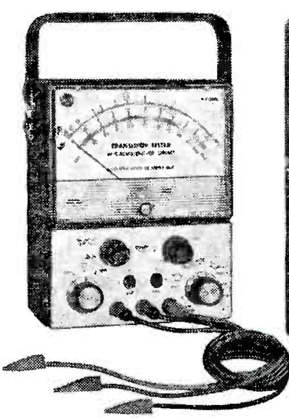


The RCA-500A all solid state, battery operated VoltOhmyst eliminates warm-up time, eliminates zero-shift that can occur in tube operated voltmeters. Completely portable. Only $75.00.* Comes with shielded AC/DC switch probe and cables.

For a complete catalog with descriptions and specifications for all RCA test instruments, write RCA Electronic Components, Commercial Engineering, Dept. B-141W, Harrison, N.J. 07029.

*Optional Distributor resale price. Prices may be slightly higher in Alaska, Hawaii, and the West.



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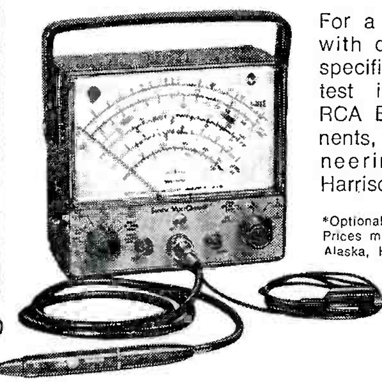

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CHAPTER 1

USEFUL PROJECTS

When the decision had been made to publish in this issue of the ELECTRONIC EXPERIMENTER'S HANDBOOK both the esoteric "Pitch Reference" (page 27) and the rock group guitar amplifier (page 55) the staff had the nagging feeling that it was running from the sublime to the ridiculous. But that is the nature of hobbyist experimental electronics. It can embrace an enormous gamut of construction projects—some useful to but a few, others the delight of many.

As usual in this category of projects we have included several items that will delight other members of your family. The kids will spend hours playing with the light-controlled model cars (page 73) and gadget-happy car enthusiasts will want to build either the "G-Whiz" (page 39), "Accura-Time" (page 19), or "Omni-Alarm" (page 66).

A big hit around many homes is our lead story on the "Dynadim" (page 11) an unusual controller for room light level. For the audio enthusiast who might not find use for the Pitch Reference or guitar amplifier, we have especially included a simplified single-channel color organ and a few words of wisdom about tuning up your bass reflex enclosure.

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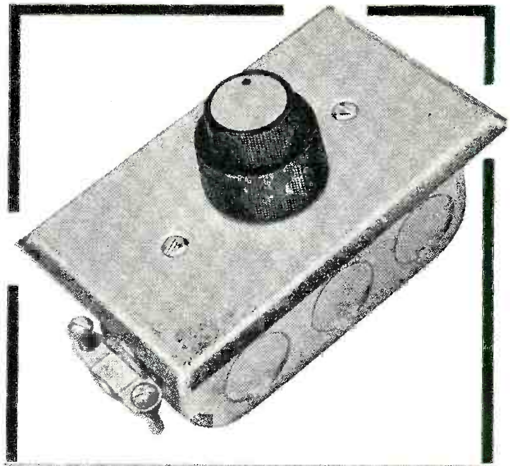
YOU'RE ENTERTAINING and would like the lights down low to set the "mood." But to have them there to start with or to lower them noticeably would spoil the effect. If your home lighting is equipped with the "Dynadim"—the dimmer with a difference—you're in business.

The Dynadim is an unobtrusive wall-mounted device that lets you dim room lighting to any preset level, even full off, automatically and at an almost unnoticeably slow rate. All you do is set a control for the dimming level desired and push in a knob.

Aside from its obvious use as a mood setter at parties, the slow extinguishing action of the lighting possible with the Dynadim can serve as a sleep inducer and a safety device in the home. For example, after setting the Dynadim for timed full off, you have ample opportunity to get into bed before the lights extinguish. So, stubbed toes, bruised shins, and even broken bones that result from collisions with furniture in the dark are eliminated.

If the extinguish rate is set for a sufficiently long time, the slow dimming action can help you to relax, making your eyes heavy-lidded. Before you know it, you're fast asleep. And the Dynadim is especially handy to have around when the kids insist that the lights be left on after they are put to bed.



Build The DYNADIM

Home Lighting Control

THE 500-WATT DIMMER WITH A DIFFERENCE

BY RUSSELL J. BIK

How It Works. To obtain proper dimming action, the Dynadim must be connected in series with the a.c. power source and the load (lamp or fixture to be controlled) via terminals *A* and *B* in Fig. 1.

The power to the load is regulated by the dimmer, specifically by the triac *Q3*. The triac acts as a switch that closes at some point during each alternation of the input power. To cause *Q3* to conduct, a trigger pulse (produced by the discharge action of *C2* through *Q2* and the primary of *T1*) is applied to the gate of the triac. The triac continues to conduct for the remainder of the alternation.

The point in the alternation where *Q3* is triggered into conduction determines how much power is supplied to the load. If triggering is early, the lighting glows at a higher average intensity than if triggering is late.

The time constant of *R9* and *C2* is rather long compared to a single alternation. (The values shown were selected

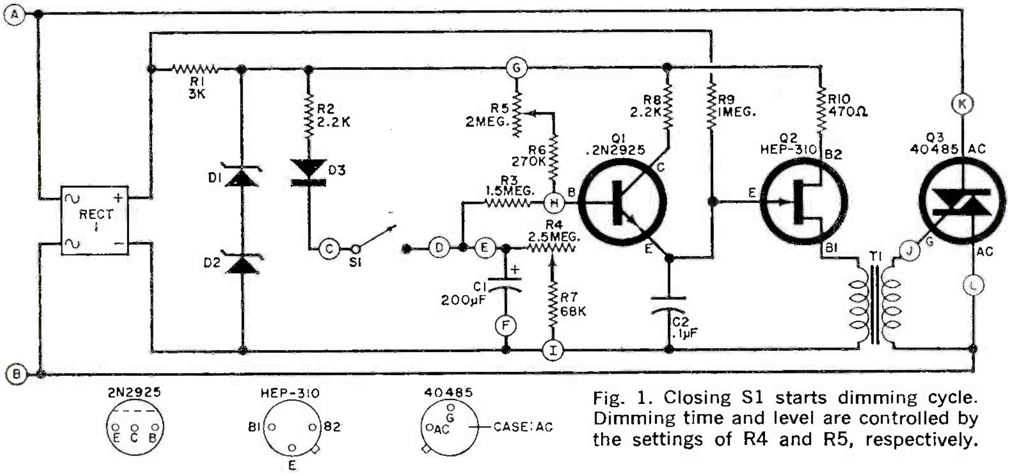


Fig. 1. Closing S1 starts dimming cycle. Dimming time and level are controlled by the settings of R4 and R5, respectively.

PARTS LIST

C1—200-μF, 25-volt electrolytic capacitor
C2—0.1-μF, 25-volt paper or mylar capacitor
D1, D2—12-volt, 1-watt zener diode (General Electric Z4XL12B or similar)
D3—HEP-154 diode (Motorola)
Q1—2N2925 transistor
Q2—HEP-310 unijunction transistor (Motorola)
Q3—40485 triac (RCA)
R1—3000-ohm, 5-watt resistor
R2, R8—2200-ohm, ½-watt resistor
R3—1,500,000-ohm, ½-watt resistor
R4—2,500,000-ohm, linear-taper potentiometer
R5—2,000,000-ohm, linear-taper potentiometer in tandem with R4
R6—270,000-ohm, ½-watt resistor
R7—68,000-ohm, ½-watt resistor
R9—1-megohm, ½-watt resistor
R10—470-ohm, ½-watt resistor
RECT1—VS-248 bridge rectifier assembly
S1—S.p.s.t. switch, push-pull type (part of R4-R5 combination)
T1—1:1 pulse transformer (Sprague 11Z12)
Misc:—General Electric #14-10 heat spreader; Scotch #27 glass-cloth tape; 1⅞" X 3¾" heatsink mounting plate; printed circuit board; dual concentric knobs; hookup wire; solder; hardware; etc.

The following parts are available from Pacific Circuit Systems, Box 1281, San Luis Obispo, Calif. 93401. Etched and drilled printed circuit board, $2.25; complete kit including parts, printed circuit board, and machined mounting plate, $14.95 (residents of California, add 5% sales tax).

so that the potential across *C2* just barely attains an amplitude sufficient to drive *Q2* into conduction when zero voltage is across *C1*, and *R5* is set for maximum resistance.)

Closing *S1* causes the voltage across *C1* to rise, increasing the biasing of *Q1* and raising the potential across *C2*. The charging curve of *R9-C2*, therefore, begins from a slightly higher potential on each successive a.c. power cycle. As a result, oscillator *Q2* produces the triggering pulses for the triac (*Q3*) slightly earlier in the cycle as *C1* charges through *D1* and *R2*.

An earlier triggering can also be obtained by reducing the value of *R5*. The effect on the bias of *Q1* is the same as that of raising the potential across *C2* except that a static control over lighting intensity is provided. A later triggering is obtained by opening *S1* and allowing *C1* to discharge slowly through *R4* and

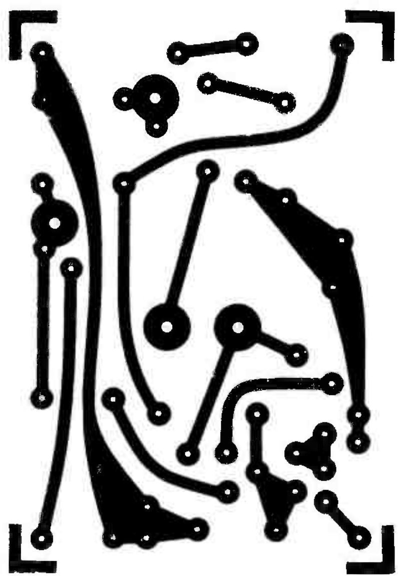


Fig. 2. Drawing shows, in actual size, the resist pattern to be copied if you make your own PC board.

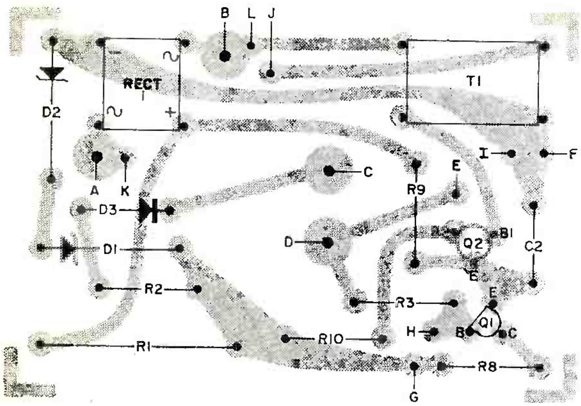


Fig. 3. Observe proper polarities when mounting diodes, transistors, triac, and rectifier assembly.

R7—the lighting diminishes as the triac triggering pulses are produced later and later in each cycle.

The high resistance necessary to prevent the voltage from being shunted away from *C1* too rapidly is obtained by inserting *R3* in the base circuit of *Q1*. The rectified power applied to the timing circuit from *RECT1* is maintained at a 24-volt level, regardless of changes in load, by zener diodes *D1* and *D2*.

Construction. The Dynadim was designed to be mounted inside a standard 4″ × 2″ junction box for wall mounting. Ample space is available inside the box for parts mounting and entrance of wires through both ends. For most permanent installations, the Dynadim's circuit simply takes the place of your present power switch. You can, however, mount the circuit inside a high-impact/heat-resistant plastic box (equipped with a power receptacle) for portable use.

An aluminum mounting plate must be fabricated to support the exterior switch plate and serve as a heat sink for the triac. The plate should be just large enough to fit inside the front of the junction box and rest on the box mounting brackets. Two holes must be drilled and tapped in the mounting plate to facilitate mounting of the exterior switch plate. Then drill the holes for mounting the plate in the box and for the shaft of the control/switch assembly.

For maximum utilization of the space available, printed circuit board construction is recommended. If you plan to etch your own board, an actual-size etching guide is provided in Fig. 2. Component placement and orientation must be the same as that shown in the drawing given in Fig. 3. When all components are mounted and soldered to the board, cut off the excess leads close to the foil to prevent short circuits.

The potentiometer/switch assembly supports the circuit board as shown in Fig. 4. This is done by plugging the switch terminals at the rear of the assembly into the holes in the board. If necessary, bend these terminals to fit. Before final mounting and soldering, apply a bead of epoxy cement to the rear of the assembly to provide solid mechanical support. For maximum safety, also cement *T1* to the board (see Fig. 5).

Mount the parts that do not sit directly flush with the circuit board. Be sure to connect the positive lead of *C1* to the lug of *R4* that is on the side that the wiper moves away from on clockwise rotation. Run an insulated wire from this junction to hole E.

The method recommended for mounting the triac is shown in Fig. 6. First carefully apply a thin film of solder to the underside of the triac's case. When cool, press the triac into the heat spreader, and apply enough heat to solder bond the two pieces together. Now apply a thick film of epoxy cement to the underside of the heat spreader, attach a 1½″ to 2″ long piece of heat-setting tape to the mounting plate opposite *R1*, and press the heat spreader onto the tape. Allow

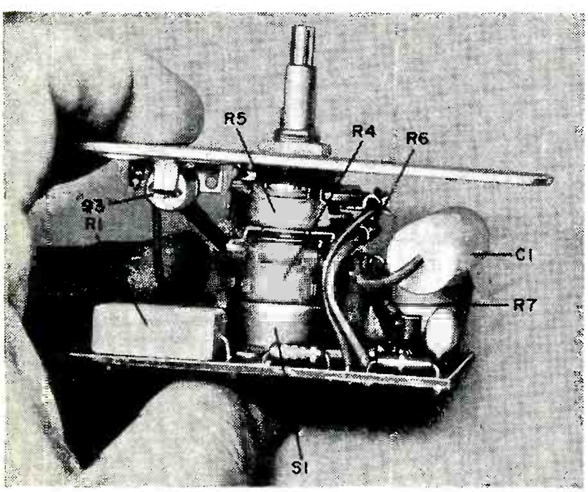


Fig. 4. For components that are not mounted flush with board, use insulated sleeving on exposed leads.

the cement to set over night; then slip insulated tubing over the leads of the triac and solder them in place.

It is recommended that you look over the circuit board carefully to make sure that all solder connections are good and all polarities are correct. Then check for short circuits to ground. (Ground, in this case, is the front mounting plate.) Temporarily connect a power cord and load to the Dynadim. (See first paragraph of "How It Works" section.) Apply line power, and check with an a.c. voltmeter to make certain that there is no voltage between the mounting plate and a cold water pipe ground. When you are satisfied that the circuit is safe, remove the power and disconnect the load and line cord.

The next step is to cut the power feed to the switch that the "Dynadim" is to replace. Make absolutely certain that the 117-volt a.c. line is "dead" before removing the switch. Remove and set aside the wall plate and switch, and locate and identify the power and load wires inside the junction box.

Connect the appropriate wires to holes A and B on the circuit board as described earlier. Then twist tightly together the remaining load and line wires and secure them with an electrical wire nut. When the wire nut is in place no bare wire must be allowed to show.

Finally, mount the Dynadim in the junction box. Carefully arrange the wires so that they do not interfere with any of the components. Replace the exterior switch plate, and set the dual-concentric knobs onto the control shafts.

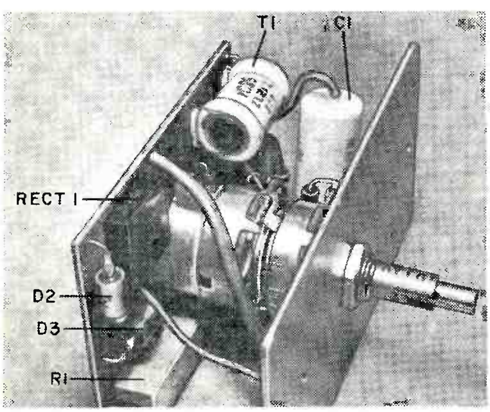


Fig. 5. Capacitor C1 should be oriented so that it sits between transformer T1 and the mounting plate.

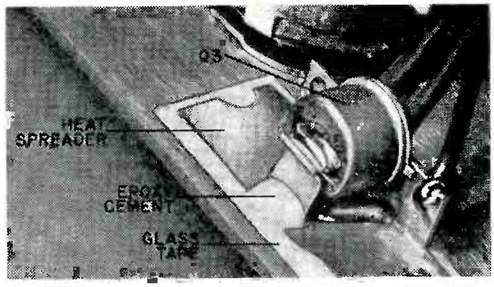


Fig. 6. Epoxy cement and glass-tape anchor insulate Q3 from front plate, provide maximum heat transfer.

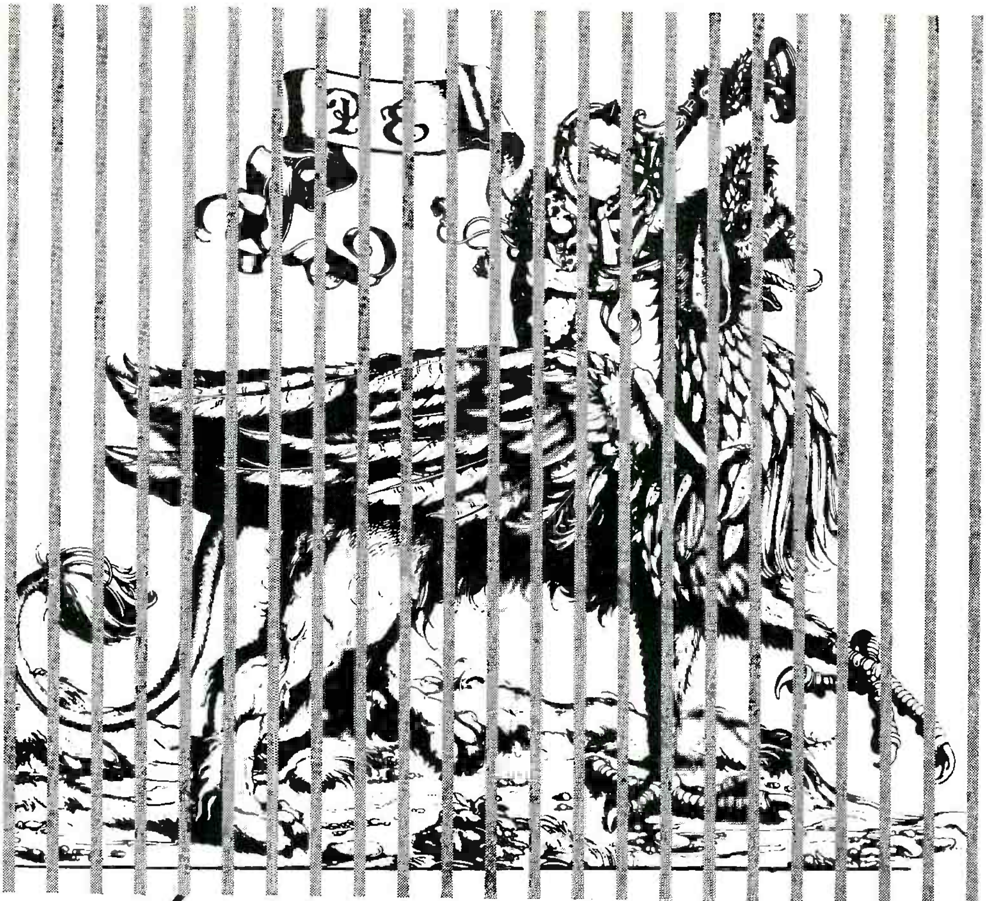
How To Use. Although conventional on/off control over lighting is sacrificed with the use of the Dynadim, the sacrifice is not great. When properly operated, the lights can be switched off and become fully extinguished—even from full on—in a matter of a few seconds.

For dimming action, a great deal of flexibility can be obtained from the Dynadim's extremely simple controls. For example, if you wish the lights to be full on and extinguish to a very dim glow over a period of say, 10 minutes, the following procedure would be followed: First rotate both concentric knobs fully counterclockwise, and push in on the smaller knob. The lights will extinguish quickly. Then, adjust the large knob to the position that gives the desired minimum illumination. Set the smaller control to a position about ⅔ clockwise, pull out until the lights come up to full intensity, and push in. It may be necessary to experiment with the setting of the smaller knob to obtain the exact time.

In general, dimming action is obtained by the above procedure. It may be a good idea to "calibrate" the controls (two concentric circles, for example) so that experimentation is unnecessary. The inner circle could be calibrated in minutes, and the outer for intensity—high; medium-high; medium; medium-low; etc.

If longer dimming times are desired, they can be obtained by increasing the values of *C1* and/or *R7*. As a rule of the thumb, the dimming time is equal to ⅝ of the time in seconds obtained by multiplying the value of the capacitor in microfarads by the sum of the resistances of *R4* and *R7* in megohms.

The "Dynadim" draws very little power when it is off. It can be treated like any electric clock or night light. -30-



WANT TO KEEP YOUR MYTHICAL BEASTS AT BAY? WHAT COULD BE BETTER THAN AN

ELECTRIC FENCE

BY LYMAN E. GREENLEE

ONE OF LIFE'S lesser pleasures is hearing your neighbor's cat or dog upset your metal garbage can—at four in the morning! Or, worrying about those expensive new evergreens the landscaper planted that afternoon. Or, listening to snooping animal sounds outside your summer cottage. Or, trying to think of a way to keep that frisky horse, cow, or lamb in its pasture.

With an electric fence, you can forget about any or all of these problems. Presented here is an inexpensive electronic system* that will deliver a disturbing (but harmless) electrical sting to any animal or person touching the item to be pro-

**This project is a solid-state version of the "Electric Fence Charger" which appeared in the Spring '66* ELECTRONIC EXPERIMENTER'S HANDBOOK.

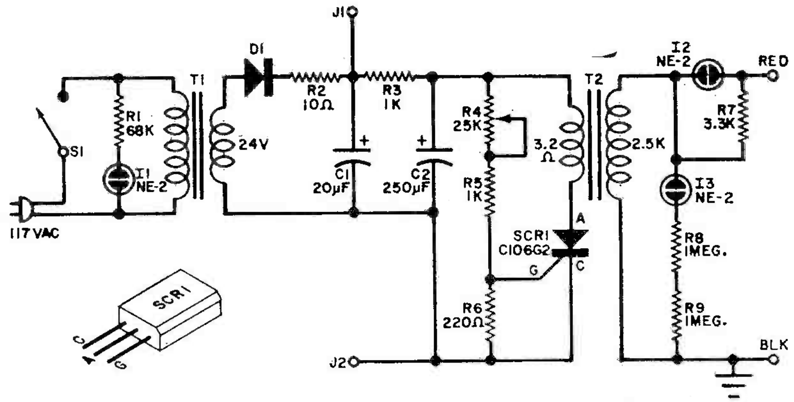


Fig. 1. The device can be powered either from an a.c. power line or from a conventional 45-volt "B" battery. There are no critical parts or adjustments.

PARTS LIST

C1—20-µF, 50-volt electrolytic capacitor
C2—250-µF, 50-volt electrolytic capacitor
D1—Silicon rectifier, 100 PIV, ½ ampere
I1, I2, I3—NE-2 neon lamp (without resistor)
J1, J2—Banana jack (one red, one black)
R1—68,000-ohm, ½-watt resistor
R2—10-ohm, ½-watt resistor
R3, R5—1000-ohm, ½-watt resistor
R4—25,000-ohm, screwdriver-adjust potentiometer
R6—220-ohm, ½-watt resistor
R7—3300-ohm, ½-watt resistor
R8, R9—1-megohm, ½-watt resistor (do NOT use a single 2-megohm resistor)
S1—S.p.s.t. switch
SCR1—Silicon-controlled rectifier (GE C106G2, or similar)
T1—Power transformer, 24-volt secondary, ½ ampere
T2—Output transformer, 2500 ohms to 3.2 ohms
Misc.—Metal or plastic case, aluminum front panel to fit case, terminal strips, snap-in plastic neon lamp holders (one red, one orange—see text), lengths of red and black insulated test prod flexible wire, hookup wire, solder, hardware, etc.

A complete kit of parts, including drilled panel, is available from Lyman E. Greenlee, P.O. Box 1036, Anderson, Indiana 46015. Order kit FC-2, $27.50.

tected—or making contact with a simple single-wire fence surrounding the area to be protected.

The fence charger has other applications as well. Since it is capable of flashing a conventional fluorescent lamp bright enough to be seen some distance at night, it can be used as a temporary emergency obstruction light. Or it can serve as a homing light—when placed on a fishing dock, for example. And, because it can be powered by a conventional 45-volt "B" battery, the project can be used anywhere, regardless of the presence or lack of a power line.

Construction. The circuit, diagrammed in Fig. 1, can be built in a metal or plastic utility box. Parts layout is not critical, and all components can be affixed to the front metal cover as shown in Fig. 2. This type of construction makes for easy assembly, wiring, and troubleshooting—in the event that it should ever become necessary. If a metal box is chosen, make sure that none of the components touches the metal to cause a possible short circuit.

Use a heat sink (long-nose pliers on each lead) when soldering the SCR, and toothed lock washers and soldering lugs for all chassis connections. For ease in output identification, use a red-insulated wire for the high-voltage lead and a black-insulated wire for the ground lead (see Fig. 1). "Power on" indicator *I1* should be housed in a red plastic holder, while "operation" indicator *I2* should have some other color plastic holder (orange, for example). Lamp *I3* is contained within the box and requires no plastic mounting.

Operation. Make sure that the far end of the red output lead is not touching anything, then turn on the a.c. power (via *S1*). "Power on" indicator *I1* should glow. When the power is applied for the first time, wait for a few minutes to allow the filter capacitors to form proper-

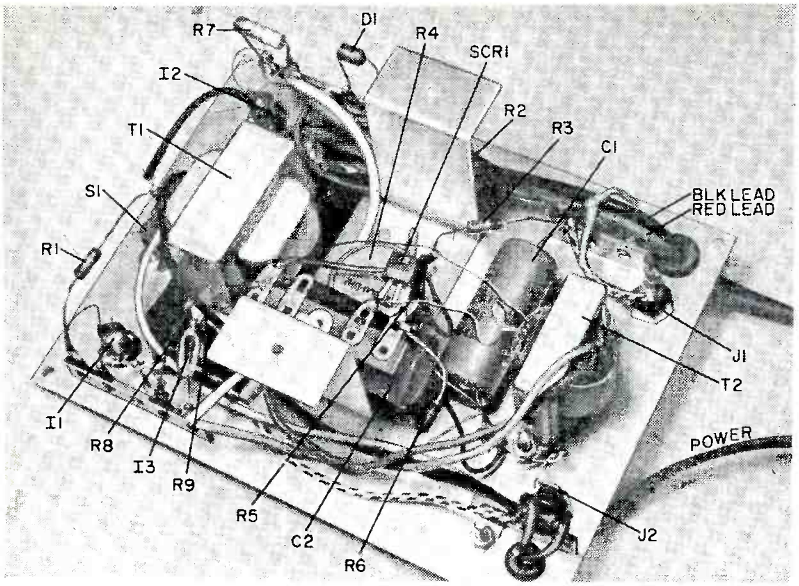
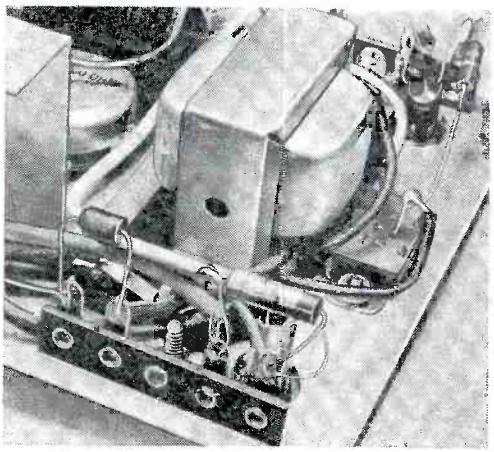


Fig. 2. All of the parts can be mounted on the rear of the enclosure cover plate.

ly. During this initial forming period, the charger will not operate.

After a few minutes, turn off the a.c. power and connect the red and black output leads to a fluorescent lamp (20 watts or more is preferred). Turn the power back on and you will see that the lamp will flash each time the circuit fires. Adjust *R4* until the lamp blinks at between 30 and 40 times per minute. This rate is about right for general operation. The rate will vary with temperature, but such variation is not important since the pulse frequency is not critical.

A 45-volt, heavy-duty "B" battery can be used to power the charger in remote applications far from commercial power lines. Connect the battery positive terminal to *J1* and the negative terminal to *J2*. Because power on/off switch *S1* will not control the device in this mode, you should disconnect the battery when the device is not actually in ser-

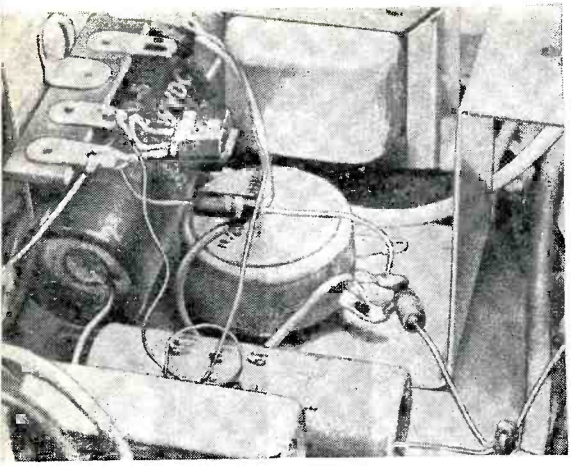


Terminal strips are used to support components and also act as tie points for the point-to-point wiring.

HOW IT WORKS

Isolation transformer *T1* steps the input line voltage down to 24 volts, which is rectified by *D1* and filtered by the combination of *R2*, *C1*, *R3*, and *C2* to produce about 45 volts d.c. This voltage would be applied across the 3.2-ohm winding of *T2* if it were not for the nonconducting SCR which acts as an open switch. As *C2* charges, the voltage across the SCR gate network (*R4*, *R5*, and *R6*) builds up. When the SCR gate receives the required trigger voltage, the SCR fires to discharge *C2* across the *T2* primary. As soon as this discharge occurs, *C2* has essentially no voltage across it, the SCR returns to its nonconducting state, and the cycle repeats itself. Triggering rate is determined by the setting of *R4*.

The turns ratio of transformer *T2* is such that several hundreds of volts are generated across the secondary for each primary current pulse. This voltage spike is passed, via *I2*, to the main high-voltage output (the red terminal). Neon lamp *I2* will flash each time a load appears across the high-voltage output and ground (black terminal). Although disturbing to both animals and humans, the generated shock pulse will cause no damage and is safe due to its very short duration.



The U-shaped metal pan acts as a support for the front panel to prevent panel distortion.

vice. In these remote applications, make sure that both the battery and the charger are kept within a water-proof container at all times.

You can check the operation of the power supply portion of the circuit during power line operation by means of *J1* and *J2*. Connect a 50-volt voltmeter positive lead to *J1* and the voltmeter common to *J2*. The meter should indicate about 45 volts.

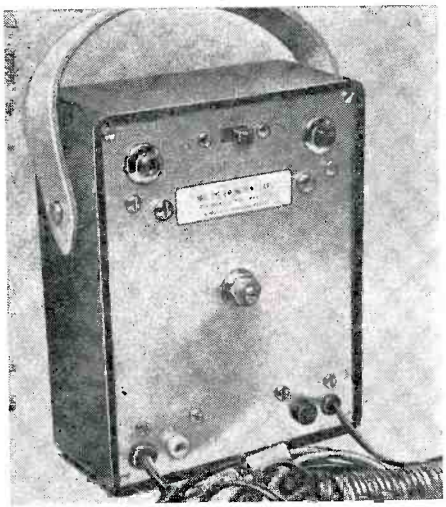
Installation. To keep a metal garbage can from being raided, place a small piece of insulating material (plastic, dry wood, or cardboard) under the can to insulate it from the ground. Then connect the red lead from the charger to the can proper, and connect the black lead to a good ground stake near the can. If the ground near the can is slightly moist, the device will work better.

If the can is usually kept on a dry cement or gravel walk, first lay down a piece of metal screen a couple of feet larger in diameter than the garbage can to serve as the ground. Then insulate the can from this ground with a piece of plastic, dry wood, etc. Connect the red lead to the can, and the black lead to the screen. In both cases, ALWAYS be sure that the charger is turned off before a garbage collection—or you may have another kind of trouble!

Any metal object can be protected in the same manner, provided that it is insulated from the ground, and that an intruder must stand on the ground (or a metal screen) in order to touch the metal object.

To make an electric fence, mount a series of electrical standoffs, one to each fence post, along the area to be protected. The height above ground is dependent on the animal you want to keep out (or in), and should be about knee to chest high for most applications. Then run a bare metal wire through the insulators with the far end terminated with an insulator (do not ground this end or any point along the wire), and the near end connected to the red output terminal (high voltage). Drive a metal rod into the ground for the black (ground) lead. A metal fence post or waterpipe can also be used.

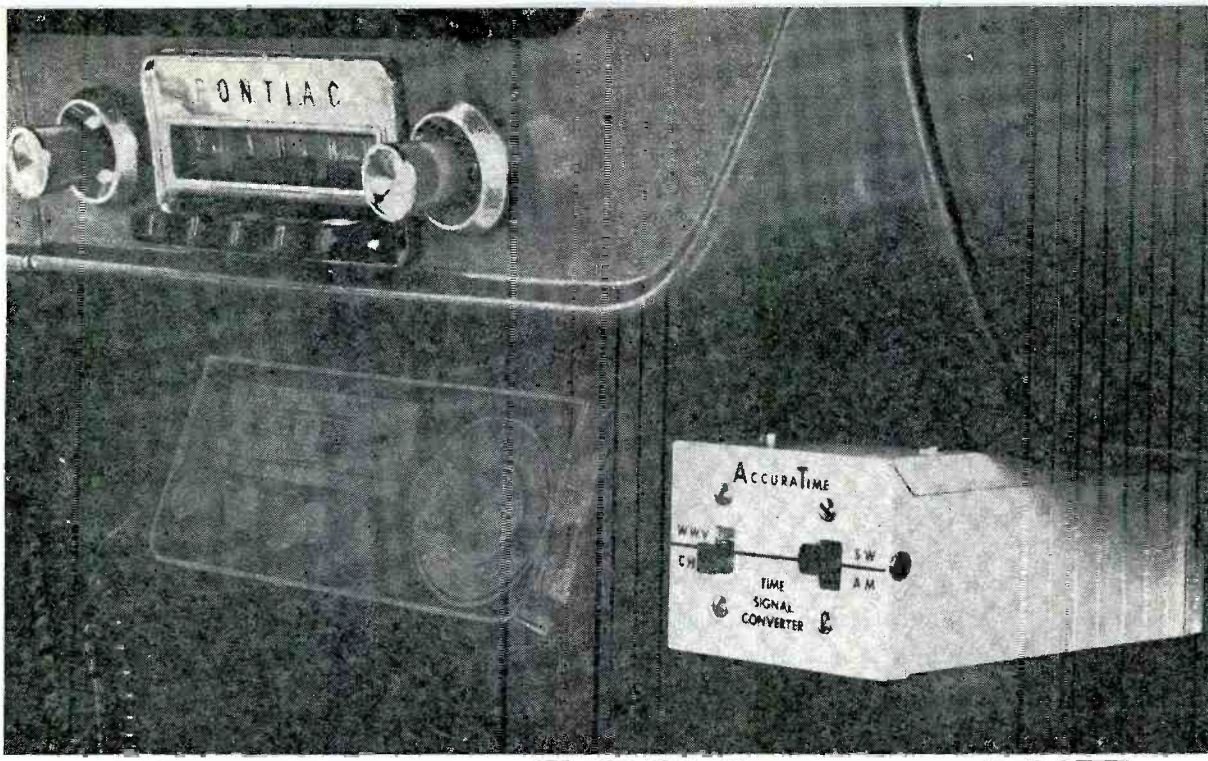
Almost any arrangement can be employed to protect various areas, as long as you remember to have the high-voltage lead (red) connected to a bare wire (supported off ground by insulators), and have a good ground connection for the black lead. In very dry soils, it may



The author's unit is mounted within a black plastic case fitted with a carrying handle.

be necessary to provide some form of moisture to insure a good ground contact.

To use the charger as an emergency lamp flasher, simply connect the red and black output leads to each side of a fluorescent lamp (pins not important). A 20-watt lamp can be seen for miles at night. —30—



BUILD the ACCURATIME

CONVERT YOUR CAR RADIO INTO THE WORLD'S MOST ACCURATE TIMEPIECE

BY GEORGE J. WHALEN

HOW WOULD YOU like an "electronic" clock with an accuracy far better than one second per year? This "electronic" clock announces the time each minute in English and French and will also tell you about such weird things as whether or not there have been any solar flares in the last 24 hours. If that isn't enough, this ubiquitous device will also let you listen in on standard frequency audio tones, or even the 41- and 31-meter international broadcasting bands.

If you have a friend that drives in sports car rallies, he is going to want you to build him one of these "electronic" clocks—so be prepared.

Outside of building the device, the only other thing you need is either an automobile AM or transistor AM radio. Named the "AccuraTime," this fixed-tuned little crystal-controlled short-wave converter receives the National Bureau of Standards station WWV on 10 MHz, or the Canadian Dominion Observatory station CHU on 7.335 MHz. At a flick of a panel switch, you can select either station, giving you the choice of CHU's one-second "beeps" plus voice time announcements in English and French each minute or the broad range of time, frequency, and propagation announcements made over WWV. Because of the geographical separation between these two stations, propagation effects are always different. Consequently, if propagation conditions cause one station to drop out, you can switch to the other for uninterrupted time keeping.

The "AccuraTime" converter is assembled on a small printed circuit board,

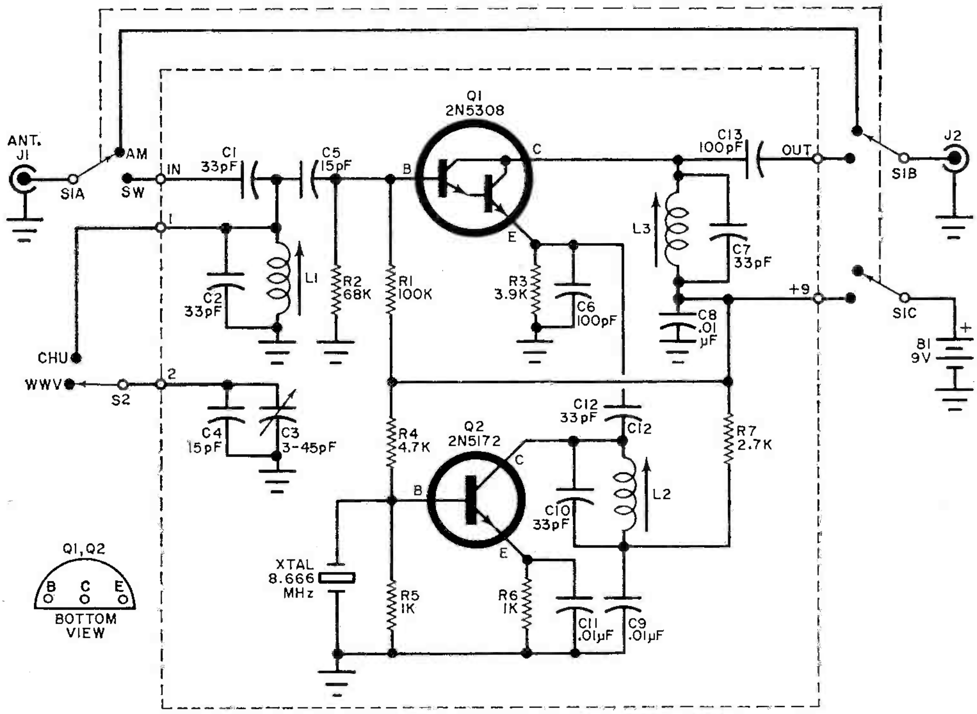


Fig. 1. The circuit is a basic high-efficiency short-wave converter using the latest in available transistors. Having an i.f. output of 1.33 MHz, it converts any car radio into a double-conversion superhet. With its tunable i.f. (the car radio), selectivity and sensitivity are both excellent.

PARTS LIST

B1—9-volt battery
C1, C2, C7, C10, C12—33-pF, disc ceramic capacitor
C3—7-45-pF trimmer (Centralab 822-BN or similar)
C4, C5—15-pF disc ceramic capacitor
C6, C13—100-pF disc ceramic capacitor
C8, C9, C11—0.01-μF, disc capacitor
J1, J2—Motorola-type auto radio jack (H. H. Smith 1207, or similar)
L1, L2—2.4-4.1-μH adjustable printed circuit coil (J. W. Miller 23A336RPC or similar)
L3—160-275-μH adjustable printed circuit coil J. W. Miller 23A224RPC, or similar)
P1, P2—Motorola-type auto radio plug (H. H. Smith 1200, or similar)
*Q1—2N5308 transistor (Also known as the General Electric D16P4)**
*Q2—2N5172 transistor**
R1—100,000 ohms
R2—68,000 ohms
R3—3900 ohms
R4—4700 ohms
R5, R6—1000 ohms
R7—2700 ohms
(all resistors ½-watt and 5% tolerance)
S1—3p.d.t. slide switch
S2—S.p.s.t. slide switch
XTAL—8666 kHz quartz crystal (Available from author—address at right—for $5, postpaid)
Misc.—Printed circuit board, battery clip, spring and lugs for battery hold-down, metal case 5¼" x 2⅛" x 3", 1-inch tapped standoffs (4), low-capacitance shielded cable, hook-up wire, solder, hardware, etc.*
**Kit of semiconductors $1.50, etched and drilled PC board $2.50; both postpaid from the G. J. Whalen Co., P.O. Box 16, E. White Plains, N.Y. 10604. (New York State residents add 2% sales tax.)*

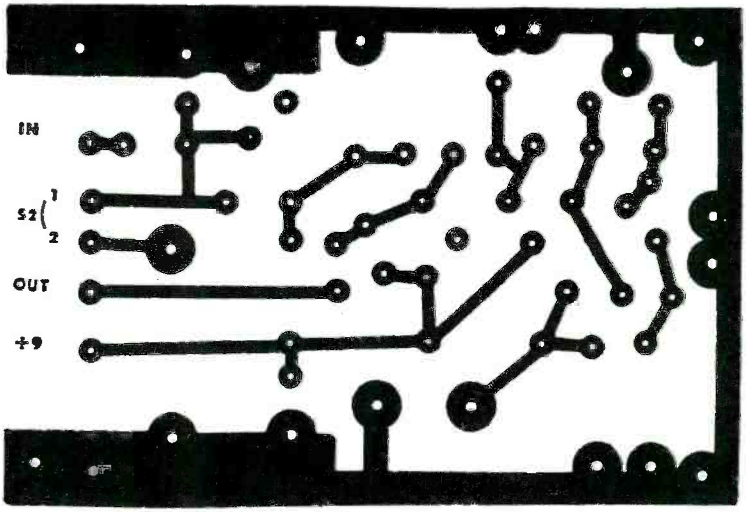


Fig. 2. Actual-size printed board is easy to duplicate (or it can be purchased). Terminal identification is the same as shown on the schematic.

which provides parts support, speeds assembly, and makes exact duplication of the author's layout and wiring a cinch! Packaging combinations are limited only by your imagination. For example, you can attach the converter to a spare AM transistor radio receiver, or even repackage the transistor radio and the "AccuraTime" printed circuit board in a single metal case to make a standard time and frequency receiver.

Construction. The circuit appearing in Fig. 1 may be assembled on a printed circuit board, similar to that shown actual-size in Fig. 2. Once the board is made (or purchased), the components are installed on the board in the locations shown in Fig. 3. Note that capacitor *C4*

HOW IT WORKS

The "AccuraTime" is a crystal-controlled r.f. converter tuned to either of two desired shortwave frequencies. The converter output is an i.f. that falls within the standard AM broadcast band. The BCB radio receiver provides i.f. gain and selectivity, detection, and audio amplification.

Separate mixer and local-oscillator stages are used (see Fig. 1) for best conversion efficiency and freedom from spurious responses. The mixer transistor (*Q1*) is a monolithic Darlington device having a very high input impedance and excellent gain.

Local oscillator *Q2* is crystal-controlled at 8.666 MHz in a tuned-base, tuned-collector configuration. This frequency is halfway between the 10.0 MHz frequency of WWV and the 7.335 MHz frequency of CHU, and produces a resultant i.f. close to 1330 kHz. Tuning the converter to either WWV or CHU is accomplished by changing the resonant frequency of the mixer tuned circuit *L1-C2*, by inserting trimmer capacitor *C3* in the circuit through selector switch *S2*.

The converter oscillator signal is injected into the mixer via *C12*. This signal modulates the r.f. current through *Q1*, varying the non-linear impedance of the emitter-base junction of the first transistor of the Darlington. The incoming r.f. signals selected by *S2* are mixed with the local oscillator signal at this point, thus developing the sum and difference signals. These signals appear across the output tuned circuit (*L3-C7*) which is made to resonate at 1330 kHz. The difference signal is fed to the output jack (*J2*).

Switch *S1* is provided to bypass the short-wave converter when only BCB listening is required. This switch simultaneously removes power from the converter through the *S1(c)* section.

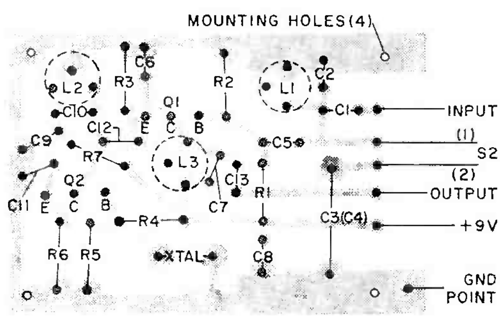


Fig. 3. Parts installation on the upper side of the board. Note that all coils have three support lugs.

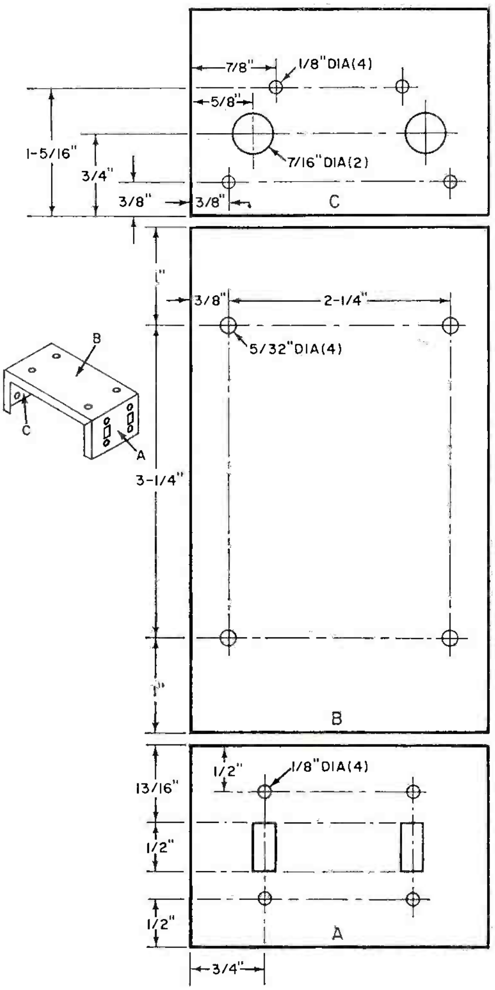


Fig. 4. All components will fit in aluminum metal box. Author used Premier aluminum box AMC-1006.

but is only soldered to the foil side of the board for increased coil support.

When all the PC board components have been soldered in place, the board should be mounted in a metal case, using a short standoff insulator at each corner of the board. The plan of the author's metal case is shown in Fig. 4. The board is then wired to the two switches (*S2*, the s.p.s.t. "WWV-CHU" selector, and *S1*, the 3p.d.t. "AM-SW" selector). As shown in the photograph, the two switches are mounted on the front of the metal case, while the two Motorola-type r.f. connectors are mounted on the rear wall. Battery *B1* is supported by a spring within the metal case (see photo).

Connection to Radio. To connect the assembled "AccuraTime" converter to a car radio, you will need a shielded r.f. cable fitted with Motorola male auto radio connectors at each end. The low-capacitance shielded antenna cable from an old car radio is ideal for this purpose. However, for short runs (up to 20 inches), ordinary coaxial cable such as RG-59/U may be used. This cable is connected between the output of the "AccuraTime" (*J2*) and the antenna input of the car radio. The car radio antenna is plugged into the input receptacle, *J1*. With the "AM-SW" switch in the "AM" position, the car radio will operate as usual.

If you want to use the "AccuraTime" with a conventional transistor AM radio, you must add a coupling coil to the radio receiver's ferrite antenna bar as

is soldered across the terminals of trimmer *C3* on the *foil* side of the PC board. After all components have been installed, recheck that the correct parts are in the correct holes and make sure that both transistors have been properly installed.

Before installing the crystal (XTAL), lightly sand the pins of the crystal holder to prepare them for soldering. Place the crystal in position on the board and carefully solder it into place. Make sure that you do not prolong the soldering operation. Excessive heat can fracture the crystal. Note also that coils *L1*, *L2*, and *L3* have three mounting pins arranged in a triangular configuration. Pin 2 of each coil is not connected into the circuit

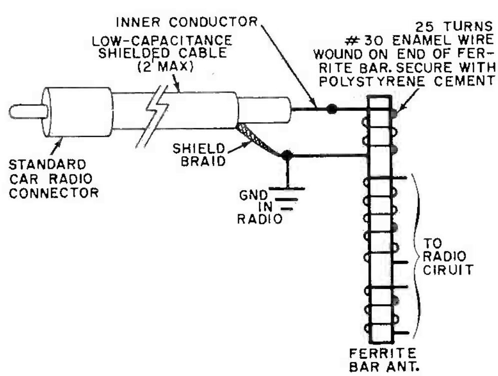
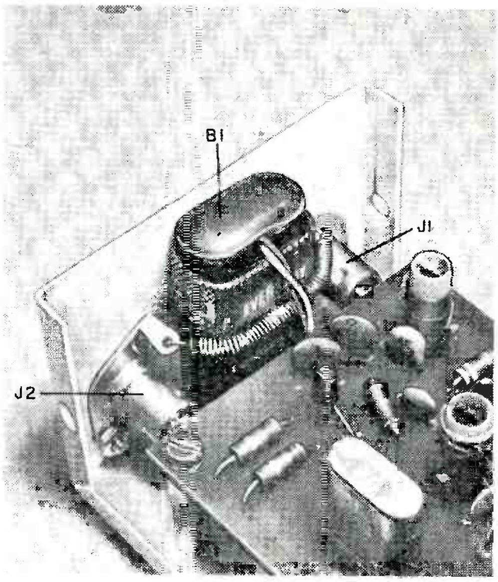


Fig. 5. Make this modification if you use the converter with a transistor radio. Make sure that the radio is shielded to eliminate the unwanted BCB signals.

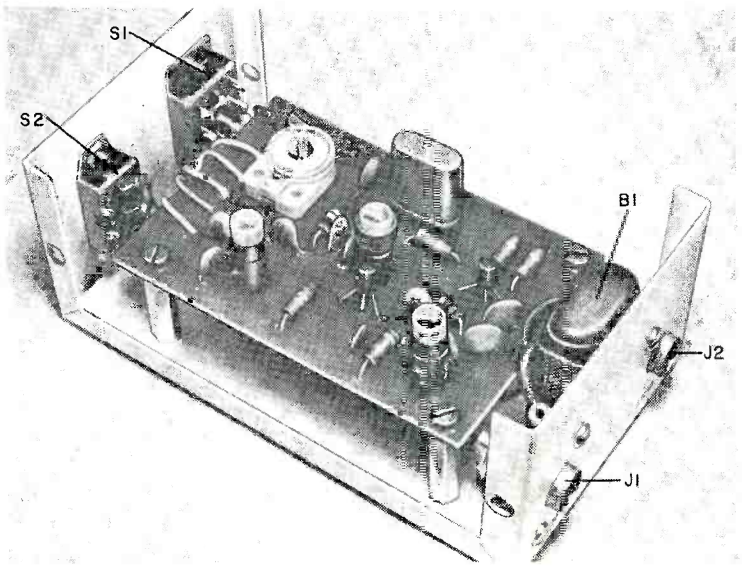
shown in Fig. 5. This coupling coil consists of 25 turns of #30 enamelled wire wound at one end of the ferrite bar. Attach a low-capacitance coax cable to the new coil and solder a Motorola auto radio connector at the other end. This plug mates with *J2* on the converter. Pass the cable through a hole drilled in the radio case.

If you want to make a WWV-CHU laboratory-type time signal receiver, remove the AM transistor radio receiver from its case and mount it with the "AccuraTime" PC board in a metal case. Wind the coupling coil (Fig. 5) around the ferrite antenna bar of the transistor radio, ground one end of the coil and connect the other end to capacitor *C13* on the converter board. Shield the entire converter/receiver combination, making some provision to gain access to the tuning and volume control on-off switch of the transistor radio. The same 9-volt battery can be used for the receiver and converter, and switch *S1* is not required.



View of the "C" side of the chassis showing placement of the two Motorola-type jacks, and method of mounting the 9-volt battery.

The finished converter within its chassis. After final tune-up, secure each coil slug using a little cement or putty. This prevents them from moving and detuning during any vehicle vibration.



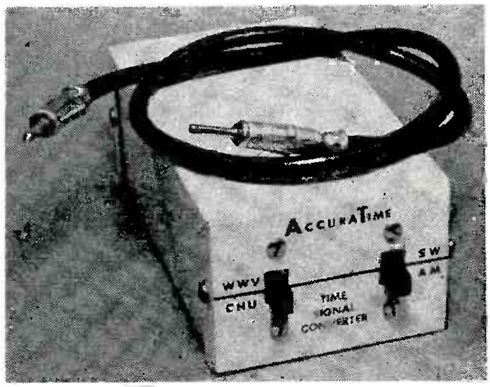
WWV—National Bureau of Standards, Ft. Collins, Colorado, 10 MHz. The signal from this station is complex and serves many functions besides time keeping. Identification may be made by the "time tick" that occurs each second (omitted at the 59th second) and a double tick at the exact minute. These ticks, and all other modulation, are removed during the period between 45 and 49 minutes before the hour.

At the start of each five-minute interval, 600- and 440-Hz standard audio tones are alternated and last for two minutes. The tone is followed by a special computer time code lasting for one minute and sounding like a coarse "buzz." There is one exception to this progression: the 600-Hz tone that starts the hour lasts three minutes and there is no computer code.

The last 30 seconds of each five-minute interval consists of an announcement, both in English and in slow-speed, tone-modulated Morse code, of the station call letters and location and the exact time. Special "Geoalerts" and time correction signals are transmitted between the 18th and 19th minute past the hour.

Alignment. With the car radio antenna connected to the converter and the converter output connected to the car radio as previously described, extend the car radio antenna to about 40″, turn on the car radio, and place the converter "AM-SW" switch (*S1*) in the "SW" position and the "WWV-CHU" switch (*S2*) in the "WWV" position. Tune the car radio to 1330 kHz and peak its antenna trimmer for maximum noise hiss or signal pickup. On some car radios, the antenna trimmer is located next to the antenna input jack, while on other receivers it is accessible either through the bottom or side of the chassis. Some car radios conceal it behind the tuning knob.

Once the car radio trimmer has been peaked, use a plastic hexagonal alignment tool to peak up the coils in the converter. Adjust converter oscillator coil *L2* until the receiver noise level rises indicating that the oscillator is working properly. Peak output coil *L3* for maximum noise level in the receiver. Then peak mixer coil *L1* for maximum noise. Rock the car radio tuning dial back and forth around 1330 kHz (1.33 MHz) until you tune in the clock ticks or tone transmission of WWV. Once you locate WWV, touch up coil *L1* for maximum signal strength. Set the "WWV-CHU" switch to the "CHU" position and tune down the radio dial very slightly until you hear the distinctive one-second "beeps" of CHU, or the English and French time announcements. Peak CHU by adjusting trimmer capacitor *C3*.



The completed "AccuraTime" converter makes a neat package, is self powered, and does not change operation of the radio to which it is connected.

With the converter set to receive CHU, tuning the car radio between 1300 and 1600 kHz (1.3 to 1.6 MHz) enables partial coverage of the 40-meter ham and 41-meter broadcast bands. With the converter set to receive WWV, tuning the car radio between 830 kHz and 1100 kHz covers most of the 31-meter international broadcast band.

When used with a transistor radio, connect an outdoor antenna to *J1* of the converter, connect the converter to the coax cable feeding the radio antenna, and turn on both converter and receiver. Set the radio to 1330 kHz, put the "AM-SW" switch (*S1*) of the converter on "SW," and the "WWV-CHU" switch (*S2*) on "WWV"; then follow the same alignment procedures described above for car radio installation. —30—

CHU—Dominion Observatory, Ottawa, Ontario, Canada, 7.335 MHz. This time-signal-only station can easily be identified by the tone-modulated "time ticks" that occur each second with the exact minute tick 2½-times longer, and the exact hour tick 5-times longer. The 29th tick is omitted, as is the 51st through 59th. During this latter period, time announcements of the hour and minute are made in English and French. Also, the first through tenth ticks are omitted at the beginning of each hour.

While you were out...

TELEPHONE MONITOR TELLS IF SOMEONE CALLED

BY H. St. LAURENT

ONE OF THE drawbacks of the conventional telephone is that you have to be aware that it is ringing. This may present a problem if you are hard of hearing or are out of earshot when it rings. On the other hand, if you run a small business and want to know if anyone calls during your absence, you could use a device that would turn on a lamp when the phone rings. Then when you return to your shop, if the light is on, you know that you should call the answering service to get the message.

The Phonoalarm described in this article (and shown schematically in Fig. 1) is a relatively simple electronic device that does not make direct connection to the phone, but operates by induction. Whenever the phone rings, it energizes a remote bell or buzzer or a conventional 117-volt light in step with the phone's ringing. At the flip of a switch, the alarm can be changed so that the external circuit remains energized after the phone stops ringing. In this mode, a manual reset switch is used to turn the device off.

Construction. The Phonalarm is built into a shallow non-metallic tray, just large enough to accommodate the base of the phone being used. The top cover of the tray (supporting the phone) *must* be non-metallic to allow the phone ringer's magnetic field to penetrate the alarm.

Except for the location of the pick-up coil, component arrangement is not critical. In the author's version, shown in Fig. 2, the phone-operated indicator lamp *I1* and the manual reset pushbutton switch *S1* are on the front of the

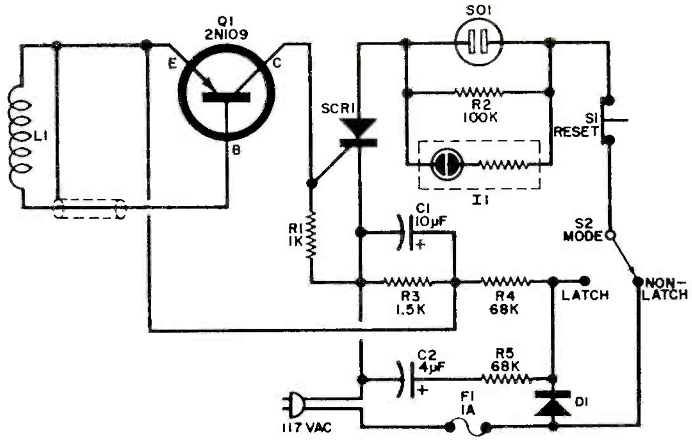


Fig. 1. Telephone pickup coil L1 detects the magnetic field of the telephone ringer. The current developed is amplified by the transistor and used to trigger the SCR. This in turn applies power to the indicator light and the external circuit through chassis socket SO1. It is understood that Lectromek (see address below) may also have a complete kit available for about $17.00. We suggest writing them for additional information if you're interested.

PARTS LIST

C1—10-µF, 10-volt electrolytic capacitor
C2—4-µF, 150-volt electrolytic capacitor
D1—1-ampere, 400-PIV silicon rectifier
F1—1-ampere fuse
I1—Neon pilot lamp assembly with series resistor for 117-volt operation
L1—Telephone pickup coil (flat type)
*Q1—2N109 transistor**
*R1—1000-ohm**
R2—100,000-ohm
R3—1500-ohm
R4, R5—68,000-ohm
(*all resistors ½-watt*)
S1—Normally-closed miniature pushbutton switch
S2—S.p.d.t. switch
SCR1—1-ampere silicon-control rectifier (GE C106-B1 or similar)*
SO1—117-volt chassis mounting socket
Misc.—Shallow non-metallic tray to fit telephone base, non-metallic cover to fit tray, cement, rubber feet (4), power cord, wire, fuse holder, solder, hardware.
**A kit of parts including Q1, R1, and SCR encapsulated in a single module is available as PA-110 from Lectromek, P.O. Box 824, Warwick, R.I. 02888 for $5.*

tray; the power input line and power outlet socket *SO1* are on the back. Transistor *Q1*, resistor *R1* and the *SCR* must be mounted very close to each other to avoid electrical noise pickup that may cause false triggering. The author's version did not include the optional "Mode" switch *S2*. If this switch is used, it can be mounted on either the front or rear wall. Secure the electronic components within the case, but do not mount induction coil *L1*. This coil must be provided with a length of shielded single-conductor cable so that it can be moved for best pickup.

To determine the proper location for *L1* (which depends on the type of phone used), place the phone upside down on a pillow, making sure that the handset is firmly in place. Put the cover of the Phonoalarm tray in position so that it fits the base of the phone. With power ap-

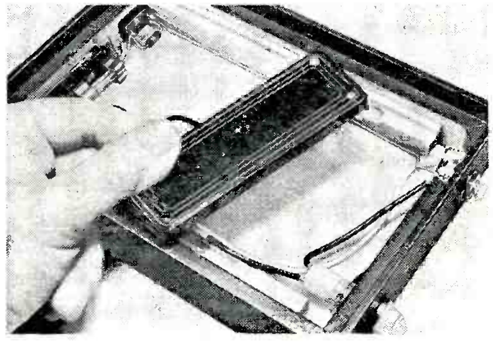
(*Continued on page* 34)

HOW IT WORKS

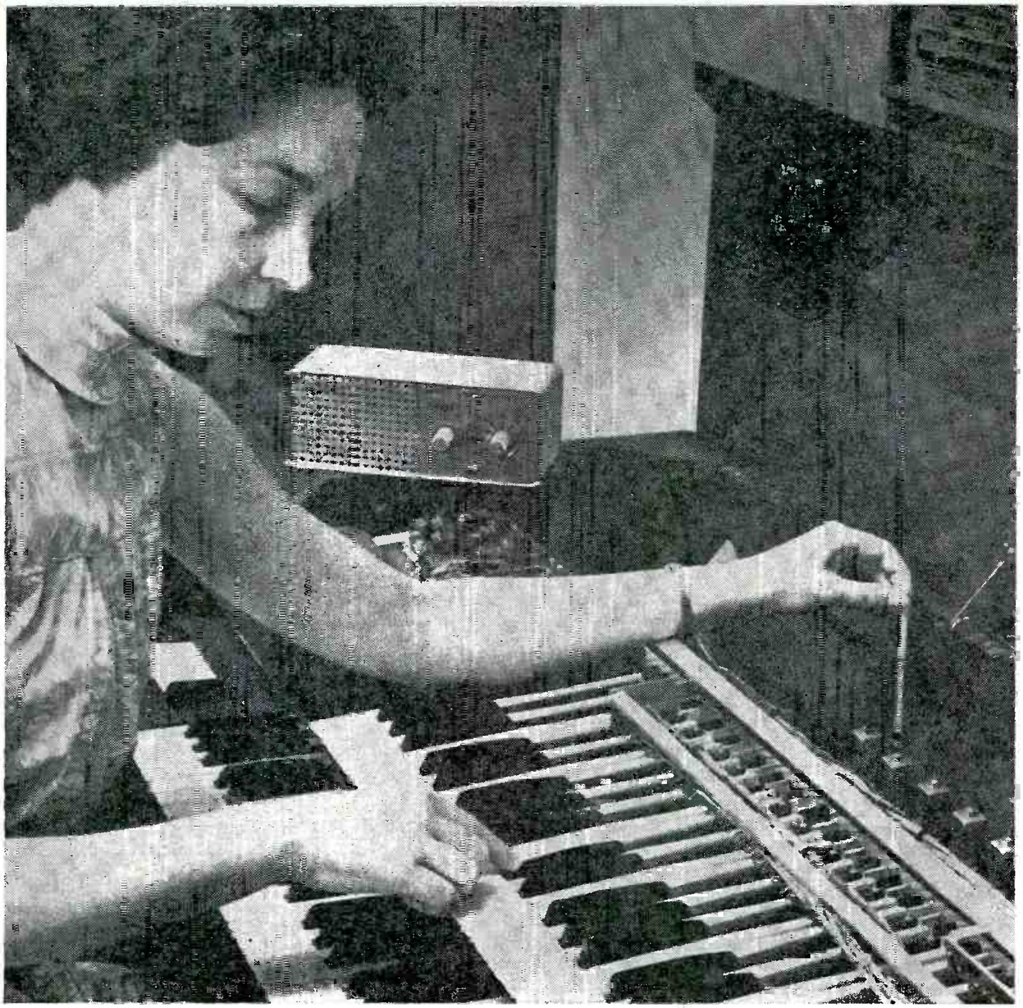
When the phone rings, the alternating magnetic field set up by the ringer coil is picked up by induction coil *L1*. This signal is amplified by *Q1* and applied to the gate of *SCR*, which is in series with the 117-volt a.c. power and outlet *SO1*. When the *SCR* is on, power is applied to *SO1* and neon indicator *I1* also turns on.

With switch *S2* in the NON-LATCH position, the *SCR* is automatically shut off and power is removed from *SO1* when the gate signal is removed. When *S2* is in the LATCH position, input power to the *SCR* is rectified by diode *D1* so that the *SCR* will not turn off when the gate signal is removed, and *SO1* is continuously supplied with power until reset switch *S1* is depressed, opening the circuit.

The rectifier-filter combination of *D1* and *C2* also supplies d.c. power for *Q1* through *R3*, *R4*, and *C1*.



Do not permanently mount the telephone pickup coil until you have found the proper axis and position.



BUILD A MUSICAL

PITCH REFERENCE

INTEGRATED CIRCUITS ARE USED TO DEVELOP TWELVE MIDDLE TONES FOR ORGAN TUNEUP

BY DON LANCASTER

NOTHING MARS THE PLEASURE of playing a musical instrument like having it be out of tune. If your ear is good, you can tune a guitar or a violin using a pitch pipe or a tuning fork. Tuning a piano or an organ is usually more difficult, requiring complex equipment, lots of experience, and an expert ear.

Tuning a musical instrument of any type can be made almost foolproof if you have available a source of musical pitches covering one whole octave. That's what the "Pitch Reference" does. It is an integrated-circuit frequency synthesizer that generates twelve of the middle notes of the equally tempered musical scale to an accuracy better than the best ear can determine and with a stability unattainable by the finest set of tuning forks.

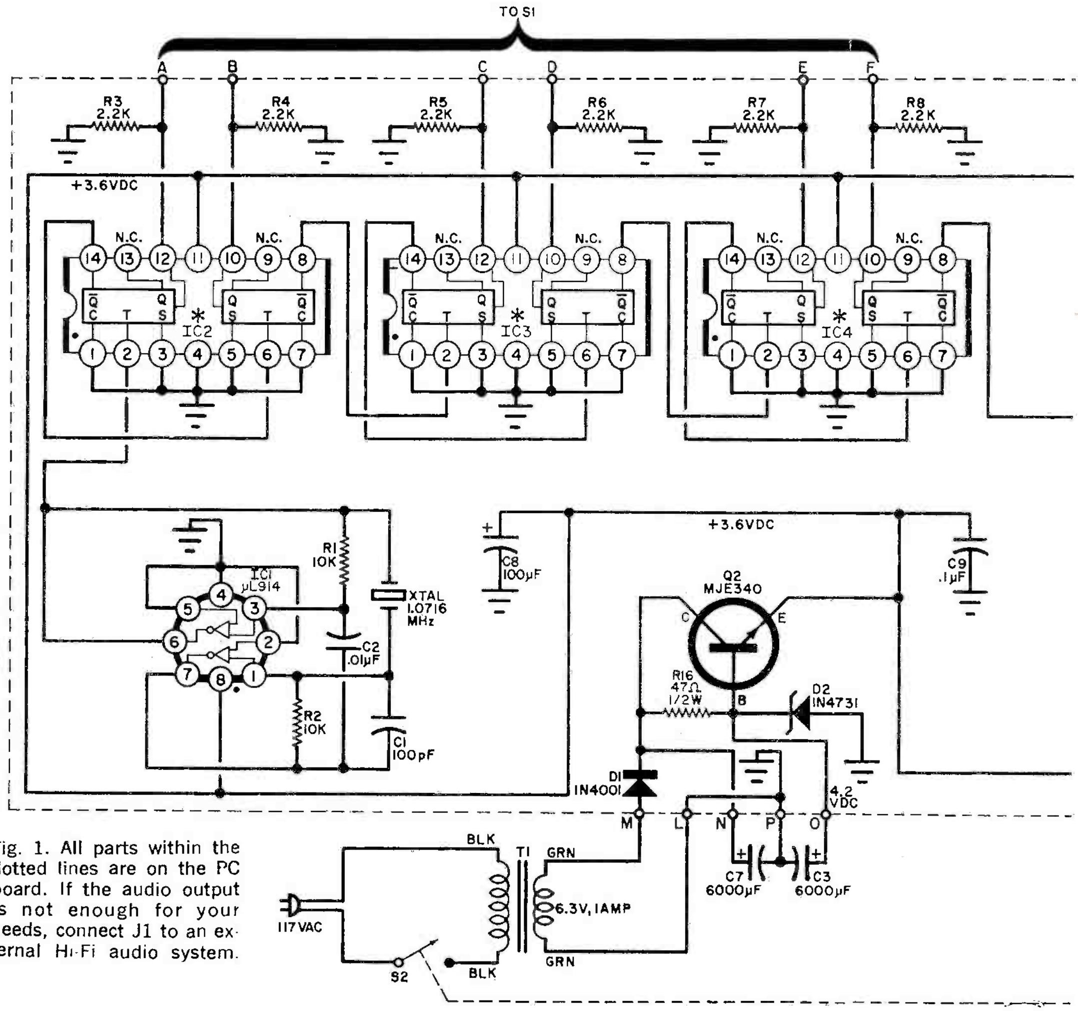
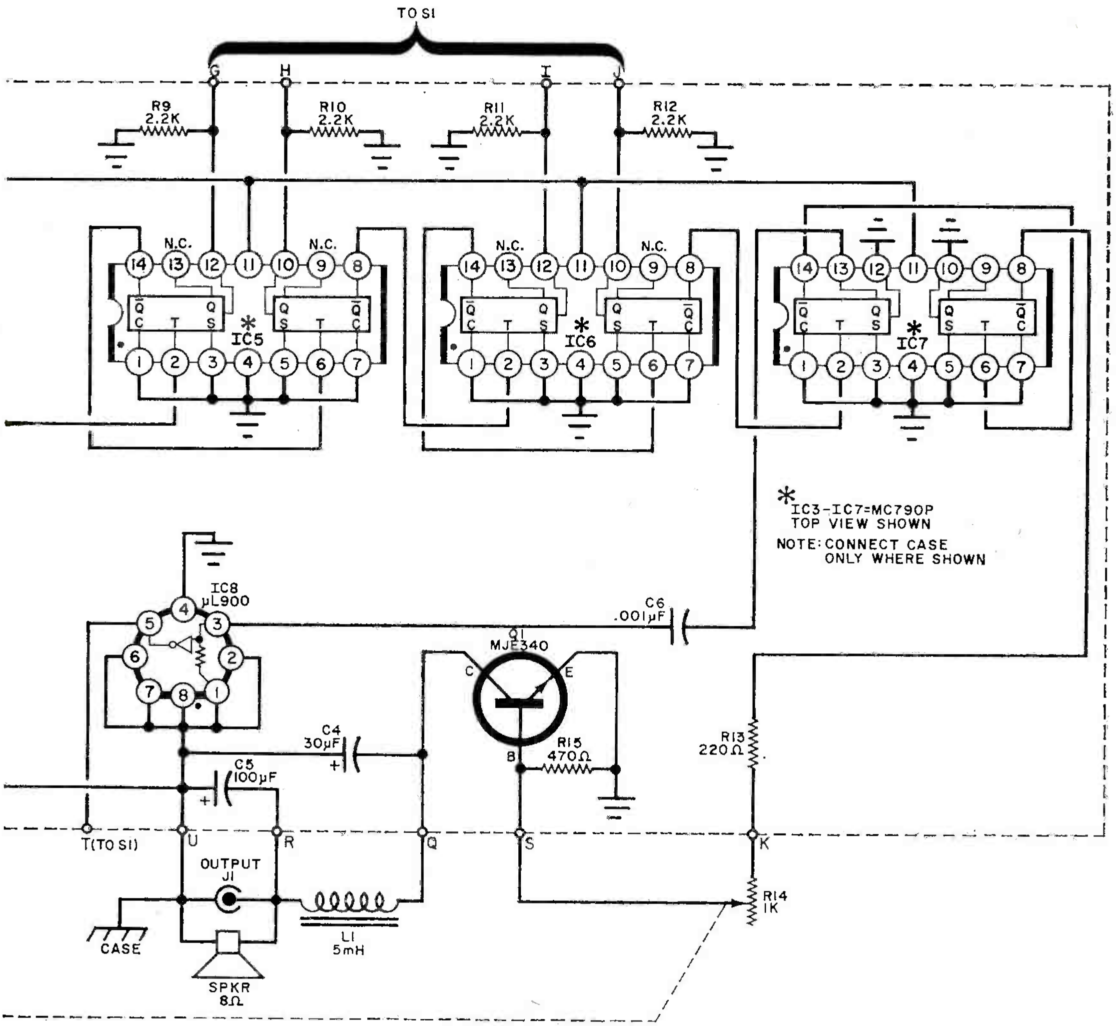


Fig. 1. All parts within the dotted lines are on the PC board. If the audio output is not enough for your needs, connect J1 to an external Hi-Fi audio system.

PARTS LIST

C1—100-pF dipped mica capacitor
C2—0.01-μF mylar capacitor
C3, C7—6000-μF, 10-volt computer-grade electrolytic capacitor (Sprague 36D602G010AA2A or similar)
C4—[illegible]0-μF, 6-volt electrolytic. Do not substitute
C5, C8—100 μF, 6-volt electrolytic. Do not substitute
C6—0.001-μF mylar capacitor
C9—0.1-μF, 10-volt ceramic disc capacitor
D1—1N4001 diode (Motorola)
D2—1N4731 4.2-volt zener diode (Motorola)
IC1—μL914 dual two-input gate (Fairchild)
IC2-IC7—MC790P dual flip-flop (Motorola)
IC8—μL900 buffer (Fairchild)
J1—RCA phono jack
L1—[illegible] toroid (Thordarson TOR779 or Triad EA005. Do not substitute.)
Q1, [illegible]—MJE340 transistor (Motorola)
R1, R2—10,000-ohm, ¼-watt resistor
R3-R12—2200-ohm, ¼-watt resistor
R13—220-ohm, ¼-watt resistor
R14—1000-ohm linear potentiometer with s.p.s.t. rotary switch (S2)
R15—470-ohm, ¼-watt resistor
R16—47-ohm, ½-watt carbon resistor
S1—7-pole, 12-position, continuous rotation, non-shorting selector switch
S2—S.p.s.t. switch attached to R14
Spkr—3 x 5 oval PM speaker, 8-ohm
T1—Filament transformer; secondary 6.3-volt, 1-ampere
XTAL—1.0716-MHz series-resonant crystal
Misc.—Case, dialplate, line cord and strain relief, wirenut, front decorative grill, knobs, mounting feet, capacitor clips, standoffs, terminals, pop rivets, wire solder, backup plate for controls, crystal clip, PC terminals, heatsink clip and plastic mounting hardware for Q1 and Q2, sleeving, cement, etc.
Dialplate: Genuine Metalphoto Dialplate available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014. In black and silver $3.00; red, gold, or copper $3.45, postpaid in USA. Stock number PRF-1.
Kits and Special Parts: The following are available from Southwest Technical Products Corp., Box 16297, San Antonio, Texas 78216. Etched



and drilled printed-circuit board (part number 154), \$3.50.

The following manufacturers will grind the 1.0716-MHz crystal and encase it in a wire-lead holder. Check for price and delivery time.
Texas Crystals, 1000 Crystal Drive, Ft. Myers, Florida 33901
International Crystal Mfg. Co. Inc., 10 N. Lee, Oklahoma City, Oklahoma 73102
CTS Knights Inc., 101 E. Church St., Sandwich, Illinois 60548

Note: All Motorola semiconductors available from Allied Radio, 100 N. Western Ave., Chicago, Ill. 60680. Related data sheets from Motorola Semiconductor, Box 955, Phoenix, Ariz. 85001. Data sheets and distributor list on IC1 and IC8 available from Fairchild Semiconductor, 313 Fairchild Dr., Mt. View, Calif.

With the Pitch Reference, tuning an electronic organ or guitar is a snap. Add the basic wedges and a tuning hammer, and you can start tuning a piano electronically, listening only for fundamental unison beats that even an untrained ear can easily detect. The Pitch Reference is also dandy for tuning up a band, an orchestra, or even for making intonation studies on a solo instrument. Unlike a tuning fork, the Pitch Reference will "sound off" all day if necessary. Any pitch can be selected by the flicking of a switch and the volume can be adjusted. The device can also be used in physics demonstrations and sound experiments, or as a good entry in a science fair.

The line-powered Pitch Reference is built into a vinyl-clad aluminum case and

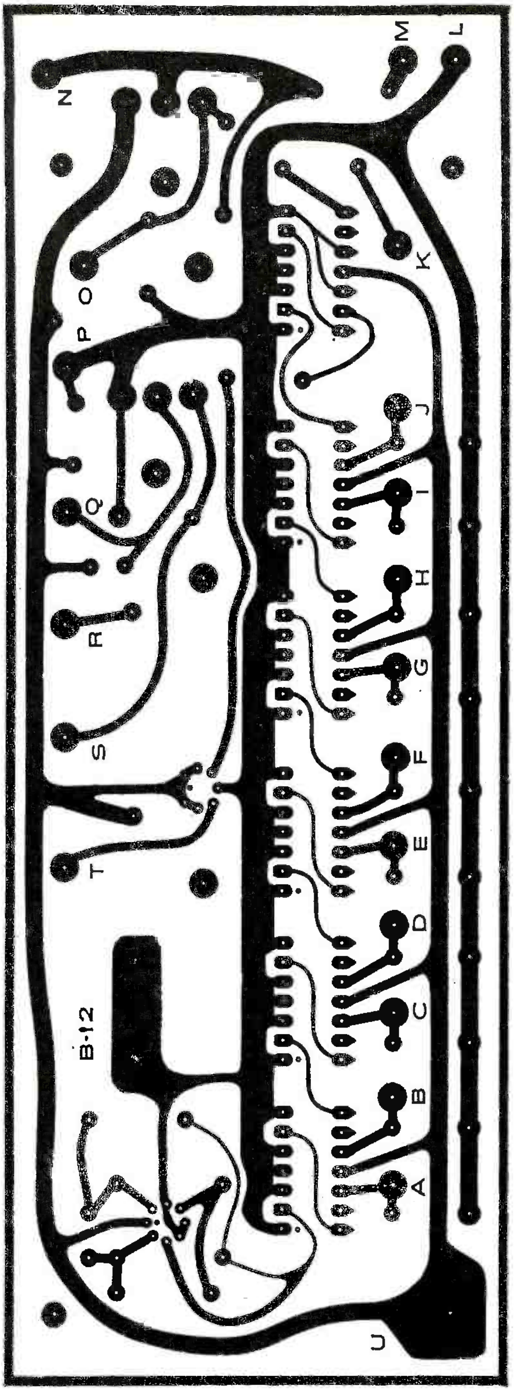
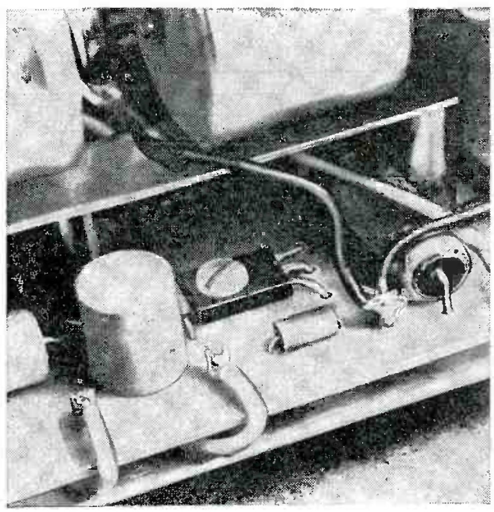


Fig. 2. Actual-size printed-board foil pattern layout. Because of circuit complexity, such a board is necessary to avoid troublesome wiring errors.

contains 8 integrated circuits and two transistors. Depending on the degree of refinement you want, you can build it for $30 to $45. A printed circuit board and dialplate are available (see listing on preceding page).

Construction. The schematic of the circuit is shown in Fig. 1. A printed circuit board is mandatory for this project. You can buy one already etched and drilled (see Parts List of Fig. 1) or you can make your own by following the layout guide of Fig. 2. Drilling details are shown in Fig. 3. A clip is riveted to this board to secure the crystal, XTAL. Insert the components as shown in Fig. 4 being very sure that the IC's are positioned and oriented as shown. Units *IC1* and *IC8* have a flat beside pin 8; the others have a code notch and dot.

The three large holes in the PC board allow you to "double deck" the filter capacitors and save some space. Use plastic bolts when mounting *Q1* and *Q2*, and make sure that both are mounted with the metallized side down. A small U-shaped heat radiator should be added to *Q2* for extra heatsinking.



Transistors are secured to the board metallized-side down, using a plastic screw. Transistors are black, flat rectangles (Q1 shown at center).

The selector switch should be wired in accordance with Fig. 5. Be extra careful with the wiring; any wrong connection will throw at least one note off the frequency.

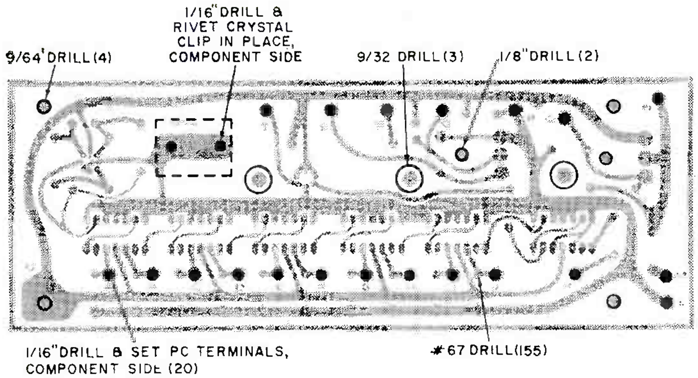
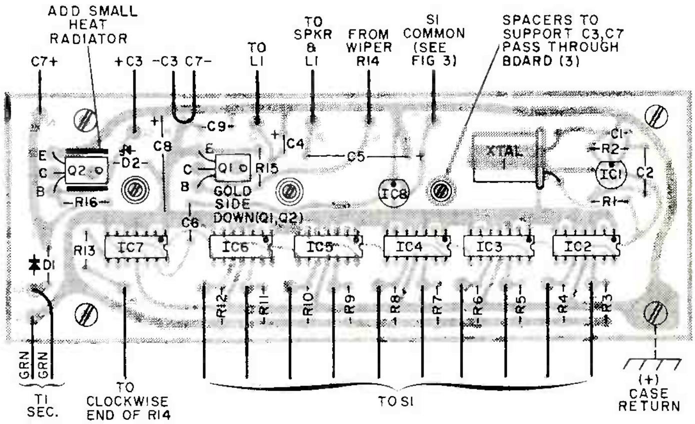
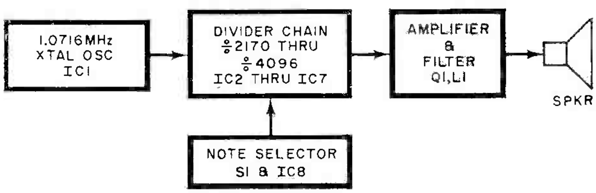


Fig. 3. Drill the PC board as shown here. The three largest holes mount the filter capacitors' standoffs. The use of PC terminals is optional. They are not supplied with the kit.

Fig. 4. Component installation. The six rectangular IC's (IC2 through IC7) are identified by a notch and dot at one end; IC1 and IC8 have either a flat or dot adjacent to pin 8. Both transistors are mounted metallized side down and secured by plastic screws. A heat sink is required at power transistor Q2.





HOW IT WORKS

The twelve notes from C4 to B4 (C4 is middle C and the beginning of the fourth octave on the piano) are synthesized by starting with a fixed 1.0716-MHz crystal oscillator and dividing this frequency by 12 different ratios varying from 4096 to 2710. The division is absolutely synchronized and produces a dozen output frequencies. The table shows the actual note frequencies, the division ratios, and the generated frequencies. Since all of the division are by even numbers, the counter is arranged to produce a symmetrical square-wave output, which is selected, by switching, to be within ½ cent of the actual pitch. The square wave is amplified, filtered to remove the fundamental sine wave, and applied to the speaker and an audio output jack.

The schematic is shown in Fig. 1. A regulated power supply is essential in this case to prevent intermodulation and confusion between power-supply ripple and the intended output pitch. The supply, consisting of *D1*, *D2*, and a regulator transistor, *Q2*, has an output of 3.6 volts d.c. at ½ A, with very low ripple.

The crystal oscillator *IC1* produces a 1.0716-MHz square wave, which is supplied to a counting chain or digital divider consisting of *IC2* through *IC7*. If the counting chain were allowed to divide by itself, it would always divide by 4096 and produce 261.6 Hz for C4. To get the other notes, we add extra counts exactly equal to the difference between the number we're trying to divide by and the original 4096. These extra counts are generated by *IC8* and are supplied to selector switch *S1*, a 7-deck, 12-position switch. With the correct switch programming, the proper number of additional counts are added in just the right places to produce the correct notes.

The output of the counting chain goes through loudness control *R14* and amplifier transistor *Q1*. The output of *Q1* is then filtered so that the fundamental sine wave is applied to the speaker and output jack.

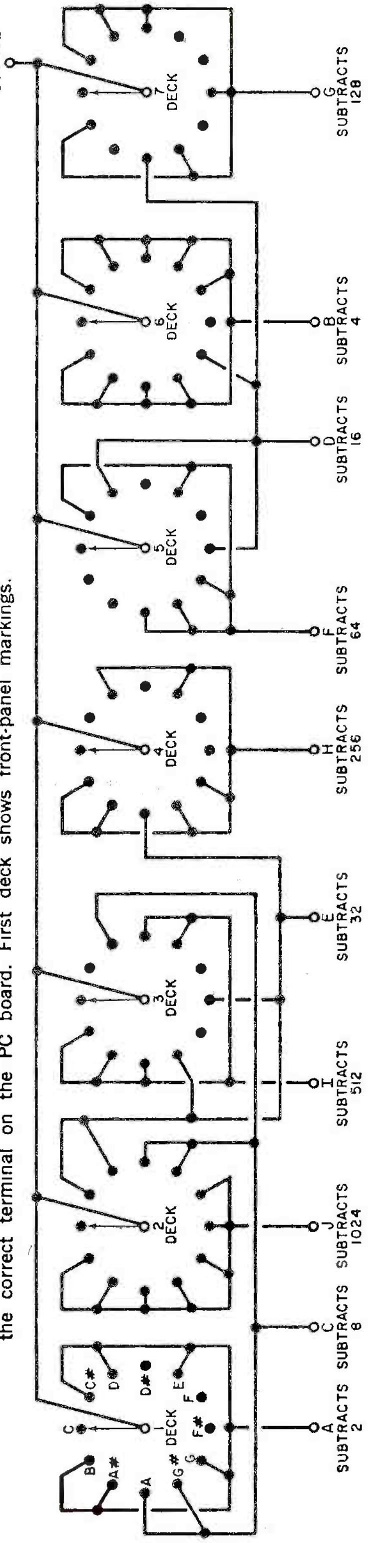
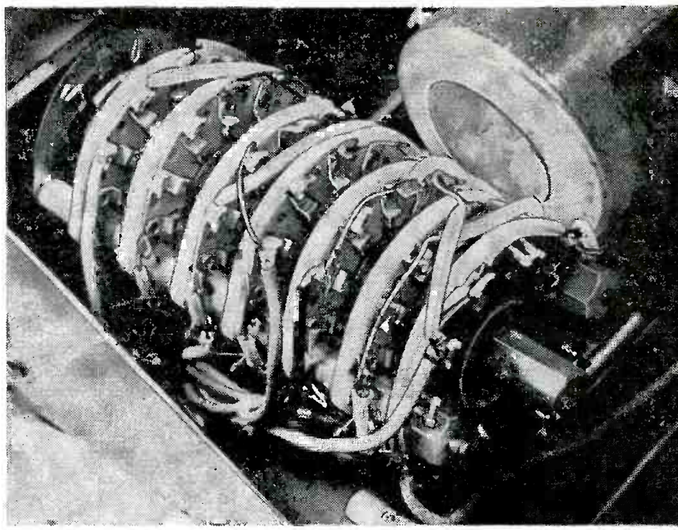
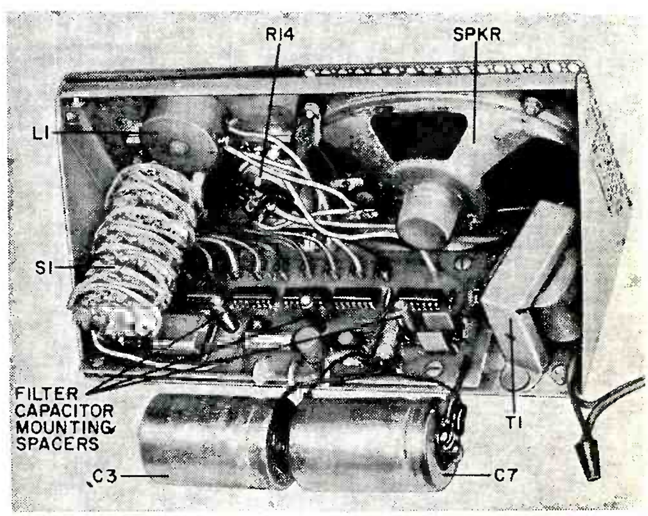


Fig. 5. Be very careful when wiring S1 to make sure that each output goes to the correct terminal on the PC board. First deck shows front-panel markings.

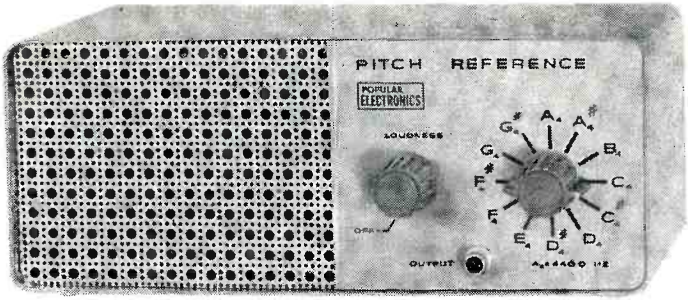


Good wiring practice and neat soldering will ease switch assembly. Use insulated wire where possible.

You can use almost any enclosure you wish, but watch out for any possible mechanical resonance. Fairly large ventilation holes should be provided in the rear to prevent case resonance and any back-pressure effects. The 3 × 5 oval speaker should be shock-mounted using grommets or some other means. Finally, the grill and grillcloth should be glued in place to prevent any possible rattle from vibration.

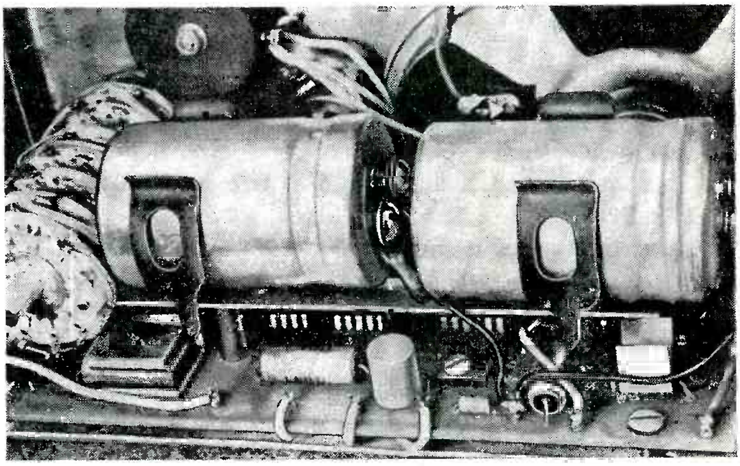


Capacitors C3 and C7 "double-deck" over PC board. With a little care, a compact assembly is possible.



The completed Pitch Reference can be dressed up by using a commercially available dial-plate (see Parts List). The cover should have one or two one-inch holes at the rear to prevent any cabinet resonances.

The two filter capacitors are clip mounted to a short strip of metal secured to the three spacers. Make sure that the end of the capacitor does not short-circuit any of the switch terminals.



ABOUT PITCH

Each octave of a piano scale consists of 12 notes spread out over a 2:1 frequency range, the frequency of the 13th note being precisely twice that of the first. For centuries, musicians have experimented with absolute pitch and the spacing between individual notes. In common use today, however, is the equally tempered, 12-note scale with A4 (the A above middle C) set at 440.0 Hz.

Equal temperament means simply that there is a constant percentage difference in frequency between every two notes. To get twelve notes equally spaced on a percentage basis over a 2:1 frequency spread, each successive note must be $\sqrt[12]{2}$ or roughly 6% higher or lower in pitch than its neighbor. In this way, slight differences in sharps and flats for the various musical keys are averaged out so that twelve different notes per octave can handle virtually any key.

The 6% interval between notes is called a *semitone*, and musicians call 1/100 of a semitone a *cent*. A 1-cent accuracy in frequency is equal to 0.06%.

Since $\sqrt[12]{2}$ is an irrational number, there is no possible way to generate it exactly, and consequently no way to generate a scale precisely. The question is, "How good can we get?" The very best musicians can sometimes spot a ±3-cent cyclic error in pitch, and the very finest tuning forks are only accurate to ±1 cent. They drift a cent or so for every four degrees F of temperature variation.

The Pitch Reference described here is accurate to ±0.5 cent, making it twice as good as the best tuning fork you can buy and six times better than the best musician. Being crystal controlled, it is permanently calibrated and does not age or drift over long periods of time.

Operation. Usually, you will set the Pitch Reference to the same note to which you are tuning the instrument. If the instrument is out of tune, you will hear a distinct low-frequency beat note, perhaps several times a second. Adjust the instrument tuning until the beat note disappears. This is called unison tuning (zero beating). Further adjustment of the instrument will cause detuning in the opposite direction, and a beat note will occur again, the number of beats increasing the farther out of tune the instrument is made. Beat notes may possibly be caused by ear nonlinearity. You'll get the best results if the sound from both the instrument and the reference go in the same ear.

The Pitch Reference can be used to tune octaves other than the one starting at middle C. For example, any C in the scale can be tuned by using the C4 reference. If sufficient volume is not available, an amplifier and speaker system can be connected to the front-panel output jack.

Variations in pitch can be purposely introduced by changing the crystal in the reference to one that is higher or lower in frequency (sharper or flatter in pitch). This is sometimes desirable in tuning certain older instruments and for tuning the extreme octaves at either end of a standard piano. —30—

PITCH REFERENCE OUTPUT DATA

NOTE	DIVISION RATIO	APPROXIMATE FREQUENCY (Hz)	STANDARD TRUE FREQUENCY (Hz)
C4	4096	261.6	261.6
C4#	3866	277.2	277.2
D4	3650	293.6	293.7
D4#	3444	311.2	311.1
E4	3250	329.7	329.6
F4	3068	349.3	349.2
F4#	2896	370.0	370.0
G4	2734	392.0	392.0
G4#	2580	415.4	415.3
A4	2436	439.9	440.0
A4#	2298	466.3	466.2
B4	2170	493.8	493.9

WHILE YOU WERE OUT

(*Continued from page 26*)

plied to the alarm, have someone call your telephone number. As the phone rings, slide *L1* around the cover until indicator lamp *I1* comes on, and 117-volt power is available at the outlet *SO1*. Mark this position of *L1* and cement the coil in place. In some rare installations, it may be necessary to mount *L1* on the top of the cover under and between the four cushioned feet of the phone.

If "Mode" switch *S2* is in the NON-LATCH position, the indicator lamp (and the outlet power) will go on and off in step with the ringing of the phone. If *S2* is in the LATCH position, *I1* and *SO1* will be energized with the first ring and will remain on when the phone stops ringing. Push *S1* to reset the system. —30—

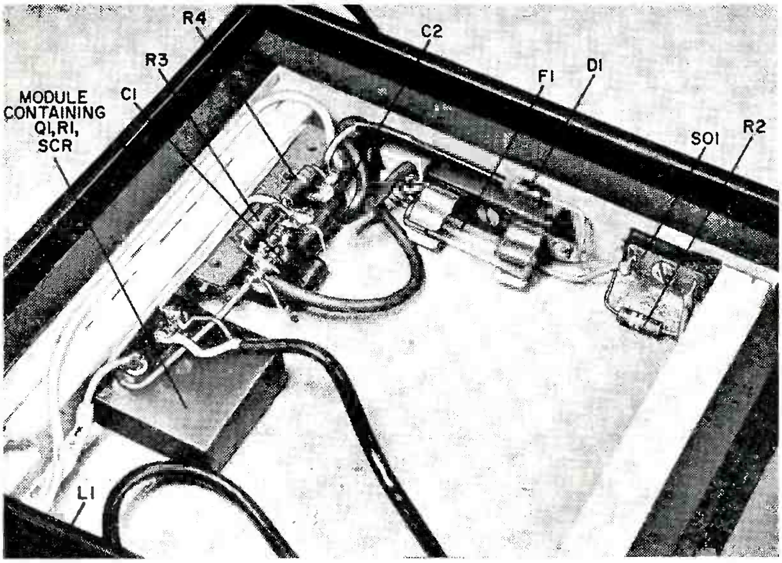
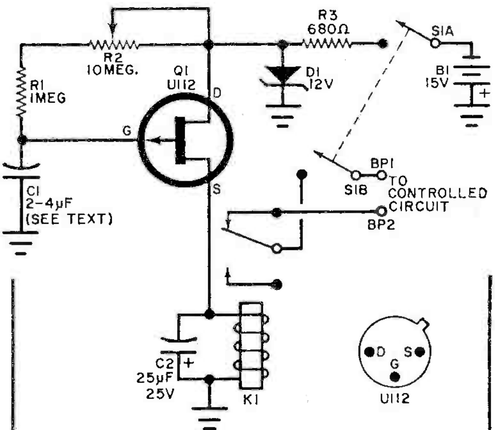


Fig. 2. This is the simplified parts arrangement in the tray under the telephone used by the author. The module is available from Lectromek for $5, postpaid.

BY B. W. BLACHFORD

BUILD THE FET INTERVAL TIMER

Accuracy and simplicity in a single transistor circuit



Almost any p-channel FET similar to the recommended U112 can be used. A type n-channel may work if the polarities are reversed.

B1—15-volt battery
BP1, BP2—Five-way binding posts
C1—2- to 4-μF, 100-volt capacitor (see text)
C2—25-μF, 25-volt electrolytic capacitor
D1—12-volt, ½-watt zener diode
K1—S.p.d.t. relay with 1-mA energizing current (Sigma type 4F-8000-S/SIL, or see text)
Q1—Field-effect transistor, p*-channel (Siliconix U112, or similar)*
R1—1-megohm, ½-watt resistor
R2—10-megohm, linear-taper potentiometer
R3—680-ohm, ½-watt resistor
S1—D.p.s.t. switch

THE ACCURACY OF THE TIMER you use for experimenting, photography, and the like is not usually too critical. When it is, why compromise by using an inexpensive, not-too-accurate timer? You don't have to spend a small fortune to make a very accurate, very stable interval timer. The timer described in this article is extremely accurate and relatively inexpensive.

As shown in the schematic diagram, when *S1* is closed, power is simultaneously applied to the timer circuit and the device being controlled. (If you prefer a timed-off cycle, *BP2* can be connected to the open contact of *K1*.) As soon as power is applied, *C1* begins to charge through *R1*, *R2*, and *R3*.

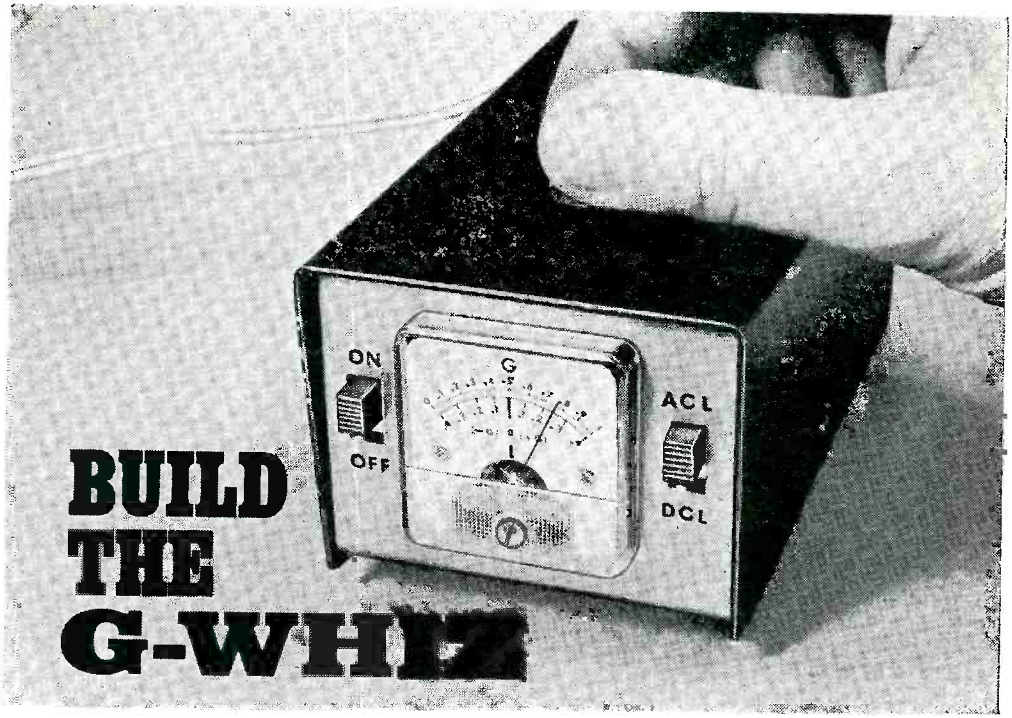
The potentials at the gate and source of *Q1* rise as *C1* is charging, and consequently, the current through the coil of *K1* also rises. At some point, determined by the setting of *R2*, the charge on *C1* is sufficient to cause enough current flow through *Q1* to energize *K1* and remove (or apply) power to the controlled device.

Current through the circuit is, at most, 1.5 mA when the components specified are used, even after *K1* closes; so neither *K1* nor *Q1* can be damaged if *S1* is left in the ON position after energization. Opening *S1* puts *Q1*'s gate-to-source terminals into a forward-bias condition, allowing *C1* and *C2* to discharge through the winding of *K1* and resetting the timer for the next cycle. As a result, a delay of about 1-2 seconds must be allowed before the timer will again accurately time another cycle.

The timing rate of the circuit depends on the values of *R1*, *R2*, *R3*, and *C1*, and the characteristics of the particular FET used. The timing rate can be varied between 6 and 60 seconds with the resistance values specified and a 2- to 4-μF capacitor for *C1*.

In use, *K1* must be adjusted so that it picks up at approximately 0.5 mA. The Sigma relay specified has a mechanical adjustment for this purpose. If you use another brand or model relay, its winding should be rated at about 8000 ohms and require a maximum of 1-mA pull-in current. Almost any *p*-channel FET can be used for *Q1*. -30-

BUILD THE G-WHIZ



SIMPLE ACCELEROMETER MEASURES POSITIVE OR NEGATIVE G FORCE

BY GEORGE J. WHALEN

EVER WISH THAT YOU had some way to check your car's acceleration performance under actual road conditions? Or, would you like to check the effect that a tune up, carburetor adjustment, change of fuel grade, timing correction, valve setting, or change in tire pressure has had on your car's performance? Or, if you have stick shift, would you like to determine the optimum shift speeds for each gear to get best performance and fuel economy?

You can do all of this with the "G-Whiz," an indicating accelerometer similar to instruments used widely in aerospace applications, military aircraft, and missile systems. The G-Whiz is specially designed for automotive use and measures both acceleration and deceleration. Except for a 12-volt power supply, it requires no electrical connection to the vehicle. It provides the driver with an accurate means of checking the car's overall road performance and may even help in correcting poor driving habits.

In coming years, accelerometers like this one may become standard equipment on all new high-performance cars, so here is your chance to get ahead of the times.

Construction. The circuit of Fig. 1 is assembled in the U-shaped portion of a 5″ x 3″ x 2¼″ metal case, drilled as shown in Fig. 2. A cover fabricated by following the layout of Fig. 3 can be covered with a contact-adhesive leatherette finish. Construct the mounting brackets for *R5* and *R4* as shown in Fig. 4. Build, or purchase (see Parts List) the pendulum following the information given in Fig. 5.

Mount zero-adjust potentiometer *R5* on its bracket (see Fig. 4), and mount the bracket as shown in the photos. Mount all the other parts, except for po-

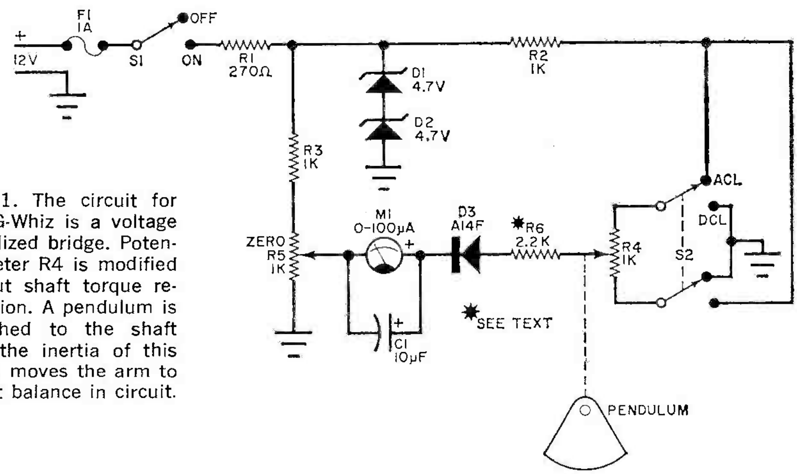


Fig. 1. The circuit for the G-Whiz is a voltage stabilized bridge. Potentiometer R4 is modified to cut shaft torque restriction. A pendulum is attached to the shaft and the inertia of this mass moves the arm to upset balance in circuit.

PARTS LIST

C1—10-μF, 15-WVDC electrolytic capacitor
D1, D2—4.7-volt zener diode
D3—A14F silicon diode (General Electric)
F1—1-ampere fuse
M1—100-μA meter
R1—270-ohm, ½-watt resistor
R2, R3—1000-ohm, ½-watt resistor
R4—1000-ohm subminiature linear potentiometer (Mallory MLC-13L or similar)
R5—1000-ohm linear potentiometer
R6—2200-ohm, 5%, ½-watt resistor (see text)
S1—S.p.d.t. switch
S2—D.p.d.t. switch
Misc.—Pendulum lead weight (see text), 5-point terminal strips (2), case, fuseholder, right-angle brackets, knob, wire, solder, etc.
A complete kit of parts including punched case, mounting material, etc., is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, $12.75 postpaid.

tentiometer *R4* and the pendulum as shown in the photos, and wire point-to-point in accordance with the schematic. The author elected to solder *S1* and *S2* to the front wall of the chassis. Mount a 5-pin terminal strip at *R5* bracket mounting screw (point B in Fig. 2) and a 5-pin terminal strip at *R4* mounting bracket (point A in Fig. 1).

Potentiometer *R4* will have to be opened and its wiper contacts adjusted to reduce its shaft torque requirement to the minimum. Remove the nut and lockwasher from the shaft bearing and hold the potentiometer so that the shaft faces you. Using a small, thin-blade screwdriver, gently pry up the tabs securing the metal cover to the shaftplate. Slip the cover off to expose the resistance element and wiper assembly. Hold the potentiometer by the shaft and look through the side into the space between the wiper assembly and the resistance element. The larger wipers contact the resistance element and are arranged in opposition. To reduce contact friction, slip a tiny jeweler's screwdriver (or sewing needle) under the back of each contact and gently pry upward a fraction of an inch. After doing this to both wipers, check shaft rotation and note that less

HOW IT WORKS

The circuit, shown in Fig. 1, is basically a bridge that can be balanced at zero G by means of potentiometer *R5*. The pendulum is physically attached to the shaft of potentiometer *R4*; and if the pendulum tries to rotate about its pivot axis, the bridge becomes unbalanced and meter *M1* indicates the amount of unbalance (meter scale is calibrated in G values). The position of *S2* determines the direction of current flow through *R4* so that an increasing positive-going voltage may be obtained from the movement of the *R4* wiper arm in response to either a backward swing (acceleration) or forward swing (deceleration) of the pendulum. Resistor *R6* is selected to set the full-scale current through *M1* to correspond to +45°, or —45° of potentiometer shaft rotation from its normal (zero G) position.

Diode *D3*, in series with the meter, permits current to flow in only one direction, preventing the needle of *M1* from slamming against its limit stop during a sudden stop when *S2* is set for acceleration, or vice versa. Capacitor *C1* provides electrical damping of the meter to smooth out peak transients due to the inertial effects of the eccentric weight.

Power is obtained from the car's 12-volt d.c. system via fuse *F1*, current-limiting resistor *R1*, and a 9.4-volt regulator consisting of zener diodes *D1* and *D2*.

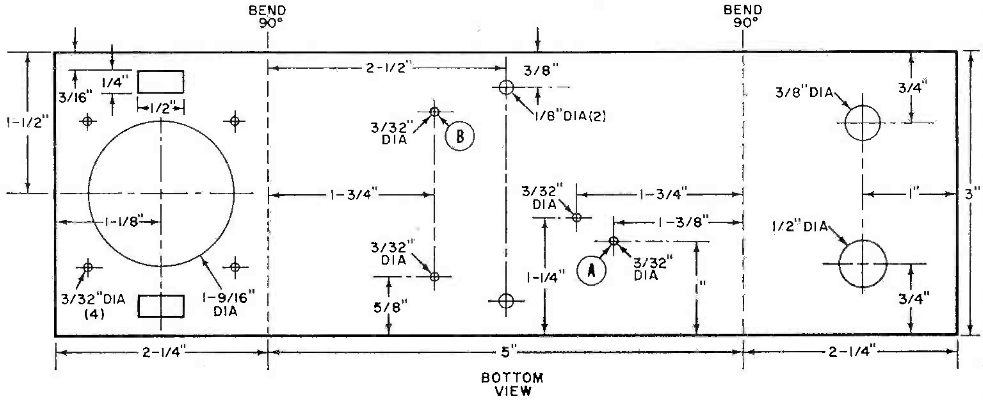


Fig. 2. The author bent a chassis and cover out of sheet metal. The bending, drilling, and cutout information is shown above. The two slide switches are soldered to the rear of the front panel.

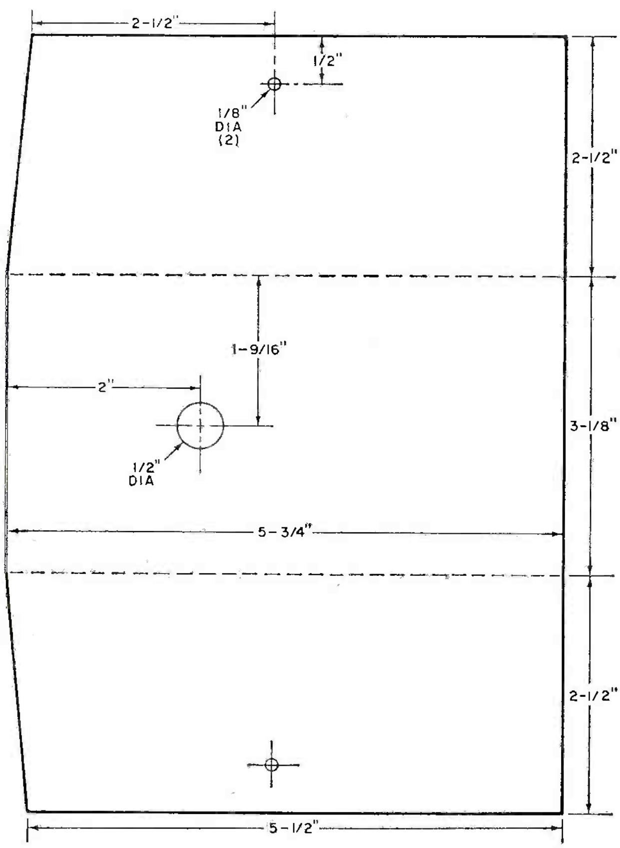


Fig. 3. The cover forms a cowl over the front panel. If desired, the front can be cut in a straight line.

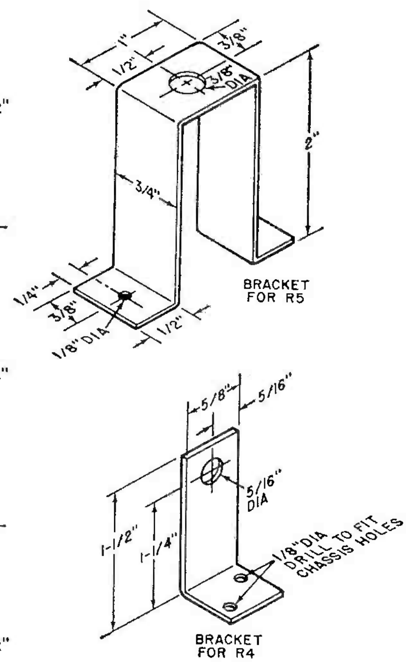
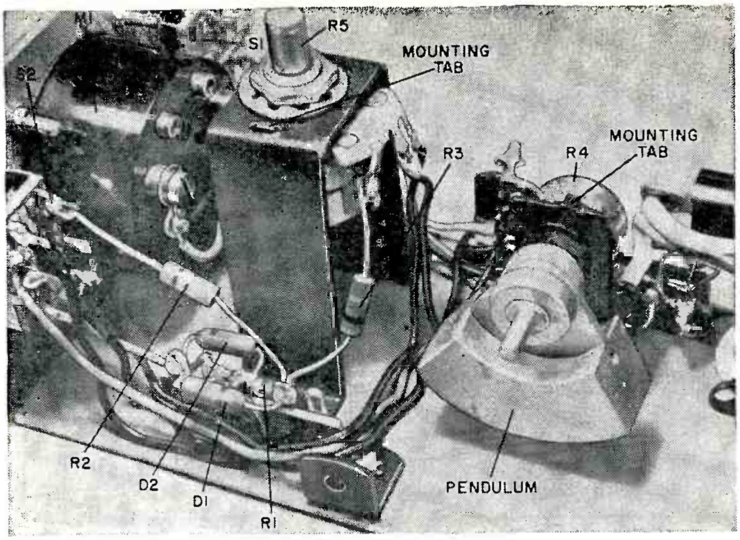


Fig. 4. The mounting brackets for the two potentiometers can be made from sheet metal or aluminum strips.



Wiring and assembly is open but very rigid. The pendulum must have room to swing freely. The shaft of zero-G setting potentiometer R5 is accessible through a hole in cover of the metal box.

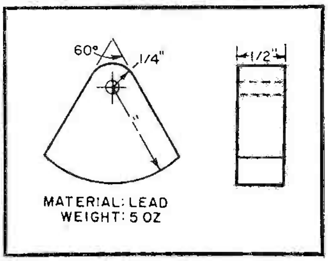
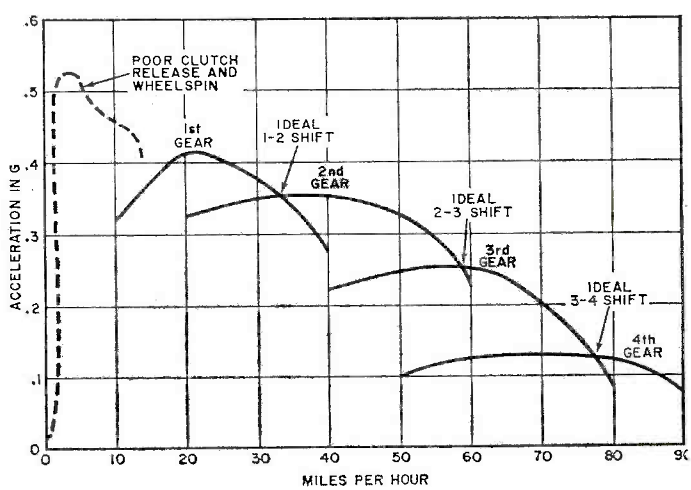


Fig. 5. You can fashion a pendulum from a piece cut from an old tuning flywheel.

torque is required to rotate the shaft. Next, loosen the tiny pair of wipers directly opposite the first pair (riding on the center slip ring). Use a tiny sewing needle to lift each finger gently to reduce contact pressure. Again check shaft torque to see that it has again been reduced. Inject a drop of contact cleaner and lubricant on the contacts. Calibrate the meter using the table as a guide.

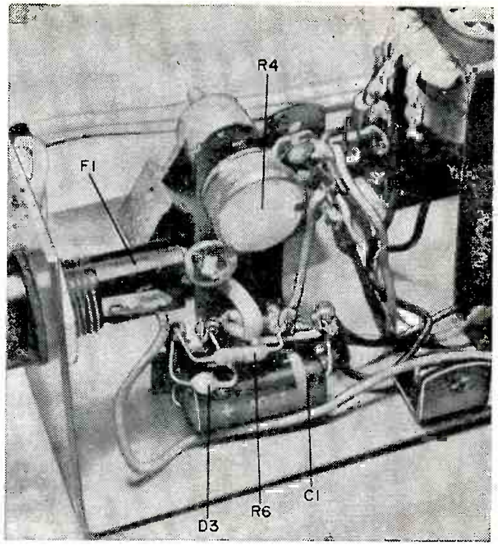
Before replacing the cover, check the resistance between either end terminal and the rotor to make sure that contact is still established. If necessary, you may have to tighten up on the contact fingers very slightly. Slip the metal cover back on the pot, making sure that the cutout is opposite the three terminals and does not contact either of the terminals. Use

Fig. 6. A typical stick-shift sports car should produce G forces roughly equivalent to those in this graph. If you plot a similar graph you will be able to determine the optimum speeds for shifting of gears.



the flat blade of a screwdriver to bend the securing tabs flat against the shaft-plate. Mount *R4* in its right-angle bracket (see Fig. 4) so that its mounting tab rests atop the bracket. Secure the bracket in place.

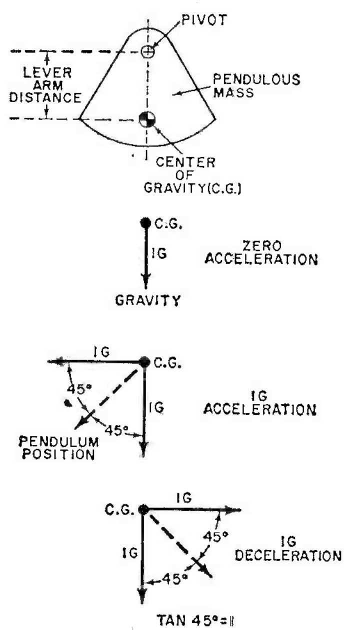
Being very careful, coat the potentiometer shaft with solder from its end to a point about ½ inch from the shaft bearing. Do not get any solder between the shaft and bearing. After the shaft has been tinned, install it in position on its mounting bracket as shown in the photos. Temporarily jumper the two end terminals and connect an ohmmeter between the end terminals and the wiper. Rotate the shaft of the pot for maximum indication on the ohmmeter and leave the shaft there. Slide the pendulum on the pot shaft, trying to keep the pot shaft from rotating. When the pendulum is positioned close to the shaft bearing, recheck that *R4* is at true midscale with the pendulum hanging straight down, then solder the pendulum to the shaft. After the metal cools, swing the pendulum back and forth and note that the ohmmeter shows a resistance variation, and that the weight swings freely across a 90° arc. Connect *R4* into the circuit.



Drilled and tapped right-angle brackets (top center and bottom right) are used to hold cover in place.

Install a pair of small right-angle brackets on the chassis base (see photos) so that the cover can be easily attached. Make sure that all wiring is dressed away from the area of pendulum swing so as not to hinder operation.

HOW A PENDULUM RESPONDS TO ACCELERATION



All forces acting on the pendulum mass act on its center of gravity, which is eccentric with respect to its pivot point. The lever arm is the distance from the pivot point to the center of gravity and transmits the force acting on the center of gravity to the pivot in a rotational manner.

The pendulous mass responds to the "pull of gravity" and tends to hang down (toward the center of gravity of the earth) unless acted upon by the horizontal push of acceleration or deceleration forces. Thus, gravity provides the reference against which the horizontal forces are compared.

The physical response of the pendulum to gravity and acceleration is a vectorial quantity, since the two forces act at right angles to the center of gravity. The pendulum acts to maintain an equilibrium position, balancing the two forces by rotating in a vertical arc about the pivot. If the two forces are equal, the pendulum assumes a 45° angle from its zero acceleration position. For lesser acceleration or deceleration forces, the pendulum pivots to a smaller angular position. The tangent of the angle described by the pendulum's position under acceleration or deceleration is equal to the horizontal G force.

Testing. Insert the fuse (*F1*) and connect the power cord to source of 12 volts d.c. observing lead polarity. With *S1* turned ON, the voltage across zener diodes *D1* and *D2* should be 9.4 volts, indicating that the regulator is working properly. Place the G-Whiz on a flat horizontal table and with the power still turned on, set *S2* at ACL and adjust *R5* (zero control) until the meter just indicates zero G (left-hand scale limit).

Since it is difficult to simulate one-G forces, the best thing to do is displace the pendulum to simulate this force. For this, you will need a 45° triangle. Stand the triangle up on one of its sides (not the hypotenuse), and place the case on the hypotenuse with the meter facing down. Note that the pendulum swings so as to "point" straight down due to the pull of gravity. The meter should indicate one G (at right-hand scale limit). If the meter does not read exactly full scale (one G), the value of *R6* will have to be adjusted.

Now place the device on a flat horizontal surface, set *S2* to DCL and adjust *R5* for a zero indication on *M1*. Place the case on the hypotenuse of the triangle, meter face up, and note that the pendulum swings to hang down and the meter indicates full scale (right-hand limit).

Once tested, install the cover on the device, feeding the shaft of *R5* through its hole and place a small knob on the shaft of *R5*.

Installation. The G-Whiz can be installed almost anywhere in the car as long as it is mounted as horizontal as possible. Make sure that the long side of the chassis is always parallel to the direction of travel of the vehicle. (The swing arc of the pendulum must be in the direction of vehicle travel.) The device can be bolted, strapped, or secured with two-sided adhesive tape to the top of the dashboard or other convenient horizontal surface. If the case is slanted to one side or the other, the pendulum will not respond to true acceleration but to an angular component of this force, thus producing erroneous indications. However, if the long side of the chassis is slightly tilted, this can be corrected by adjusting *R5* for a true zero.

Road Testing. Before testing the G-Whiz, make sure that you can observe all traffic safety laws before performing the following tests. It is advisable to have a passenger use a clipboard, pad, pencil, and stopwatch to record the meter readings.

Before making the road tests, remember that the G-Whiz is sensitive to horizontal attitude, so try to use a level road for best accuracy.

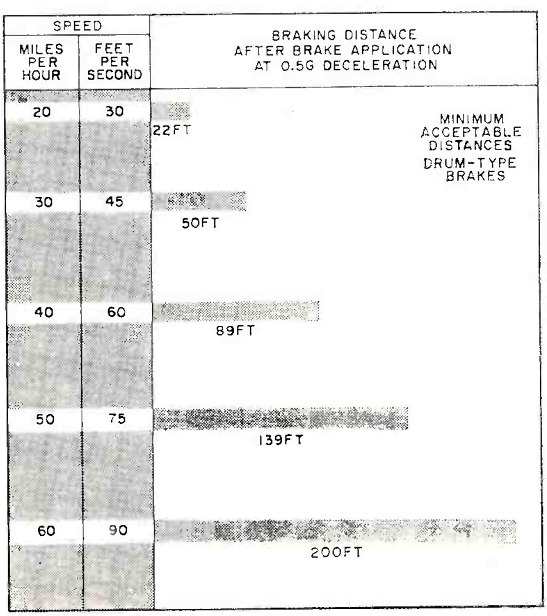


Fig. 7. The G-Whiz is an excellent device to check performance of drum or disc-type brakes. A good test is to decelerate at 0.5 G and measure the braking distance vs. miles per hour. Acceptable distances are shown in this graph. Brake fading can be observed on the G-Whiz as described in the text on page 46.

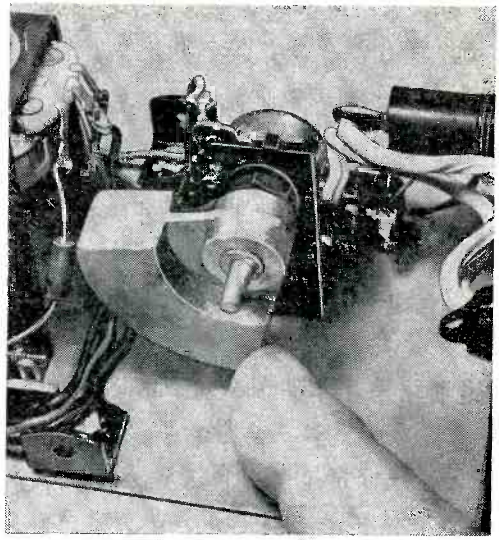
With the car stopped, turn on the power (*S1*), set *S2* to ACL, and rotate *R5 to* set the meter needle just to the left-hand zero mark (0 G). The driver watches the road and keeps an eye on the speedometer, while the passenger watches the G-Whiz dial. Start the car, put it in low gear, and make as fast a start as possible. At each 10-mph interval, the driver calls out "check," and the passenger records both speed and G readings. Carry out this procedure to at least 10 mph faster than your normal shift speed for this gear. This speed depends on your type of car. Therefore, before you begin, check your manual to determine just how fast you can go in this gear without damaging the vehicle.

Next, perform the same test in second gear. Start in first, then shift to second about 10 mph slower than the normal shift speed. Accelerate full throttle to at least 10 mph faster than normal second-to-third shift speed, calling out each 10 mph so that the passenger can record both speed and G value. Do the same for any other gears you have in your vehicle, starting at about 10 mph slower than normal and running to about 10 mph faster.

Once all the data has been recorded, a graph similar to that shown in Fig. 6 can be plotted. On a sheet of conventional linear graph paper, draw a horizontal axis marked in miles per hour from zero to 100 mph, letting each small box represent 2.5 mph. Draw a vertical line from the 0-mph point and mark this off from zero to one G with each small box representing .025 G.

Once the acceleration curves have been drawn on the graph, they can be interpreted. Obviously, first gear is the big performer, as indicated by the sharp rise in G readings in comparison with the other gears in Fig. 6. This is also the gear in which most errors can be made. For example, popping the clutch or excessive wheel spin may decrease efficiency in this gear as shown by the sudden high-G peak of the dashed-line curve of Fig. 6. If your actual curve shows this characteristic, you need to improve your clutching and braking techniques.

Note that the curves for each gear overlap. The crossover point in each case represents the ideal shift point between the two gears. If you shift out of a lower gear as the acceleration is tapering off into a higher gear where more acceleration can be picked up, you can maintain a higher overall acceleration. If your car is equipped with an engine tachometer (RPM), you may be surprised at the relatively low RPM readings corresponding to each ideal shift point. Contrary to popular belief, winding out in each gear and running near the engine red line actually wastes time, results in decelera-



Before sealing up the G-Whiz makes a bench test to be absolutely positive that the pendulum is free.

WHAT IS G?

To understand what "G" is, you must first understand the difference between speed and acceleration. Speed is a measure of distance traveled per unit of time, usually expressed in feet per second or miles per hour. Acceleration is a measure of change in speed per unit of time, expressed in feet per second per second or miles per hour per second. Remember that you can have speed without acceleration, but you can't have acceleration without speed.

Since the units for acceleration are somewhat cumbersome, it is usually expressed simply in terms of the letter G. Taken from the word *gravity*, the G is an international standard unit defined as the acceleration produced on a dropped object by the earth's gravitational field. In actual figures, an acceleration of one G is equal to 32.2 ft/sec/sec/or 22 mph/sec.

Precise measurements of low values of G can tell us quite a bit about the performance of our cars, as explained in the article.

tion due to frictional losses, and poses the threat of valve float. The reasons can be found in your engine manual. Most engines deliver maximum torque at fairly low RPM, while maximum horsepower occurs at a somewhat higher RPM. Always remember, it is the torque that counts!

Checking Brakes. To check the brakes, place *S2* in the DCL position and rotate *R5* until the meter needle just rests on the left-hand zero-G mark. Accelerate the car to 40 mph and firmly apply the brakes as you would for a hard stop. The meter should indicate about 0.5 G if your car is an American make, equipped with conventional drum brakes. If your car is equipped with disc brakes, you may pull as high as 0.7 to 0.9 G. Minimum acceptable braking distances for cars equipped with drum brakes are shown in Fig. 7. You should obtain a 0.5-G reading within these distances.

To check the fade characteristics of the brakes, make a series of hard stops from 40 mph, noting the G readings. Fade will be evidenced by a lowering of the G value each time.

Economy Driving. Except for major repair costs, the biggest expenses incurred in operating a car are for gasoline and tires. Exact figures vary, but they may total 12% of the original cost of the car each year. It is assumed that the driver uses the proper driving techniques—no jack-rabbit starts or hard stops—and that the car is kept tuned up.

While the car is in motion, place *S2* in the ACL position, and adjust *R5* until the meter indicates the zero-G center of the lower scale. In this way you can check both drag and accelerator "diddle" at highway cruising speeds. Drag results from the aerodynamic resistance of the car, excessive tire friction, and the viscosity of the lubricant in the crankcase. Accelerator "diddle" is a driver problem. Some people unconsciously tap the accelerator; and with each tap, the carburetor pump squirts a stream of gas into the throat. The amount of gas is not enough to alter the vehicle speed much, but the wasted gas can add up. Once you have attained the desired highway speed, drive to keep the needle at the zero-G center mark.

METER CALIBRATION

METER CURRENT (μA)	G	PENDULUM ANGLE (deg)
0-to-1 G scale*		
0	0	0
13	.1	6
26	.2	11
39	.3	17
51	.4	22
62	.5	26.5
71	.6	31
79	.7	35
87	.8	38.5
94	.9	42
100	1.0	45
.4-0-.4 scale		
100	+.4	22 (aft)
89	+.3	17 (aft)
76	+.2	11 (aft)
63	+.1	6 (aft)
50	0	0 (null)
37	−.1	6 (fwd)
24	−.2	11 (fwd)
11	−.3	17 (fwd)
0	−.4	22 (fwd)

**Pendulum angle is measured from the normal null when the chassis is horizontal and the pendulum hangs straight down. The 0-to-1 G scale applies for either ACL or DCL conditions. In the second, zero-center scale, aft (+) is for acceleration with the pendulum swing to the rear of the chassis, while fwd (forward) is for deceleration with the pendulum swing to the front of the chassis. A low-voltage power source and a series potentiometer can be used to produce the desired meter current deflections.*

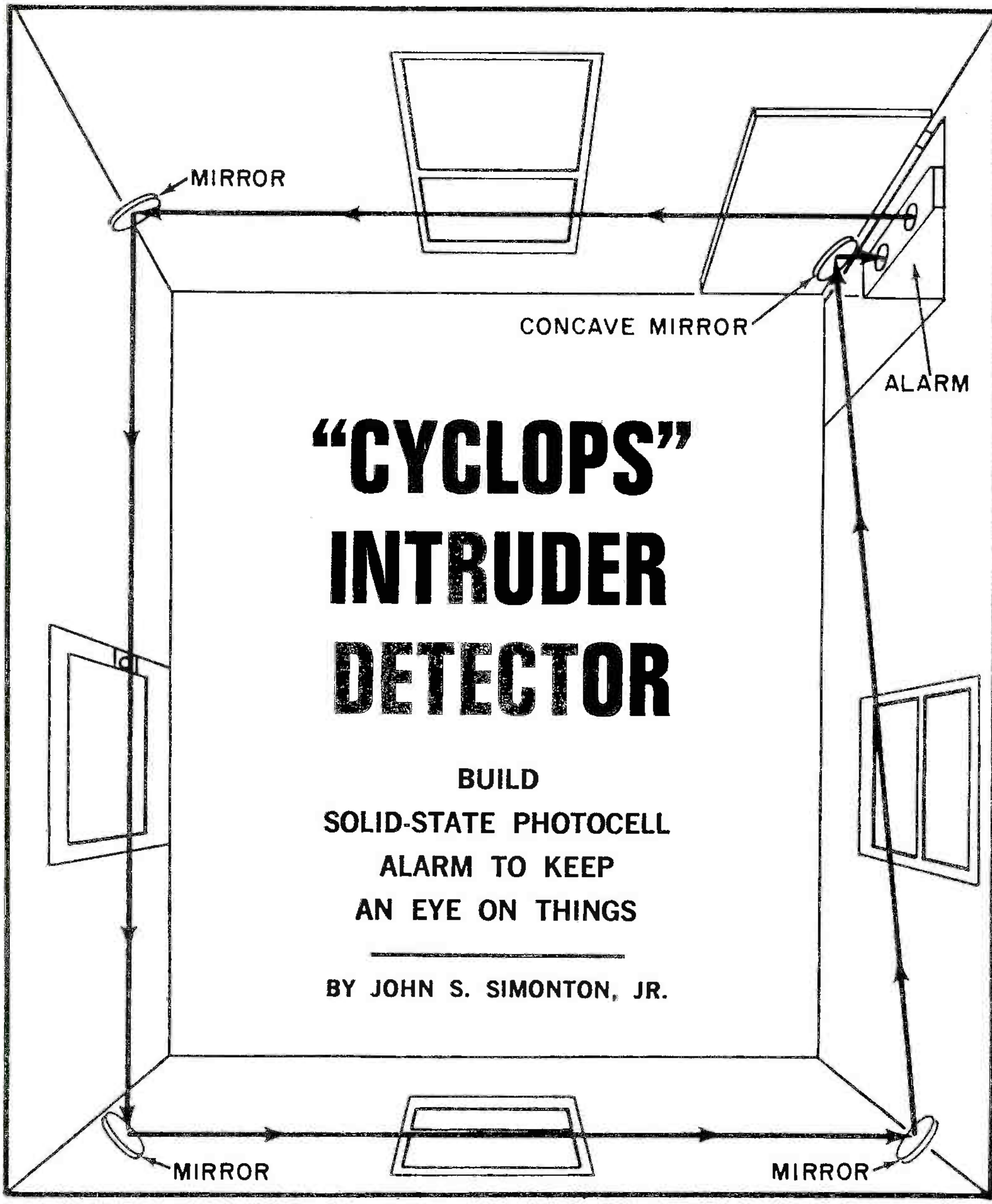
You can detect drag by removing your foot from the accelerator after reaching a constant speed and observing the reading in G's as the needle deflects to the left of the center-scale zero. Drag increases with speed, so make this test at an initial speed of 60 mph. The deeper the needle dips, the greater the fuel-robbing drag. Drag can be reduced by keeping tire pressure up to recommended value and compensating for excessive weight (passengers, etc.) by increasing the tire pressure slightly.

Heavyweight lubricants are also a source of drag. These thick lubricants may be all right for hot weather driving, but they can become a sticky medium that contributes to drag at moderate and cold temperatures. Change your lubricant to fit the season. —30—

"CYCLOPS" INTRUDER DETECTOR

BUILD SOLID-STATE PHOTOCELL ALARM TO KEEP AN EYE ON THINGS

BY JOHN S. SIMONTON, JR.



HERE IS a little unit that is about as useful as another pair of eyes when you want to protect an area from intruders. If anyone, or anything, crosses an invisible line formed by a beam of light, an alarm sounds and does not turn off even though the intruder backs away from the line. The only way to shut off the "Cyclops Intruder Detector" is to use a special "key" that will be in your possession.

This circuit has several advantages over most other optical intrusion alarms. It has no mechanical parts that might conk out when you need them most; when armed, but not triggered, power consumption of the alarm portion is very low and a set of batteries will last a long time; and, finally, it generates a distinctive sweeping audio tone that can be very easily heard even at low audio volume.

Sensitivity is quite good. You can de-

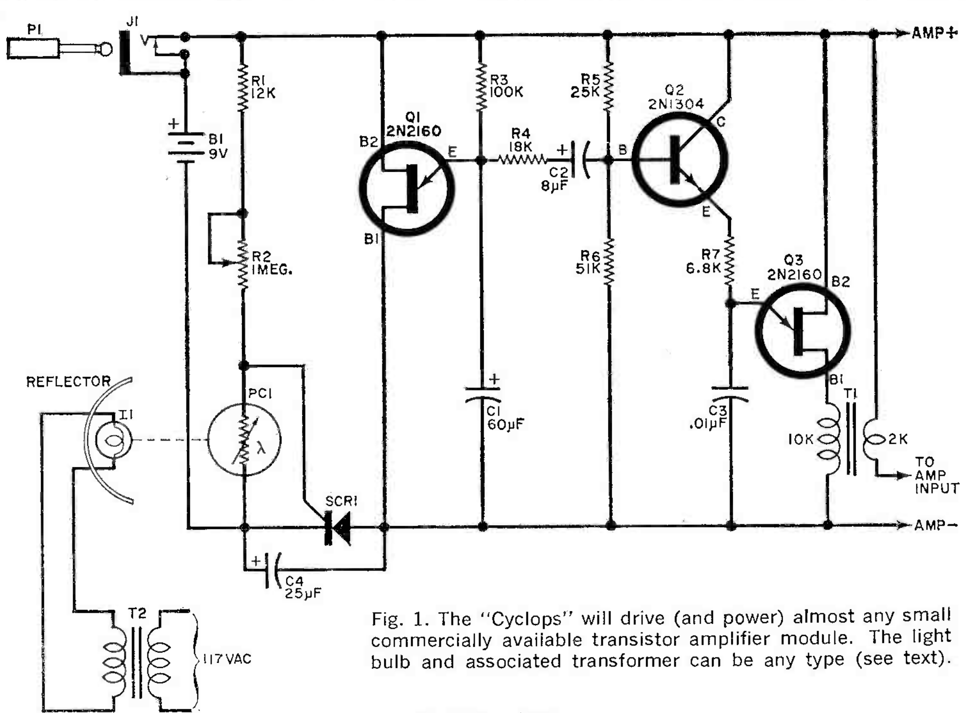


Fig. 1. The "Cyclops" will drive (and power) almost any small commercially available transistor amplifier module. The light bulb and associated transformer can be any type (see text).

PARTS LIST

B1—9-volt battery
C1—60-µF, 6-volt electrolytic capacitor
C2—8-µF, 6-volt electrolytic capacitor
C3—0.01-µF capacitor
C4—25-µF, 12-volt electrolytic capacitor
I1—Pilot lamp to suit T2
J1—Closed-circuit phone jack
P1—Mating plug for J1 (unwired)
PC1—Photocell (Clairex CL707HL or similar)
Q1, Q3—2N2160 unijunction transistor
Q2—2N1304 transistor
R1—12,000-ohm, ½-watt resistor
R2—1-megohm potentiometer, linear taper
R3—100,000-ohm, ½-watt resistor
R4—18,000-ohm, ½-watt resistor
R5—25,000-ohm, ½-watt resistor
R6—51,000-ohm, ½-watt resistor
R7—6800-ohm, ½-watt resistor
SCR1—Silicon-controlled rectifier, 50 volts, 1 amp
T1—Miniature driver transformer, 10,000-ohm primary, 2000-ohm secondary
T2—Filament transformer to suit I1
Reflector—as desired—see text
Misc.—Transistor amplifier and speaker (if desired), printed circuit board, 1-1/16"-diameter pill bottle, flat black paint, plastic cabinet, solder, wire, etc.*

**An etched and drilled PC board is available from PAIA Electronics, Inc., P.O. Box 14359, Oklahoma City, Okla. 73114, for $2.50.*

termine just how much of an area you want to cover, and build a light source as needed. It is even possible to use a red filter over the light source so that it will be almost invisible at night.

The alarm is made up of three sections: the trigger circuit; the tone generators; and the audio amplifier. This latter unit can be any commercially made amplifier and is not considered as part of the alarm circuit in this article.

Construction. The alarm circuit appears in Fig. 1. To reduce the possibility of wiring errors, an actual-size printed board (Fig. 2) can be used. Install the components according to Fig. 3, observing the polarity of the electrolytic capacitors and the semiconductors.

Although the alarm output signal can be fed to any type of amplifier, the author used a low-cost transistor amplifier of the type available at almost any electronic distributor to permit the entire alarm to be mounted in a single package. After completing the alarm circuit, connect the alarm "Amp+" output to the amplifier positive-voltage lead, connect the alarm "Amp—" lead to the amplifier negative lead, and connect the alarm signal output to the input of the amplifier.

Photocell *PC1* is mounted inside a conventional 1$\frac{1}{16}$-inch plastic pill bottle, the inside of which has been painted *flat* black. To mount *PC1*, first extend the leads of the cell by soldering a length of wire to each of the two cell leads (use a heat sink). At the rear of the pill bottle, drill a couple of $\frac{1}{16}''$ holes to accommodate the two cell leads. Place a couple of drops of adhesive on the rear of the cell, then slide it into the pill bottle (sensitive end towards the open end of the bottle), and secure the cell to the rear face of the bottle.

The light source in the prototype uses a reflector salvaged from an old flashlight with the associated bulb holder. The bulb can be powered either by a lantern battery or by a filament transformer from the power line. (If the a.c. supply is used. the alarm will signal the instant that the a.c. power is interrupted, either by accident or design.) In either case, make sure that the power supply and the bulb filament voltage agree.

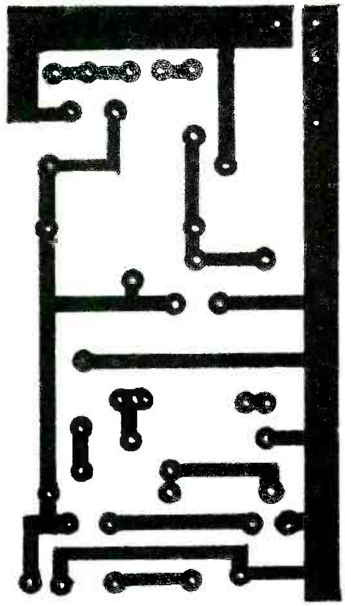


Fig. 2. Actual-size PC board for those who want to make their own. A commercial unit is available.

HOW IT WORKS

The trigger circuit consists of *PC1, R1, R2,* and *SCR1*. The SCR is normally in its non-conducting state; therefore, no power is supplied to the alarm. When *PC1* is illuminated by a beam of light from bulb *I1*, its resistance is low; essentially no voltage is applied to the gate of the SCR, and the SCR remains in the off condition.

If the light beam is interrupted, the resistance of the photocell increases and the voltage at the junction of *R2* and *PC1* goes up. If *R2* is properly adjusted, the increased voltage at the gate of the SCR will be enough to trigger the SCR on. Once this happens, power is applied to the alarm circuit. Because an SCR will not automatically turn off when operating on d.c., the alarm can only be shut off by inserting the proper plug in normally-closed jack *J1*.

The tone generator consists of unijunction transistor *Q1*, resistor *R3*, and capacitor *C1*. Before power is applied, *C1* is discharged. When power is applied, *C1* charges through *R3* until the UJT *(Q1)* fires, thus discharging the capacitor, and the process repeats itself as long as power is applied. This action produces a sawtooth voltage—a major fraction of a second long—at the junction of *R3* and *C1*. which is applied—via current limiter *R4* and d.c. blocking capacitor *C2*—to the base of *Q2*. Transistor *Q2* acts like a variable resistor whose value depends on the current flow between the base and emitter junction. This current is the sawtooth voltage created by *Q1*. The sawtooth output of *Q2* then charges *C3* which is the frequency-determining element of UJT tone generator *Q3*. The output, taken from *Q3*, via *T1*, is the sweeping frequency alarm signal which is coupled to the audio amplifier.

If a transistor audio amplifier is used for the alarm, it will receive its operating power at the same time as the alarm, and the entire system will go into operation almost instantaneously.

The author elected to package both the alarm system and the light source in the same plastic case (see illustration on page 50), although they can be separate if desired.

Installation. Regardless of where the alarm is to be used, the light beam is reflected by one or more mirrors so that eventually it shines on the photocell, thus keeping the alarm from sounding until the light beam is broken by an intruder. Physical arrangements can differ, of course, and Fig. 4 illustrates one method of protecting a room. Use the largest mirrors available, and if several different sizes have to be used, arrange them so that the light first falls on the smaller mirrors. The author has found that a concave mirror, of the type used for shaving, makes a good final mirror.

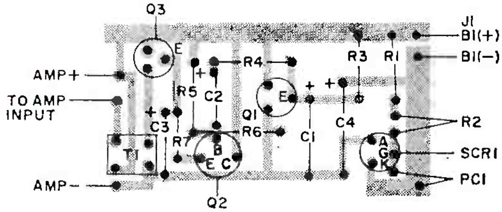
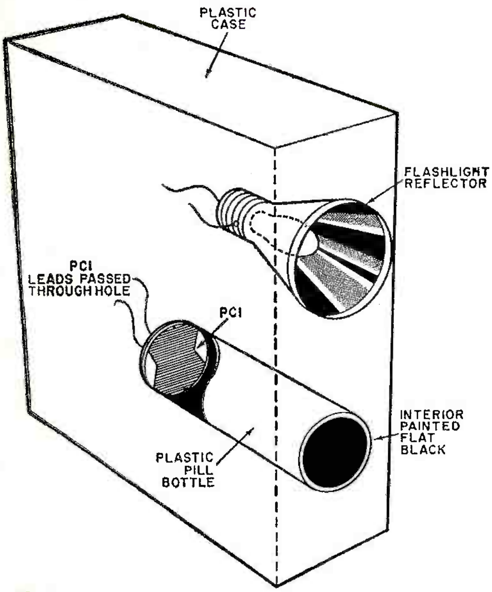


Fig. 3. Install the components as shown here, observing the polarity of semiconductors and capacitors.



Method of construction used by the author in which both light source and photocell are in a single case. Alarm circuit and audio amplifier can also be included in same housing.

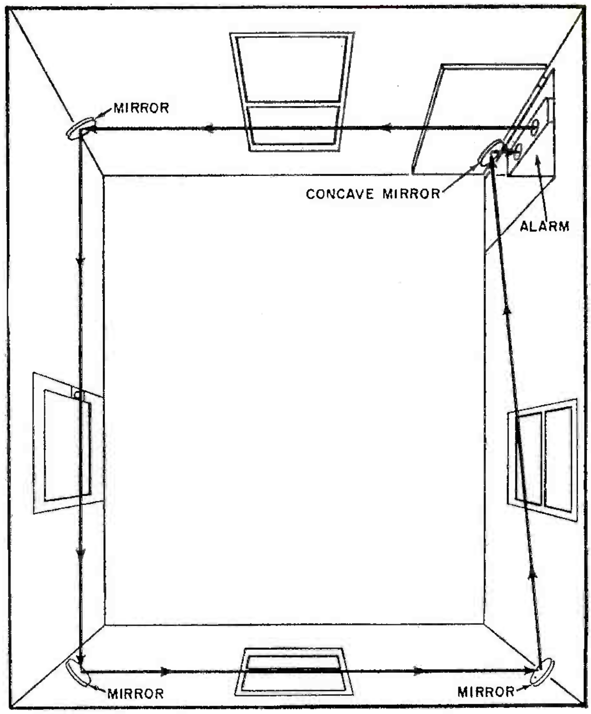


Fig. 4. Typical arrangement for protecting a room. The use of mirrors enables any shape of area to be protected. The concave mirror focuses the light on the photocell surface.

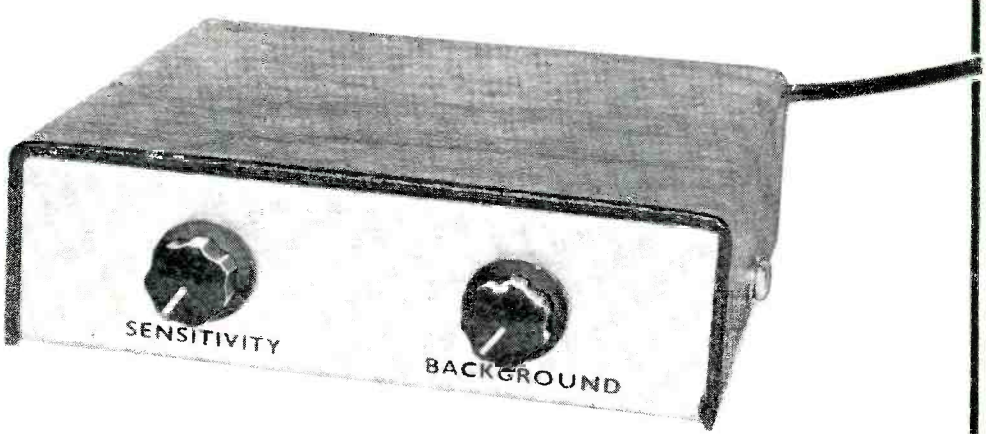
To cover just one opening (door, window, etc.), the light source can be either on one side of the opening shining into the alarm on the other side—if they are packaged separately, or both units can be on the same side of the opening with the light reflected off a mirror placed on the opposite side. The light can be "zig-zagged" to fully cover the opening.

The amount of light required to keep the alarm from sounding is determined by the light beam length, the light output of the bulb, and the type of reflector used with the bulb. Obviously, a high-power bulb in an efficient reflector (or lens system) will produce a long and useful beam path, while a lower power bulb in a poorer reflector may be good only for a few feet. Also, if a bright light source is available, it is possible to use a red filter (tinted plastic) over the reflector output so that the light beam will almost be invisible during the night. The photocell called out in the Parts List will operate in the red portion of the visible spectrum.

Operation. After the apparatus is set up, turn on the light beam and rotate *R2* (sensitivity control) to its maximum resistance position. Then set up the optical path so that the light beam shines on *PC1*, and remove *P1* from *J1*. This arms the "Cyclops" system.

Now back down on *R2* until the alarm comes on. When this point is reached, turn *R2* very slightly back (towards a higher resistance), and reinsert *P1* in *J1*. When *P1* is removed at any time, the alarm is ready to go the instant that the light beam is interrupted. Once it sounds, the only way that the alarm can be cut off is to insert *P1* in *J1* again.

The alarm will give the best results when operated indoors or at night. The ambient light of a sunny day outdoors may not provide enough light differentiation to trigger the alarm when the beam is broken. Under sunny outdoor conditions, additional shading of the photocell by extending the pill bottle with an appropriately-sized cardboard tube may help. —30—



Build The "Sonolite"

AUDIO-MODULATE 500 WATTS OF LIGHT, OR CONTROL THE SPEED OF A MOTOR—IT'S ALL THE SAME TO THIS DEVICE

BY DANIEL MEYER

DOUBLING IN BRASS as either the basis for a 500-watt color organ or as a general-purpose (up to five amperes) power controller, the "Sonolite" is easy to build and low in cost (approximately $10 per unit). For a home color organ, three "Sonolites" are required—one for the low audio frequencies, one for the mid-range, and the third for the high frequencies—plus suitable filtering.

If you have a musical group using electronic instruments, a really "far out" effect can be produced by connecting one "Sonolite" in parallel with a loudspeaker for each instrument, using a high-wattage lamp (preferably one having a built-in reflector) and a different color filter for each instrument, to illuminate the stage. The interplay of color and intensity variations as each instrument is played will produce a "wild" scene.

The addition of only a 200-ohm potentiometer and a flashlight cell will convert the "Sonolite" into a wide-range power controller, useful for controlling the power supplied to almost any device (500 watts or less) that can operate on 117 volts a.c.

Construction. The complete circuit (Fig. 1) can be mounted as shown in Fig. 2, with controls *R3* ("Background") and *R2* ("Sensitivity") mounted on one side, and the power outlet (*SO1*) and a.c. power and audio lines on the other side. The author chose to mount the circuit on two five-lug terminal strips.

Before drilling the mounting holes for

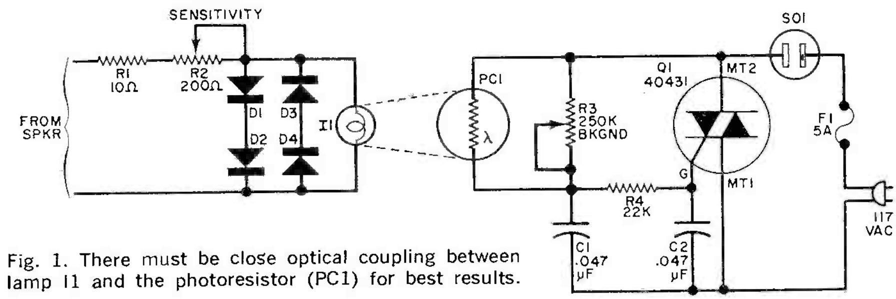


Fig. 1. There must be close optical coupling between lamp I1 and the photoresistor (PC1) for best results.

PARTS LIST

C1, C2—0.047-μF capacitor
D1, D2, D3, D4—50-volt PIV silicon diode
F1—5-ampere fuse
I1—#49 pilot lamp
PC1—Photoresistor (RCA 2529 or similar)
Q1—Triac (RCA 40431)
R1—10-ohm, ½-watt resistor
R2—200-ohm, 3-watt wire-wound potentiometer
R3—250,000-ohm potentiometer
R4—22,000-ohm, ½-watt resistor
SO1—117-volt a.c. socket
Misc.—Cabinet (Spectrum Products #533 or similar), plastic electrical tape, heat sink grease, two five-lug terminal strips, fuse holder, power line, audio line, knobs, etc.
Note: A complete kit of parts and the cabinet shown are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216 (kit 147CSL, $10.50). Individual parts are also available.

the terminal strips, make up a heat sink for the Triac (Fig. 3) and then solder the Triac to the heat sink. The two mounting holes for the heat sink are also used for supporting the two terminal lugs. Use a piece of mica sheet, with both sides covered with heat sink grease to electrically insulate the heat sink from the metal chassis.

With the heat sink mounting holes as a guide, drill the holes in the chassis. Put the greased mica sheet down first, followed by the heat sink, with the terminal strips mounted above the heat sink. Use insulating washers on both sides of the mounting hardware. Remember at all times that the strip lug affixed to the Triac heat sink will be "hot" to the other

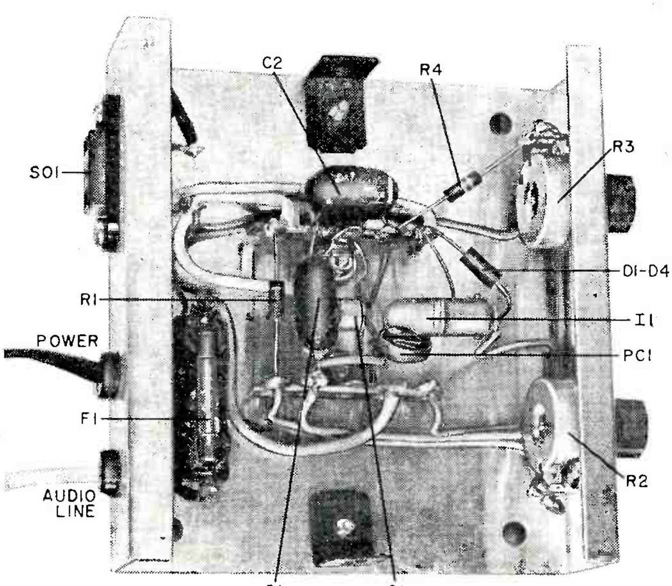


Fig. 2. The circuit is built up on two five-lug terminal strips (the type with center lug support, and two lugs on either side). The four diodes (D1 through D4) are enclosed in a piece of tubing. DO NOT use the metal chassis as a common tie point for any reason.

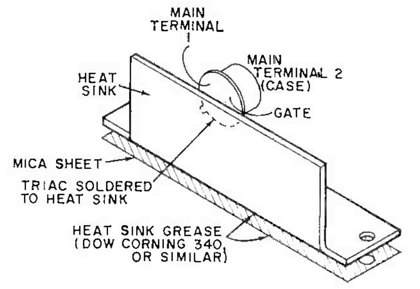


Fig. 3. The heat sink is two inches long with ½" lips. Don't forget to use heat sink grease.

side of the a.c. line. When wiring the "Sonolite," *do not* use the chassis as a common point for any part of the circuit.

Place the sensitive face of the photoresistor (*PC1*) against the pilot lamp (*I1*) at the filament end of the bulb, and wrap the pair with opaque plastic electrical tape so that only the leads of *PC1* protrude. In the "Sonolite" shown in the photograph, a metal pilot-lamp reflector was used to direct the light onto *PC1*. Although the author soldered the lamp wires directly to *I1*, a socket can be used if you prefer.

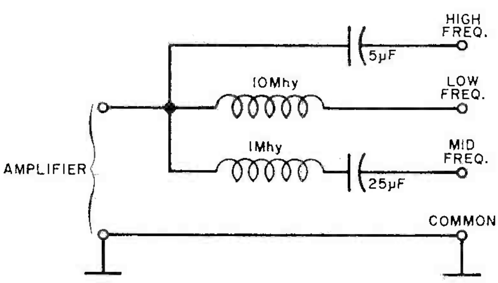


Fig. 4. Simple filter system for a three-channel color organ. Each output feeds a separate "Sonolite."

Testing. Connect a 500-watt (or lower wattage) lamp to socket *SO1* and plug the "Sonolite" into a 117-volt a.c. source. Rotating the "Background" control (*R3*) between its extremes should cause the lamp to go from completely out at one end to full on at the other end. Adjust *R3* until the lamp just goes out.

Now set the "Sensitivity" control (*R2*) to its maximum resistance position, and connect the audio input leads in parallel with a speaker. With the audio system operating, adjust *R2* until the lamp goes to full brilliance on music peaks.

To make a color organ, you will need three "Sonolites," as previously mentioned, with each supplying its own lamp. A suitable color filter for each lamp can be made from tinted plastic, with red, green, and blue being the most popular colors. The electrical filters for each group of frequencies can be made in accordance with Fig. 4.

The electrolytic capacitors in Fig. 4 can be either non-polarized types or two polarized units connected back to back. For example, the 5-μF unit in the high-frequency filter can be a pair of 10-μF electrolytics with their negative leads connected together, and the two positive leads representing a 5-μF non-polarized capacitor. Similarly, a pair of

(*Continued on page* 72)

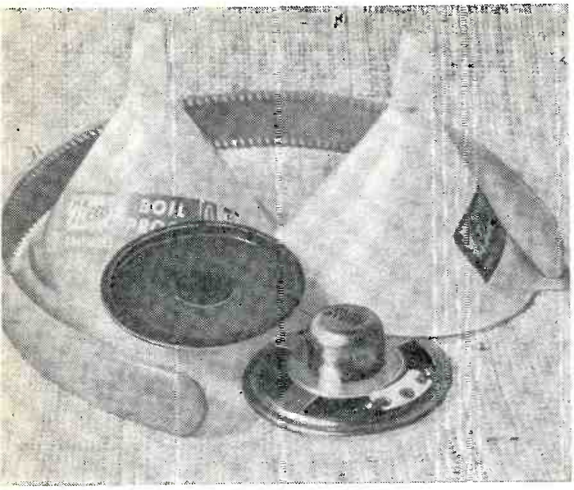
HOW IT WORKS

The "Sonolite" is a basic Triac power control system in which a low-level signal from an audio source controls the conduction time of the Triac, and therefore the amount of power supplied to the load. (A Triac is a four-layer semiconductor device, similar to an SCR, that can be switched between a conducting and non-conducting state by an external trigger voltage. Unlike an SCR, however, the Triac is a full-wave device and switches on both positive and negative half cycles of the applied a.c. power. As in SCR operation, by triggering the Triac on later in each half cycle less power is applied to the load, and conversely, switching it on earlier increases the power to the load.)

Resistors *R3* and *R4*, in conjunction with capacitors *C1* and *C2*, form a double time-constant circuit. By changing the resistance of *R3*, the firing point of the Triac can be set from about 15° to approximately 170° of the a.c. voltage cycle. In this circuit, *R3* ("Background") controls the amount of time necessary for the voltage across *C2* to reach the triggering requirement of the Triac. When the voltage across *C2* reaches this voltage point, the Triac fires, turns on the power to the load for the remainder of the cycle, and also discharges *C2*, making it ready for the next charging cycle.

Photoresistor *PC1* is connected in parallel with potentiometer *R3*. When the photoresistor is dark, it has a very high resistance, and therefore does not greatly change the effective value of *R3*. However, if *PC1* becomes illuminated, its resistance drops greatly, effectively changing the charging time of the time constant.

The light reaching *PC1* is generated by pilot lamp *I1*. This lamp, in turn, is powered by a voltage present at the audio input leads. The four diodes act as a voltage limiter to prevent blowing out the pilot lamp if the input voltage exceeds that required by the bulb. Sensitivity control *R2* determines how much of the input voltage reaches the pilot lamp.



STEREO— at 99¢ per ear

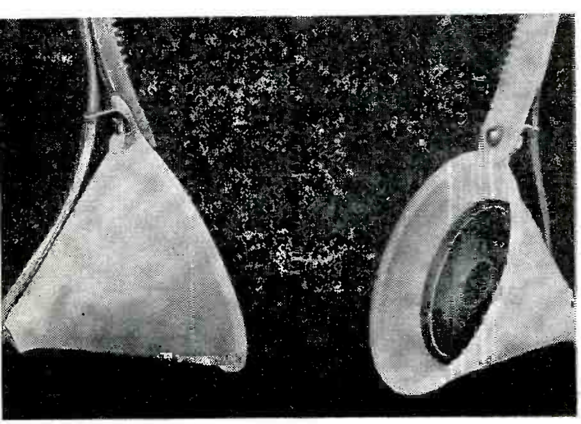
BY DAVID B. WEEMS

HERE'S A CUTE IDEA for a project that is fun to assemble and is very useful in the bargain. For about 99¢ per ear, you can put together a set of stereo headphones using ordinary household materials. Try it one evening and see.

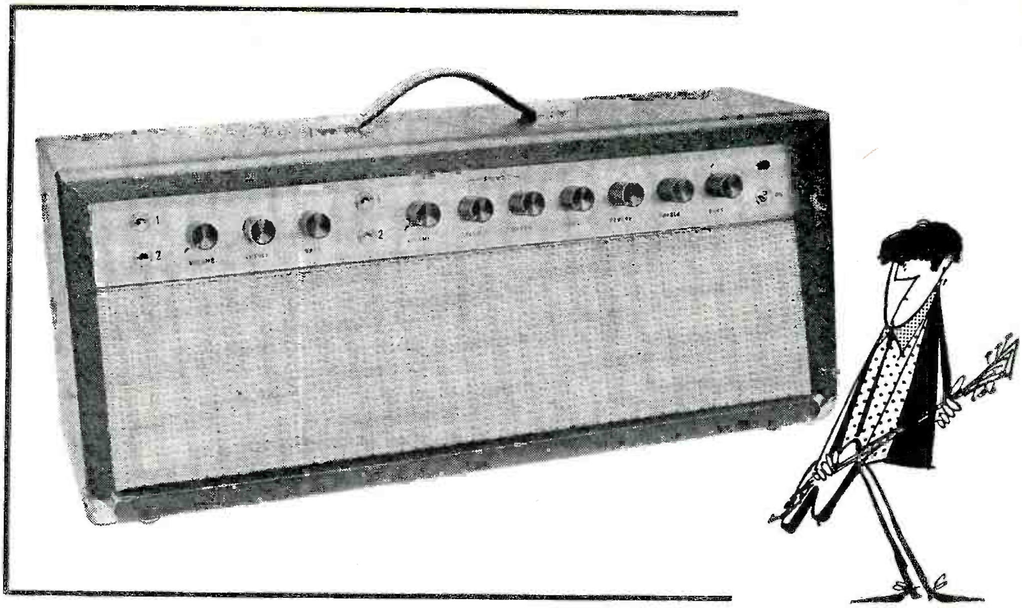
The necessary parts—shown in the photo at the top of this page—consist of a pair of two-inch diameter PM speakers, two 2-oz. plastic funnels, a plastic headband, nuts, bolts and wire. Prepare the funnels by cutting the stem down to a length of ¼". Attach the funnels to the headband (see bottom photo) with #6 hardware and bend a solder lug to make a wiring support. Solder connecting wires to speakers and bring the wires out funnel neck through solder lugs. Wire speakers in phase and fasten connecting lead to headband with silicone cement. Wad a piece of fiberglass stuffing into the funnel behind each speaker and apply a bead of silicone cement around the edge of the speaker basket to hold them in place. Then press the speakers into the funnels and allow the cement to dry. Of course, attach the appropriate connector at the end of the headset cable.

If you connect this stereo headset to the speaker terminals of your hi-fi, it is a good idea to install a 100-ohm resistor in series with each speaker. This will prevent blasting. Edge each of the funnels with a piece of foam rubber or plastic foam for comfort. —30—

To make the headset comfortable, the funnel edge should be padded with foam rubber or plastic foam. Cement in place after making the necessary cutout. Headset is very light in weight.



Speakers are wired in phase so that terminals with red dot go to hot side of amplifier output. Other speaker connections go to amplifier ground. Note use of the solder lug.



BUILD THE

M/M/M Instrument Amplifier

60-WATT SOLID-STATE GUITAR AMPLIFIER WITH TREMOLO, REVERB, AND FUZZ

BY DANIEL MEYER

HOW WOULD YOU like to build a custom sound system for your electric guitar with the exact controls and features that you want? Or, if you are satisfied with your present arrangement, how would you like some "add ons"—such as controllable fuzz, tremolo, and reverb, that can very easily be hooked up to your system? If you already have a relatively low power amplifier, how about a clean 60-watt booster so that you can be heard?

If desired, the entire system can be built "from scratch" for about $85, and will have features not found in most professional units which cost many times as much. It even includes a high-quality straight preamplifier for vocals or voice announcements.

The M/M/M (Mix, Match, Musical) Instrument Amplifier is built on four printed boards each of which can be made or purchased as a complete kit, so circuit duplication will present no problem. To put the icing on the cake, the entire system has been tested over a period of eight months by a professional combo and has aroused much comment. Circuit reliability has proven excellent.

Power Amplifier. The power amplifier circuit, shown in Fig. 1, uses five silicon transistors to insure maximum temperature stability. The two power output transistors, *Q4* and *Q5*, are complementary types, as are drivers *Q2* and *Q3*. These four transistors form a class-B, push-pull, emitter-follower power ampli-

POWER AMPLIFIER PARTS LIST

C1, C3—10-μF, 15-volt electrolytic capacitor
C2—200-μF, 6-volt electrolytic capacitor
C4—50-μF, 50-volt electrolytic capacitor
C5—4000-μF, 50-volt electrolytic capacitor
D1, D2—1N3754 diode
D3—Silicon bias diode (1N645 or similar)
Q1, Q3—MM3005 transistor (Motorola)
Q2—MM4005 transistor (Motorola)
Q4—SJ3507 transistor (Motorola)
Q5—MJ2802 transistor (Motorola)
R1—10,000-ohm, ½-watt resistor
R2, R3, R4, R9—4700-ohm, ½-watt resistor
R5—68,000-ohm, ½-watt resistor
R6—220-ohm, ½-watt resistor
R7—50,000-ohm trimmer potentiometer
R8—47-ohm, ½-watt resistor
R10—2200-ohm, ½-watt resistor
R11, R12—470-ohm, ½-watt resistor
R13, R14—0.27-ohm, 5-watt resistor
SPKR—4-ohm, 60-watt capability speaker
Misc.—Heat sink, diode clamps (2), mica insulating washers (2), mica transistor insulator, silicone grease, mounting hardware, etc.

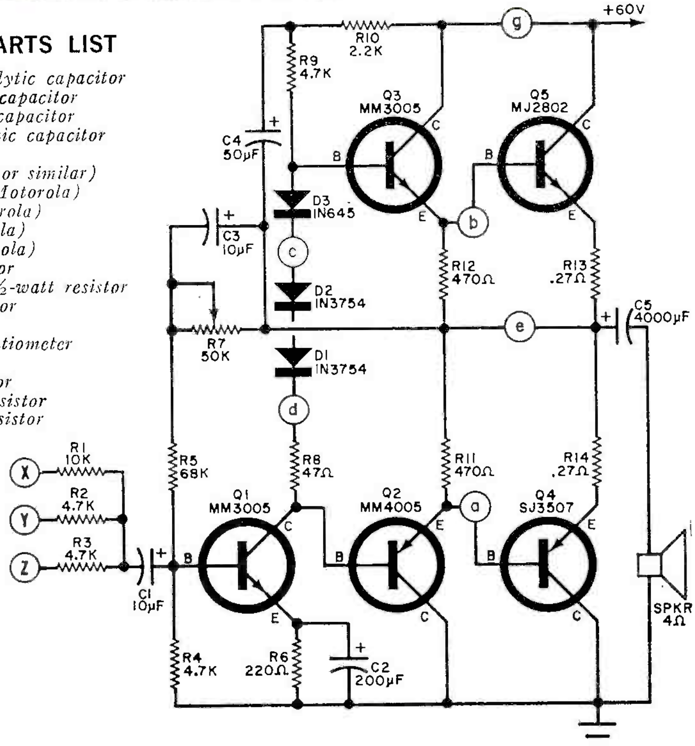


Fig. 1. This 60-watt power amplifier is a true hi-fi unit with response from 20 Hz to over 50 kHz. It can be built separately and used as a power booster for any instrument (or audio) system.

fier that provides exceptionally clean output at high power and low cost. The first stage, *Q1*, is a conventional voltage amplifier.

Diodes *D1*, *D2*, and *D3* are connected between the bases of the driver stages and provide forward bias to turn the output transistors slightly on to prevent crossover distortion. Two of these diodes (*D1* and *D2*) are clamped to the output transistors' heat sink so as to stabilize the forward bias for any variations in operating temperature of the output power transistors.

Power output is a continuous 60 watts, corresponding to a peak music power rating of about 140 watts. Frequency response is from 20 Hz to at least 50 kHz, and the amplifier is designed to supply any 4-ohm speaker that can carry the power. Two 8-ohm speakers, each having at least a 35-watt rating can be used connected in parallel.

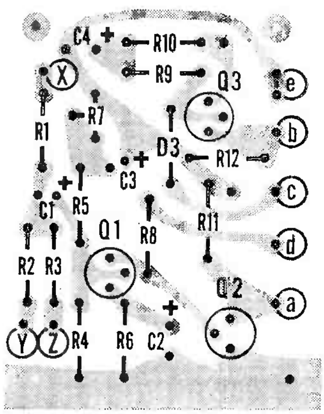
The power amplifier, with the exception of the two output transistors (*Q4* and *Q5*), their associated diodes (*D1* and *D2*), emitter resistors *R13* and *R14*, and output capacitor *C5*, is assembled on a printed board such as that shown actual size in Fig. 2. Components are affixed to the board as shown in Fig. 3. The letter-coded connections in Fig. 3 correspond to those in Fig. 1 for wiring to the external components.

The two power transistors are mounted on the heat sink, with a mica insulating sheet and insulating washers used on *Q5* only. Use a thin coating of silicone grease on both sides of the mica insulator sheet, and on the bottom of both transistors so as to make a good thermal bond between the transistors and the heat sink. One mounting screw of each power transistor should also secure a diode clamp. Insert one 1N3754 diode in each clamp, then tighten the screws. (The author's assembly is shown in Fig. 4.)

Make sure that diodes *D1* and *D2* are correctly wired into the circuit by ob-

Fig. 2. Actual-size printed board for amplifier. The two power transistors and associated components are mounted externally due to their heat dissipation.

Fig. 3. Install the board components as shown. The letter designations correspond to those in Fig. 1.



serving that a red dot on each diode case identifies the cathode of the diode. Failure to wire these diodes correctly may damage the power transistors.

Once the heat sink assembly has been completed, it can be wired to the printed board (see Fig. 1). The two emitter resistors (*R13* and *R14*) and output capacitor *C5* are mounted elsewhere on the chassis.

In testing the power amplifier, use a 60-volt power supply, preferably the one designed for this circuit and covered further on in this article. Connect a voltmeter to the junction of *R13* and *R14* (or point "e" on the circuit board), and adjust trimmer *R7* for half the power supply voltage (about 30 volts). If you have a sine-wave audio generator and oscilloscope, drive the amplifier to full output with a 4-ohm load connected and adjust trimmer *R7* for symmetrical clipping of both sides of the sine wave.

Instrument Preamplifier. The major difference between a preamplifier designed for a hi-fi system and one designed for an instrument amplifier is that in the latter case there is no need for equalization, and a greater dynamic range must be handled. A recording seldom has more than a 40-dB dynamic range (due to the limitations of the tape or record being used). However, this limitation is not placed on a musical instrument, and the preamplifier must be capable of handling

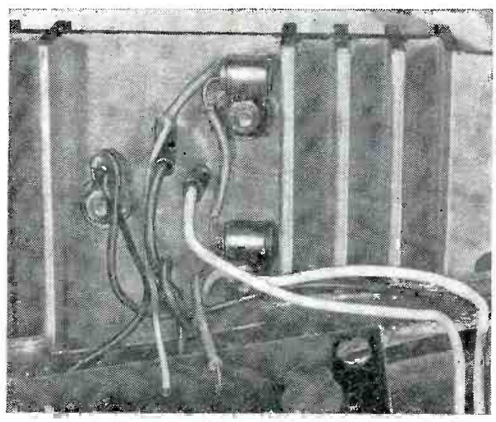


Fig. 4. Diodes D1 and D2 are thermally coupled to Q4 and Q5 by means of a heat sink and diode clamps.

in excess of 60 dB dynamic range during operation. It must also be capable of handling signals from a millivolt up to a volt or so without overloading or clipping.

The main circuit, shown in Fig. 5, makes a very useful instrument preamplifier and incorporates a number of circuits not usually found in most preamps. Besides the usual bass and treble tone controls, this preamp features a built-in fuzz and tremolo circuit.

The first stage (*Q1*) is a common-emitter amplifier directly coupled to an emitter follower output stage (*Q2*). The

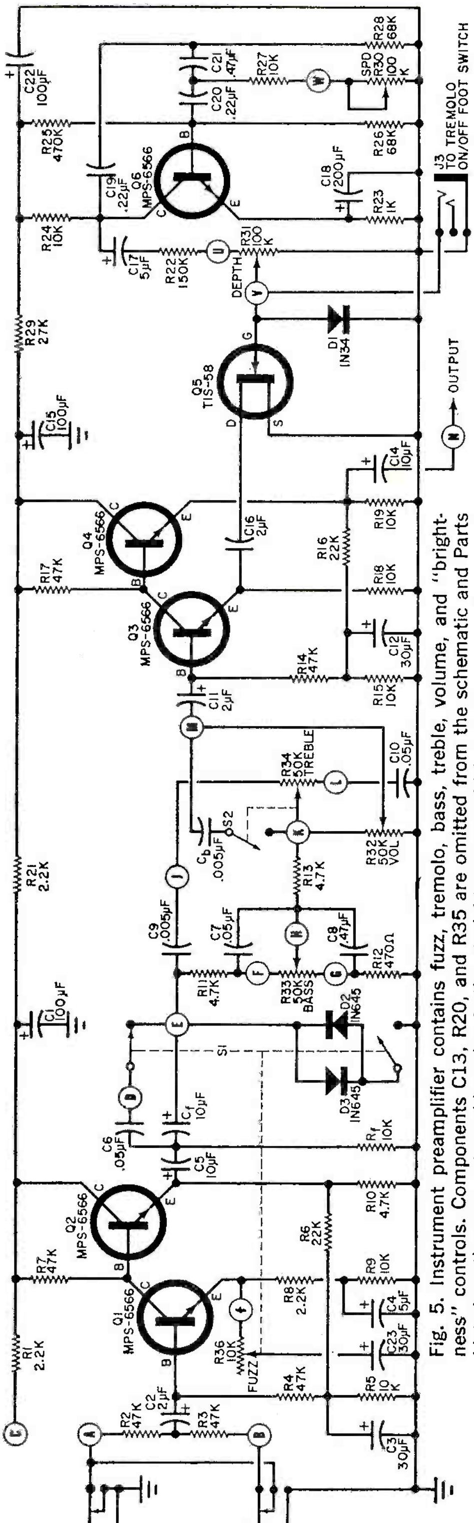


Fig. 5. Instrument preamplifier contains fuzz, tremolo, bass, treble, volume, and "brightness" controls. Components C13, R20, and R35 are omitted from the schematic and Parts List since they are not used here but in the straight preamp which is built on a similar board.

two inputs are fed to *Q1* through isolation resistors *R2* and *R3* wired so that they will be in parallel only when *J1* is being used. The emitter circuits of *Q1* and *Q2* contain the fuzz arrangement.

When "Fuzz" level control *R36* is rotated from its off position, switch *S1* operates. One pole of this switch introduces a pair of clipping diodes (*D2* and *D3*) into the audio circuit. The other pole introduces a parallel coupling capacitor (*C6*) into the interstage coupling. This switching does two things to the signal: first, the diodes clip all signals that exceed one-volt amplitude; second, all low-frequency signals are attenuated and given a sawtooth shape. As *R36* is rotated, the amount of unbypassed emitter resistance in the *Q1* circuit is reduced and the stage gain is increased, which, in turn, increases the amount of clipping and distortion caused by the diodes. This type of variable fuzz is far more versatile than the more conventional fixed fuzz.

INSTRUMENT PREAMPLIFIER PARTS LIST

C1, C15, C22—100-µF, 50-volt electrolytic capacitor (C22 can be 25-volt)
C2, C11, C16—2-µF, 15-volt electrolytic capacitor
C3, C12, C23—30-µF, 6-volt electrolytic capacitor
C4, C17—5-µF, 15-volt electrolytic capacitor
C5, C14—10-µF, 25-volt electrolytic capacitor
Cf, C7, C10—0.05-µF capacitor
C8, C21—0.47-µF capacitor
C9, Cb—0.005-µF capacitor
C18—200-µF, 6-volt electrolytic capacitor
C19, C20—0.22-µF capacitor
C6—10-µF, 15-volt electrolytic capacitor
D1—1N34 or similar germanium diode
D2, D3—1N645 or similar silicon diode
J1, J2—Closed-circuit phone jack
J3—3-conductor phone jack (same as J1 in Fig. 13)
Q1, Q2, Q3, Q4, Q6—MPS6566 transistor (Motorola)
Q5—TIS58 field-effect transistor (Texas Instruments)
R1, R8, R21—2200 ohms
R2, R3, R4, R7, R14, R17—47,000 ohms
R5, R9, R15, R18, R19, R24, R27, Rf—10,000 ohms
R6, R16—22,000 ohms
R10, R11, R13—4700 ohms
R12—470 ohms
R22—150,000 ohms
R23—1000 ohms
R25—470,000 ohms
R26, R28—68,000 ohms
R29—27,000 ohms
(all ½-watt resistors)
R30, R31—100,000-ohm linear potentiometer
R32, R33, R34—50,000-ohm potentiometer
R36—10,000-ohm CCW log taper potentiometer
S1—D.p.s.t. switch (on R36)
S2—Push-pull s.p.s.t. switch (on R34)

Fig. 7. Component layout for instrument preamplifier. Components Rf and Cf determine the degree of fuzz, and may be varied in value from those shown.

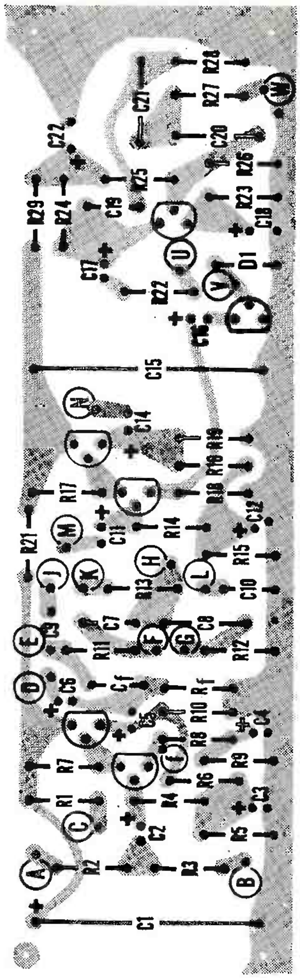
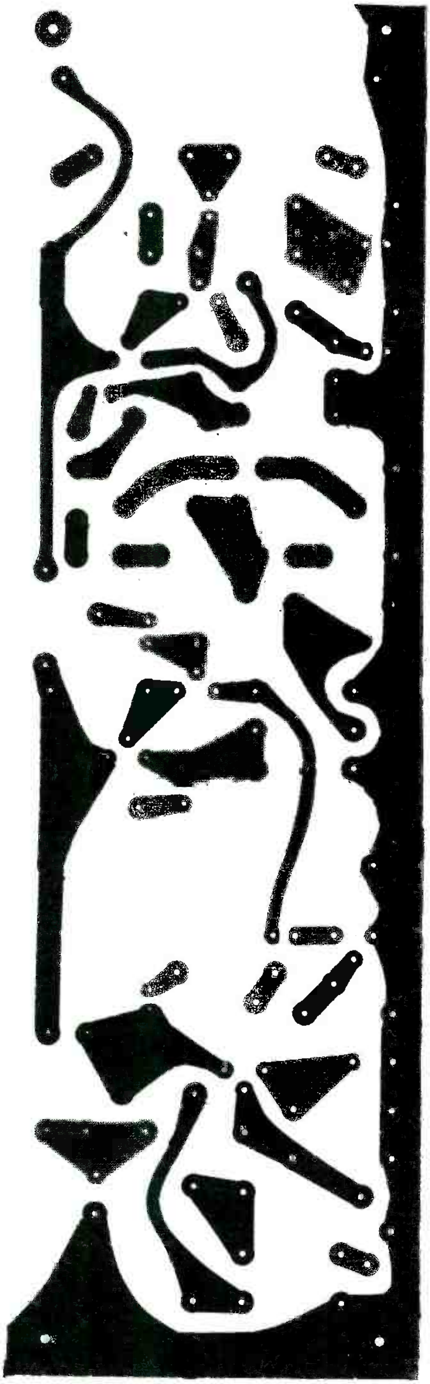


Fig. 6. Actual-size printed board for assembly of instrument preamplifier. The preamp can also be used independently with any instrument audio system.



The signal from *Q2* is then passed through a bass and treble tone control circuit (15 dB cut or boost) before it is further amplified by *Q3*. There is one unique feature about the treble control used here. When switch *S2* is activated, capacitor C_b is introduced to bypass the high-frequency sound around volume control *R32*. Introducing this capacitor in the circuit produces a "bright" signal that is a type of fixed treble boost. Although switch *S2* is shown coupled to *R34*, it can be an independent switch.

The output signal at the collector of *Q3* is directly coupled to emitter-follower *Q4*, from which it is fed to the power amplifier. However, the built-in tremolo is introduced at the emitter of *Q3*.

The tremolo circuit consists of *Q3*'s emitter bypass capacitor (*C16*) in series with a FET (*Q5*) acting as a voltage-variable resistor. As the voltage to the FET gate is varied, more or less bypass is introduced into the *Q3* circuit. This, in turn, will vary the gain of the output signal, producing tremolo (signal level variation).

Transistor *Q6* is in a phase-shift oscillator circuit whose frequency can be varied (by speed control *R30*) between 4 and 15 Hz. The a.c. output of this circuit is fed, via level control *R31*, to the gate of *Q5*. Open-circuit jack *J3* is provided so that an external footswitch can be used to turn on the tremolo if desired.

The actual-size printed board for the instrument preamplifier is shown in Fig. 6 with the components mounted as in Fig. 7. A completed board, before the semiconductors are installed, is shown in Fig. 8. This board was made from the kit.

Straight Preamplifier. The circuit for the conventional straight preamplifier, useful for vocals or general announcement purposes, is shown in Fig. 9. It is basically similar to the instrument preamplifier without the special effects circuitry, and can make an excellent preamplifier for any hi-fi system. It incorporates both bass and treble tone controls and has its own volume control.

An actual-size printed board for the straight preamplifier can be seen in Fig. 10; the components are installed as in Fig. 11. A completed board, before semiconductor installation, is shown in Fig. 12.

Reverberation Unit. This unit consists of a two-transistor driver for a spring-type reverb unit, and another two-transistor amplifier to make up the signal loss (typically about 40 dB) encountered in the spring unit. See Fig. 13.

The input signal for the reverb unit is taken from the output of the preamplifier. Because it is desirable to have as high an input signal to the spring unit as possible in a reverb system (to reduce hum and vibration noise), the input signal is amplified by *Q1*, while *Q2* is an impedance matcher used to drive the reverb spring unit. The echo signal at the other end of the spring is amplified by *Q3* and passed via emitter follower *Q4* as the output. Open-circuit jack *J1* is provided so that an external footswitch can be used to activate the reverb as desired.

An actual-size printed board for the reverb unit is shown in Fig. 14; the as-

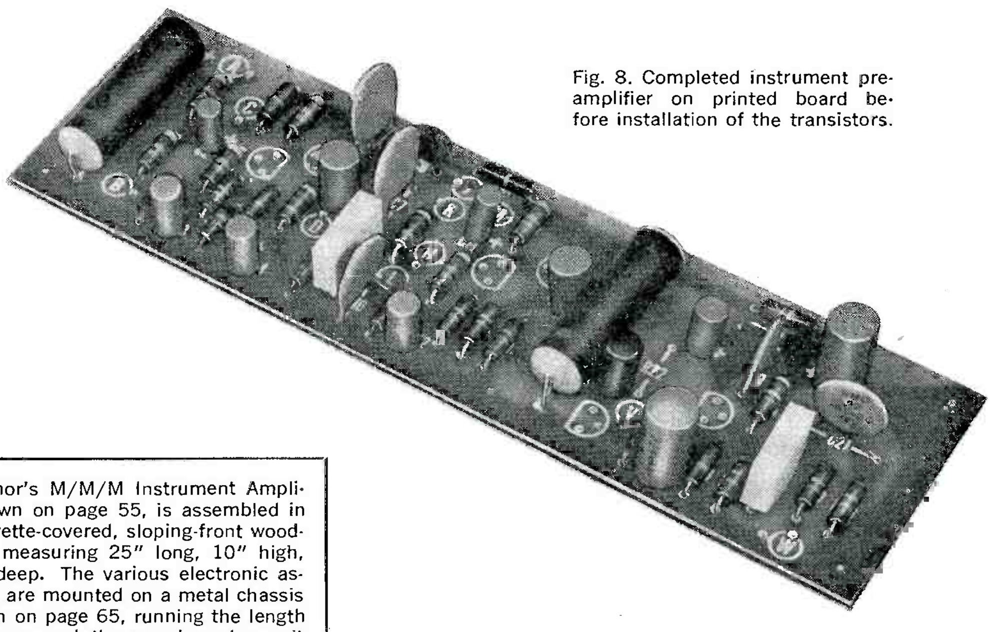


Fig. 8. Completed instrument preamplifier on printed board before installation of the transistors.

The author's M/M/M Instrument Amplifier, shown on page 55, is assembled in a leatherette-covered, sloping-front wooden case measuring 25" long, 10" high, and 7" deep. The various electronic assemblies are mounted on a metal chassis as shown on page 65, running the length of the case, and the reverb spring unit is secured to the bottom of the case.

STRAIGHT PREAMPLIFIER PARTS LIST

C1, C15—100-μF, 50-volt electrolytic capacitor
C2, C11—2-μF, 15-volt electrolytic capacitor
C3, C12—30-μF, 6-volt electrolytic capacitor
C4, C13—5-μF, 15-volt electrolytic capacitor
C6, C14—10-μF, 25-volt electrolytic capacitor
C7, C10—0.05-μF capacitor
C8—0.47-μF capacitor
C9—0.005-μF capacitor
J3, J4—Closed-circuit phone jack
Q1, Q2, Q3, Q4—MPS6566 transistor (Motorola)
R1, R8, R21—2200 ohms
R2, R3, R4, R7, R14, R17—47,000 ohms
R5, R9, R15, R18, R19—10,000 ohms
R6, R16—22,000 ohms
R10, R11, R13—4700 ohms
R12—470 ohms
R20—330 ohms
(all ½-watt resistors)
R32—50,000-ohm audio taper potentiometer
R33, R34—50,000-ohm linear potentiometer

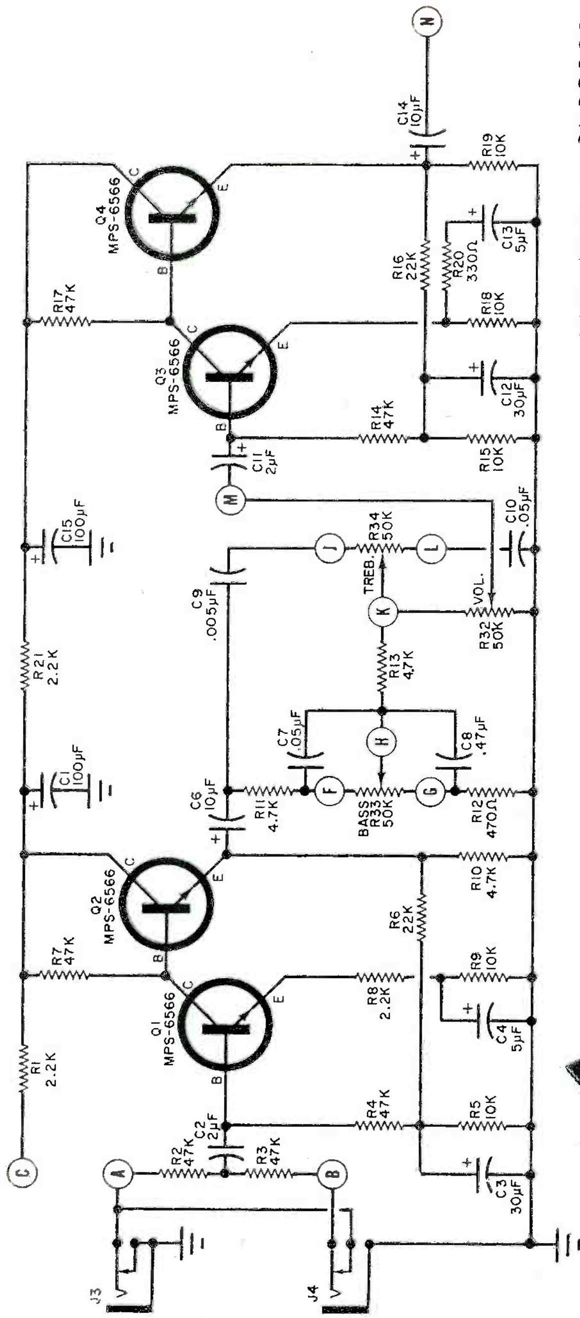


Fig. 9. The straight preamplifier is a high-quality unit having its own bass, treble, and volume controls. Components C5, J1, J2, and R22 through R31 are omitted from schematic and Parts List since they are not used here but in the instrument preamplifier on a similar PC board.

Fig. 12. The author's prototype of the straight preamplifier before installation of transistors.

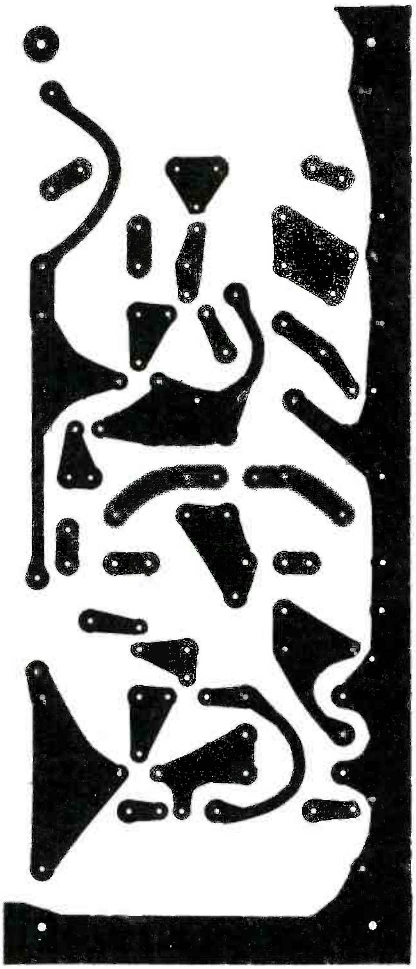


Fig. 10. You can make this actual-size printed board for the straight preamplifier yourself, or buy it etched and drilled.

sociated components are added as per Fig. 15. The completed board, before semiconductor installation, appears in Fig. 16.

Power Supply. The circuit for a power supply capable of driving the complete system is shown in Fig. 17. It is a conventional full-wave rectifier and filter capacitor combination that will deliver 60 volts at the required current. Indicator *I1* tells when the power has been applied to the system, while *S2* is placed in the position that produces the lowest hum level (if any).

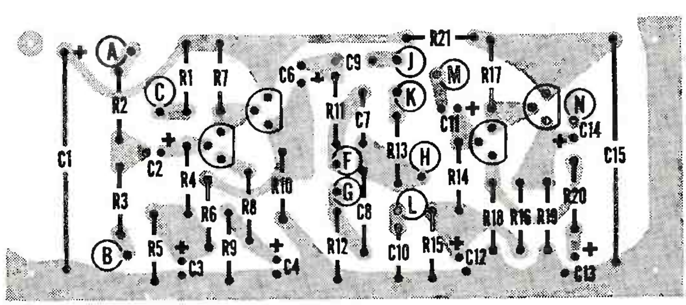
Assembling Complete System. The various components are interconnected as shown in Fig. 18. As shown in the photograph on page 55, the entire system can be mounted within a suitable case (partially sloping front), with the electronics all supported on a single cabinet-length metal chassis and with the reverb spring unit secured to the bottom of the case. The various potentiometers and switches can be mounted on the front apron of the chassis and transfer decals used to identify them. See Fig. 19 for the chassis arrangement used by the author.

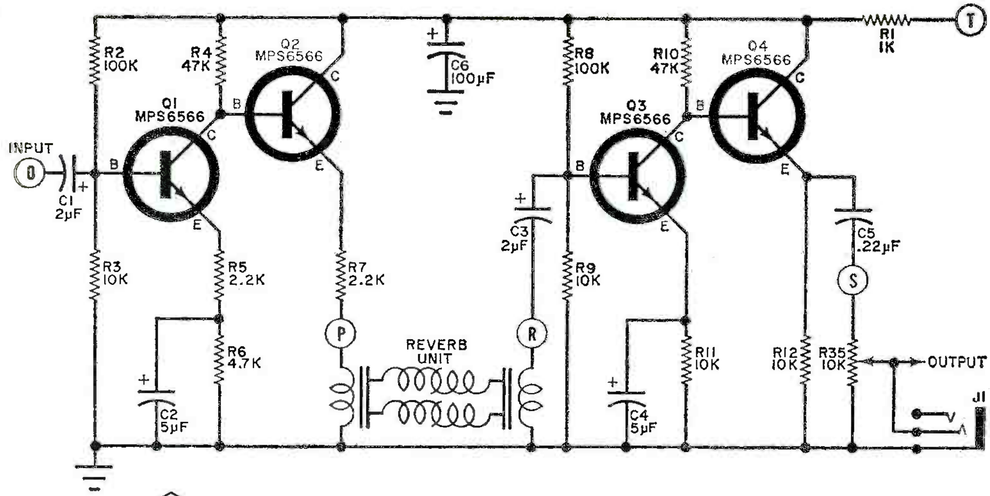
The speaker is connected to the amplifier via a telephone-type jack, as are the on-off footswitches that control fuzz, reverb, and tremolo circuits. The on-off footswitches are conventional instrument switches, available wherever electronic musical instruments are sold.

When the complete system is used, do not place it on a speaker enclosure as acoustic feedback can cause the reverb

(*Continued on page* 65)

Fig. 11. Mount the components used in the straight preamplifiers on the PC board as shown. The letter designations correspond to those in the schematic.





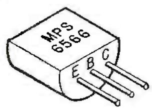


Fig. 13. Jack J1 connects to an external footswitch to turn the reverb on and off. Reverberation gain control R35 is not on the PC board but on the front panel.

REVERBERATION UNIT PARTS LIST

C1, C3—2-µF, 15-volt electrolytic capacitor
C2, C4—5-µF, 15-volt electrolytic capacitor
C5—0.22-µF capacitor
C6—100-µF, 50-volt electrolytic capacitor
J1—3-conductor phone jack (same as J3 in Fig. 5)
Q1, Q2, Q3, Q4—MPS6566 transistor (Motorola)
R1—1000 ohms
R2, R8—100,000 ohms
R3, R9, R11, R12—10,000 ohms
R4, R10—47,000 ohms
R5, R7—2200 ohms
R6—4700 ohms
(*all ½-watt resistors*)
R35—10,000-ohm linear potentiometer
1—Gibbs Type 1V-C reverberation spring unit

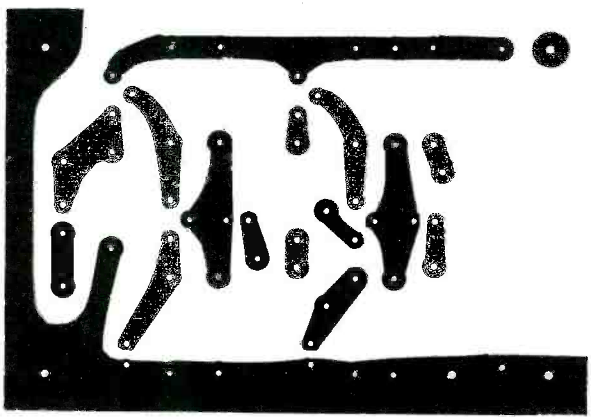


Fig. 14. Actual-size PC board (left) contains the entire reverberation circuit.

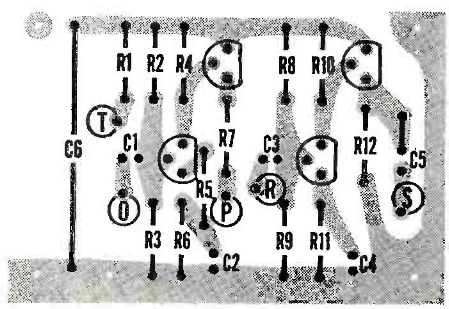


Fig. 15. Assemble the components on the printed circuit board as shown above.

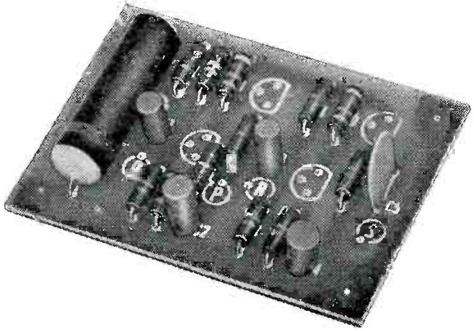


Fig. 16. The reverberation PC board should look like this before you install the four transistors.

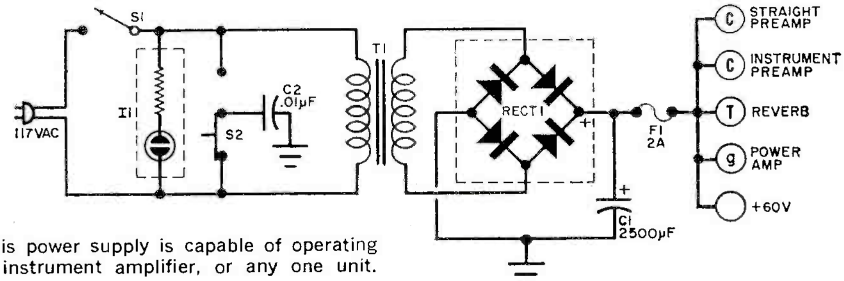


Fig. 17. This power supply is capable of operating the entire instrument amplifier, or any one unit.

POWER SUPPLY PARTS LIST

C1—2500-μF, 75-volt electrolytic capacitor
C2—0.01-μF capacitor
F1—2-ampere fuse
I1—Neon lamp and limiting resistor
RECT 1—2-ampere silicon rectifier bridge, 100-PIV (Varo VS148 or similar)
S1—S.p.s.t. switch
S2—S.p.d.t. switch
T1—Power transformer: secondary, 45 volts at 2 amperes

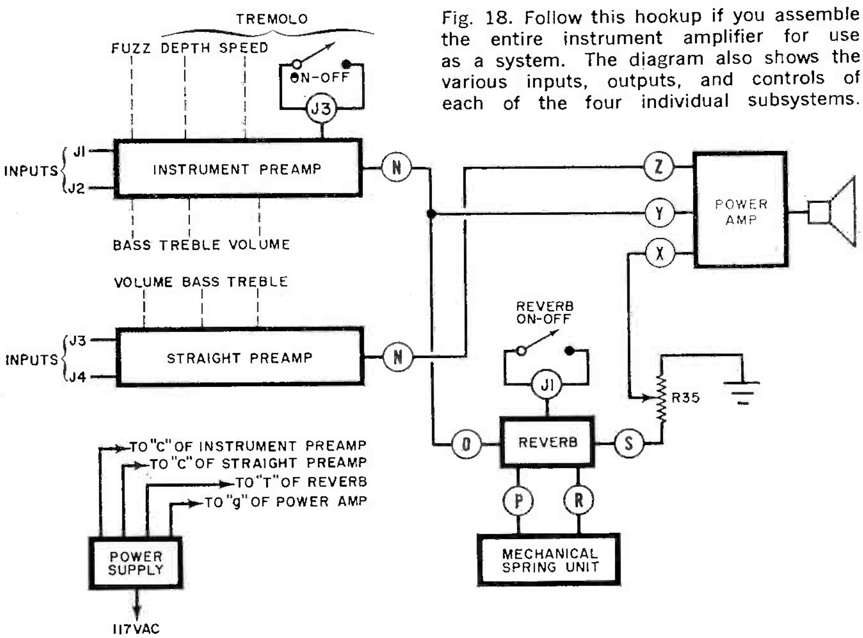


Fig. 18. Follow this hookup if you assemble the entire instrument amplifier for use as a system. The diagram also shows the various inputs, outputs, and controls of each of the four individual subsystems.

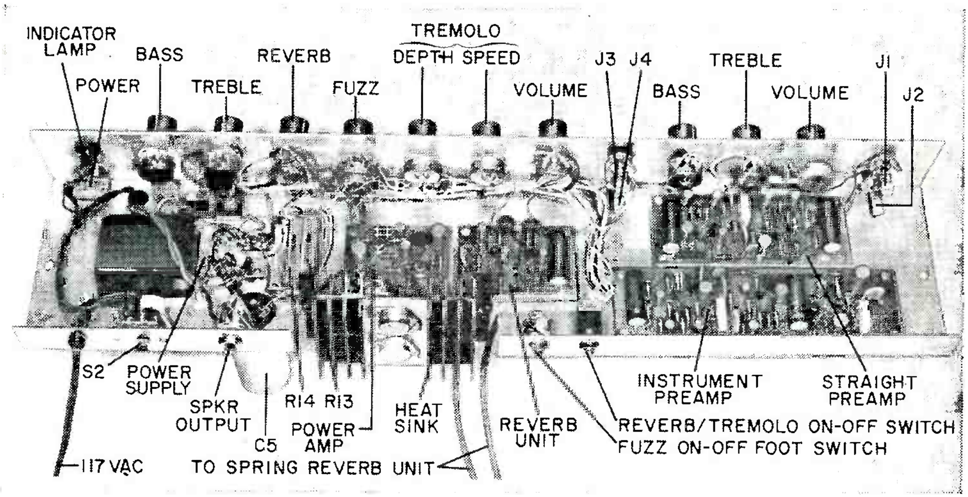


Fig. 19. The M/M/M Instrument Amplifier can be mounted on one long metal chassis. Note (below) that a complete amplifier kit is available as well as individual unit kits. All you need is a 60-watt speaker.

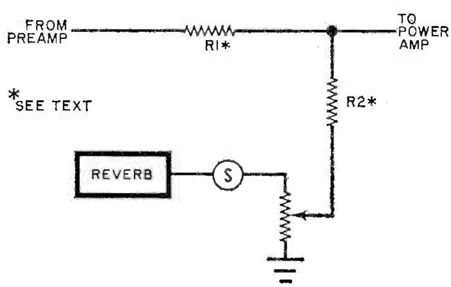


Fig. 20. Method of connecting reverb unit to any amplifier. See text at right for resistance values.

PC BOARDS AND PARTS KITS

The following are available from Southwest Technical Products: etched and drilled PC board for instrument preamplifier (#141), $3.00; straight preamplifier (#141P), $2.50; reverb unit (#141R), $2.10; and power amplifier (#141A), $2.10. A complete amplifier kit including all parts and punched chassis, less cabinet and panel markings (#MMC141) is $85.00. Send self-addressed envelope for price list on separate parts kits for each portion of the system to Southwest Technical Products Corp., 219 W. Rhapsody, Box 16297, San Antonio, Texas 78216.

spring to produce a disturbing howl. Also, make sure that the speaker used can take the full 60-watt output of the power amplifier.

Set the guitar output control to maximum, plug it into the instrument preamplifier and make the desired volume, bass, and treble adjustments. Then set in the desired amount of fuzz, reverb, or tremolo, and use the external footswitches to turn them on or off as desired.

Individual Use. Either preamplifier can be used with any power amplifier merely by applying the correct d.c. voltage, and using the signal from terminal "N" of each printed board as the output.

The reverb unit can be installed in any audio system by following the arrangement in Fig. 20. In vacuum-tube systems, *R1* and *R2* will be between 47,000 and 100,000 ohms, with the exact values determined by tests; start with a 47,000-ohm unit, remembering that there will be some signal loss. In transistor circuits, *R1* and *R2* will be between 1000 and 4700 ohms (a good compromise is 2200 ohms); again remember that some signal loss will be introduced by these two resistors. —30—

BUILD THE AUTOMOBILE

OMNI-ALARM

IF AN ENGINE TELLTALE LIGHT COMES ON, THIS ALARM WILL NOT LET YOU IGNORE IT

BY JOHN S. SIMONTON, JR.

THE MAJOR PROBLEM with automobile warning lights (commonly called "idiot lights") is that you seldom look at them because they are almost always dark, or they are so dim that you can't see them in daylight. If one should turn *on* some sunshiny day while you are concentrating on the road ahead, it may not be long before the car comes to a stop with smoke pouring from its innards.

It was to rectify this problem that the "Omni-Alarm" was created. As a bonus, the alarm not only urgently calls a driver's attention to a trouble warning signal with its insistent acoustical beeping, but also alerts the driver to the fact that he may have shut off the ignition but failed to turn off his parking (or head) lights.

Although the "Omni-Alarm" was designed for a 12-volt negative-ground system, satisfactory results can be obtained with a 6-volt negative-ground system *without* circuit modification. If you want to use the alarm in a positive-ground vehicle, it can be very easily modified —no extra parts are needed.

Construction. The circuitry for the "Omni-Alarm" (Fig. 1) can be assembled using any available construction technique. However, because mobile equipment is subject to vibration and jolting, a printed circuit board is recommended. An actual-size PC board appears in Fig. 2, which also shows how the various components are installed on the board for a negative-ground vehicle.

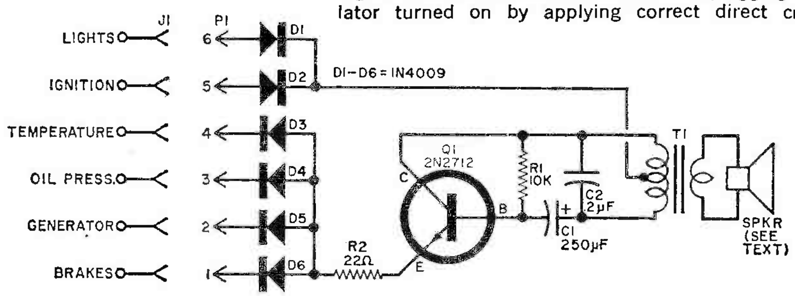
When installing the components, pay particular attention to the polarity of *C1*, *Q1*, and the six diodes. Also, because the "Omni-Alarm" is susceptible to variations in load, it is recommended that a speaker no larger than 2½" to 3" be employed.

For a positive-ground vehicle, diodes *D1* through *D6* must be reversed, and *Q1* should be a 2N107.

The author mounted his alarm in a 2¾" x 3⅛" x 1⅝" metal box with the speaker pop-riveted on one wall. A commercial multi-contact jack makes the various electrical contacts (see photo at top of this page).

To test the circuit, apply the positive terminal of a 12-volt battery to pin 5 or 6 (see Fig. 1) and the negative terminal to each of pins 1 through 4. Do not perform this test with the speaker opening

Fig. 1. Basic Omni-Alarm circuit is a "squegging" oscillator turned on by applying correct direct current.



PARTS LIST

C1—250-µF, 6-volt electrolytic capacitor
C2—0.2-µF capacitor
D1, D2, D3, D4, D5, D6—1N4009 diode
J1—Optional multi-contact plug to suit P1 (Cinch-Jones P308-AB or similar)
P1—Optional multi-contact socket (Cinch-Jones S308-CCT or similar)
Q1—2N2712 transistor—see text
R1—10,000-ohm, ½-watt resistor
R2—22-ohm, ½-watt resistor
SPKR—2½", 8-ohm speaker—see text
T1—Transistor output transformer: primary, 500 ohms CT; secondary, 8 ohms (Midland 25-634 or similar)

Note: An etched and drilled PC board is available from PAIA Electronics, Inc., P.O. Box 14359, Oklahoma City, Okla. 73114, for $3.00. The same company also has available a kit of all parts for the Omni-Alarm for $9.95.

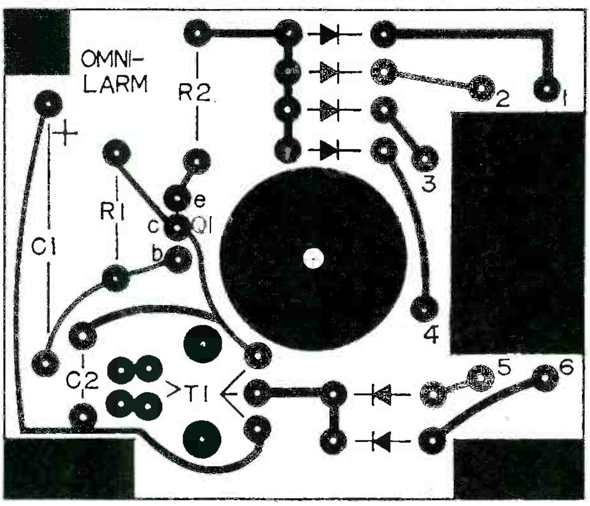


Fig. 2. Actual-size printed circuit board layout. This view also shows how the components are arranged on the non-foil surface. Note in the photo of the completed project on the preceding page that there must be a rectangular hole cut in the side of the metal cabinet to reduce speaker loading.

HOW IT WORKS

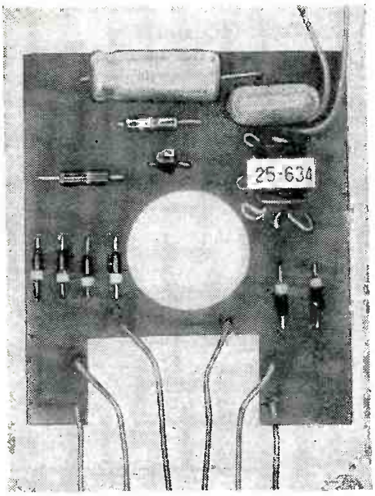
The "Omni-Alarm" circuit is a modified Hartley oscillator designed to turn itself on and off every half second or so. This switching action is a result of using a large value capacitor for *C1*. When the oscillator is activated, positive feedback via *T1* produces oscillation.

During the positive half cycle of each period, the base-to-emitter junction of *Q1* is forward-biased, with the result that capacitor *C1* causes the base of *Q1* to go negative with respect to the transformer side of the capacitor. During a portion of the negative half cycle, the base-emitter junction of *Q1* becomes reverse-biased, and the only discharge path for *C1* is through *R1* and the primary of *T1*. Because of the large time constant involved, there is still some residual charge left at the beginning of the next positive half cycle. (If *C1* had a small value, all of the charge accumulated during the positive half cycle would leak off.)

After each complete cycle, the total accumulated charge is slightly greater than that of the preceding cycle. Eventually, the point is reached at which the potential difference caused by the charge on *C1* is great enough to drive *Q1* completely to cutoff and cause oscillation to stop. With the transistor base-emitter junction reverse-biased, *C1* discharges through *R1* and *T1*. After a short time, *C1* discharges to a point where *Q1* can once again begin to oscillate.

flush against a flat surface; stand the box on one of its sides.

If the unit does not work, check the diodes for opens and polarity, and also check the transistor. If the alarm creates a tone, but does not turn itself on and off at about half-second intervals, check the values of capacitor *C1* and resistor *R1*; you may have to adjust the value of *R1*.



Top view of the finished PC board shows the neat appearance possible. The speaker magnet protrudes through the round hole in the center of the board, while the cutout at the bottom fits around the connector socket.

Installation. The wiring of the warning lights in most American cars is illustrated in Fig. 3. When the ignition switch is closed, it connects one side of the warning lights to the positive side of the battery. The other side of each warning light goes to the "senders" at the points being monitored. The "senders" are simple on-off switches that complete the circuit to the car ground in the event of a fault.

Operation of the "Omni-Alarm" depends upon the interaction of the ignition switch, headlight switch, and the various senders. When the car is not in use, both the ignition switch and the headlight switch should be off. Because the "Omni-Alarm" is not connected directly to the battery, it cannot turn on.

When the ignition is first turned on, the circuit to the positive side of the battery (via pin 5) is completed; and because the engine is not yet running, the various senders are closed. In this

(*Continued on page* 72)

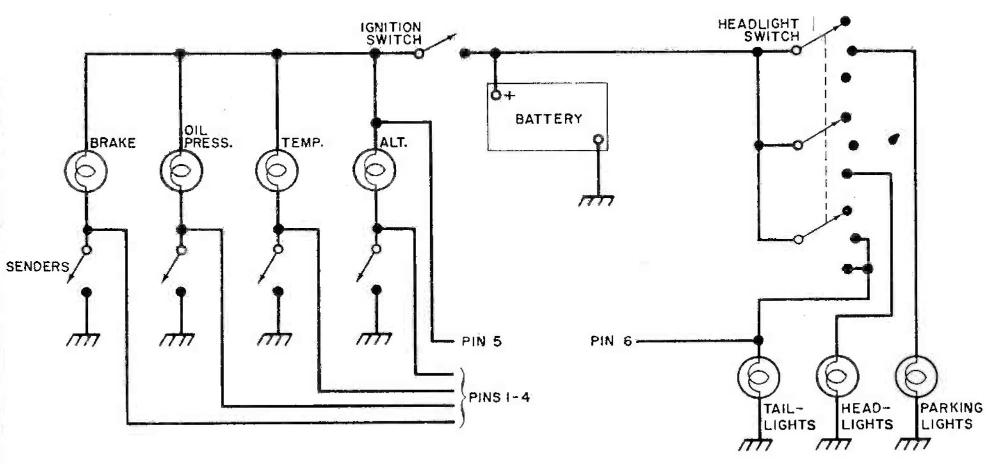


Fig. 3. Typical warning light wiring used in most American cars. The senders (except for brakes) are mounted somewhere on the engine. Make sure that pin 6 goes to the taillight connection.

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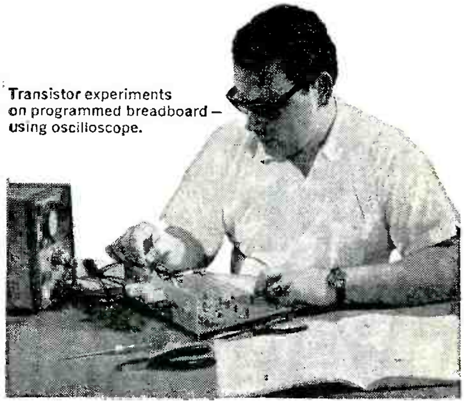

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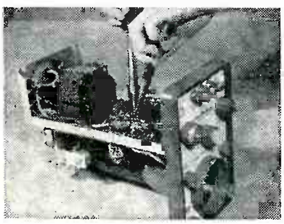

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OMNI-ALARM

(*Continued from page* 68)

condition, a ground is completed from pins 1 through 4 through the senders. The alarm sounds and assures the driver that it is in working order.

Once the engine has started, all of the sender switches should open. This action removes the ground from the alarm and the audio signal stops. If one sender should close while the car is being operated, the ground will be completed, and the alarm will sound. The operator can then check his indicator lamps for the fault. When the ignition is turned off, the alarm will not sound, since the ignition switch opens before any of the warning senders close (with the possible exception of the alternator sender).

With the headlights on, and the ignition off, the alarm is activated because it is connected to the battery positive via the taillight connection. *Do not* use the brake light connection. The taillight is used because it is on whether you select headlight operation or parking light operation of the headlight switch.

A length of multiconductor #22 gauge color-coded wire cable connects the alarm to the various sections of the car wiring. Each of the telltale lights on the dashboard can be examined to determine which lead goes to its associated sender. Remove a small section of insulation from this lead, and splice one lead of the multiconductor cable to the bared portion (soldering is preferred). The joint must be protected with a coating of electrical tape. The lead to the taillight can be run separately.

Make sure that all of this extra wiring does not interfere with the car's regular wiring—tape the multiconductor cable to other existing cables so that it doesn't droop. The order of identification of pins 1 through 4 is not important, as all the diodes are in parallel at their anode ends. Pin 5 must be connected to a point that receives 12 volts positive when the ignition switch is closed.

The completed "Omni-Alarm" can be mounted at any convenient point within the car, but make sure that it is close enough to the driver so that he can hear the alarm. -30-

SONOLITE

(*Continued from page* 53)

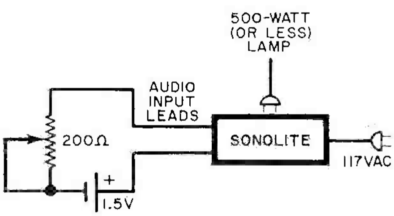
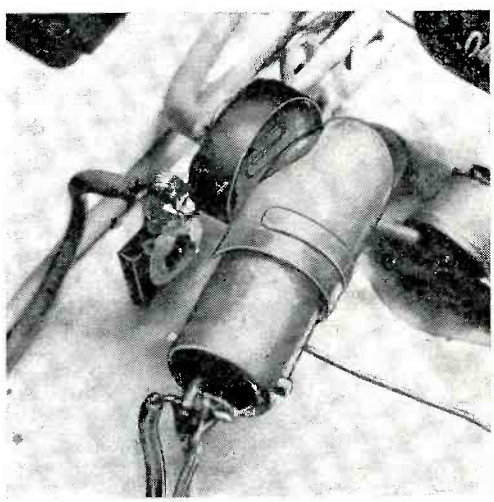


Fig. 5. Adding only two components makes the device a 500-watt power controller.

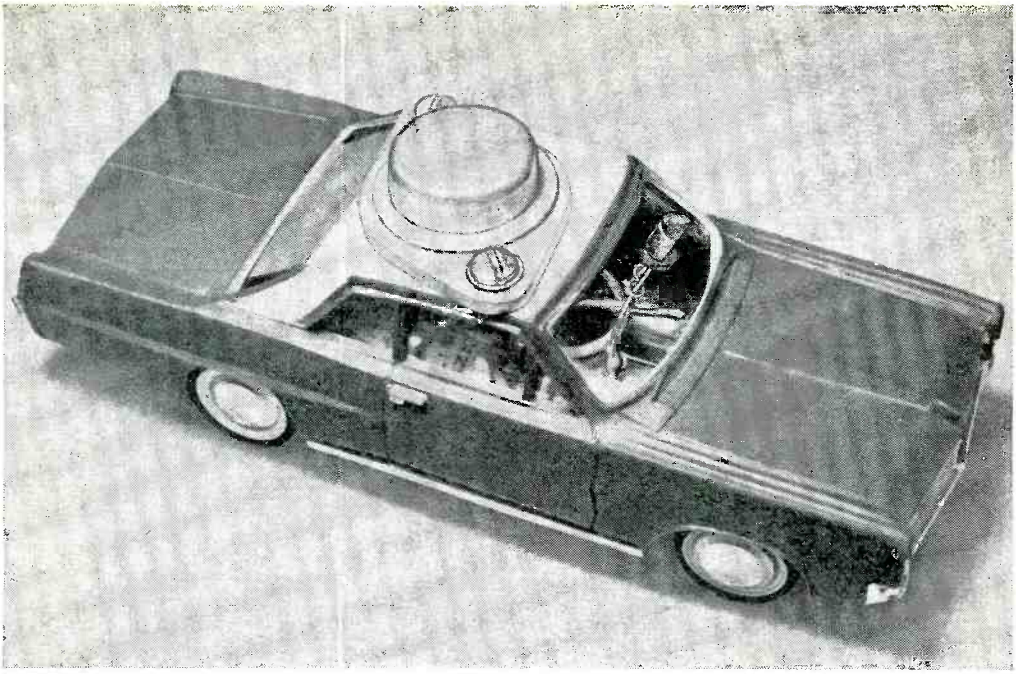
50-μF electrolytics can substitute for the 25-μF unit in the mid-range filter.

When the "Sonolite" is used in a musical group, with each instrument amplifier feeding a loudspeaker and a single "Sonolite" in parallel, each instrument can be identified with its own color.

The "Sonolite" can be turned into a general-purpose power controller (up to five amperes) by adding a 200-ohm potentiometer and a 1.5-volt dry cell as shown in Fig. 5. -30-



The author elected to use a pilot lamp reflector to couple I1 and PC1. If you don't have a reflector, place I1 and PC1 in close contact and tape the two together. Ambient light must not reach PC1 as it will affect the background control operation.



Add LIGHT CONTROL *to Battery-Powered Toys*

JUST TWO TRANSISTORS
AND A FLASHLIGHT
DO THE TRICK

BY WILLIAM S. GOHL

BY ADDING only two semiconductors to a miniature battery-powered toy car (or any other battery-driven toy), you can control its operation with a conventional flashlight at distances up to 15 feet or more. Two circuits are shown in Fig. 1, one for *pnp* power transistors (a), and one for *npn* power transistors (b). Regardless of which type of power transistor you elect to use, operation is similar.

Phototransistor *Q1* is an *npn* photo-Darlington amplifier (General Electric L14B) whose emitter-collector current is a function of the light level present on the active surface of the transparent-potted transistor. Power transistor *Q2* can be any type that will carry the motor current of the toy.

When *Q1* is supplied with enough light, it causes *Q2* to saturate and act as a closed switch for the battery-powered motor. The motor will operate as long as *Q2* is saturated, or as long as light is present on the sensitive surface of *Q1*. When the light is removed from *Q1*, *Q2* cuts off to break the circuit, just like an on-off switch.

Mounting of *Q1* and *Q2* is determined by the configuration of the toy to be controlled. A heat sink for the power transistor is not required for ordinary operation—however, it is important that the round portion of the phototransistor

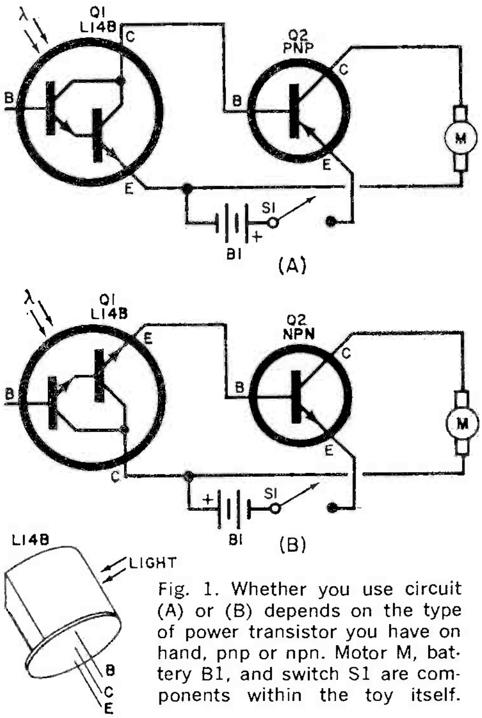
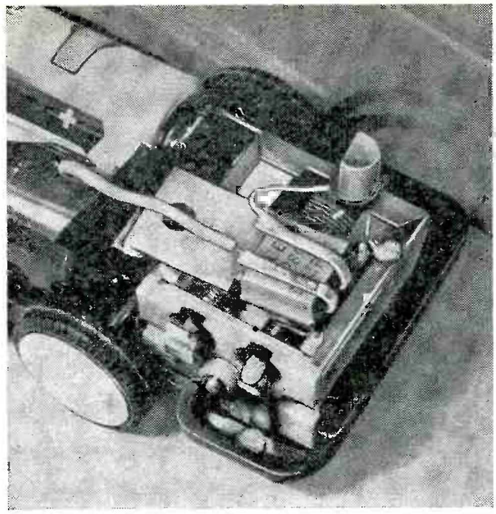


Fig. 1. Whether you use circuit (A) or (B) depends on the type of power transistor you have on hand, pnp or npn. Motor M, battery B1, and switch S1 are components within the toy itself.



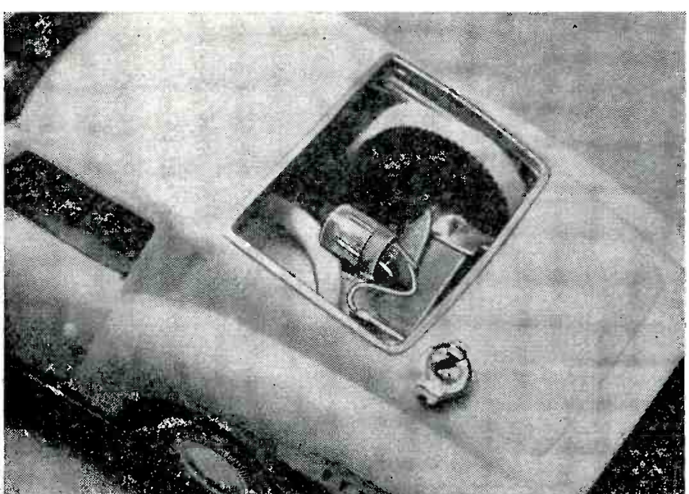
Plastic-encapsulated transistor saves space and gives neat appearance to station wagon installation.

be exposed as this is the light-sensitive side.

The motor, battery, and on-off switch (*S1*) are an integral part of the toy. The easiest installation procedure is to break the lead from the battery terminal to the on-off switch and connect the power transistor as shown in either Fig. 1(a) or (b).

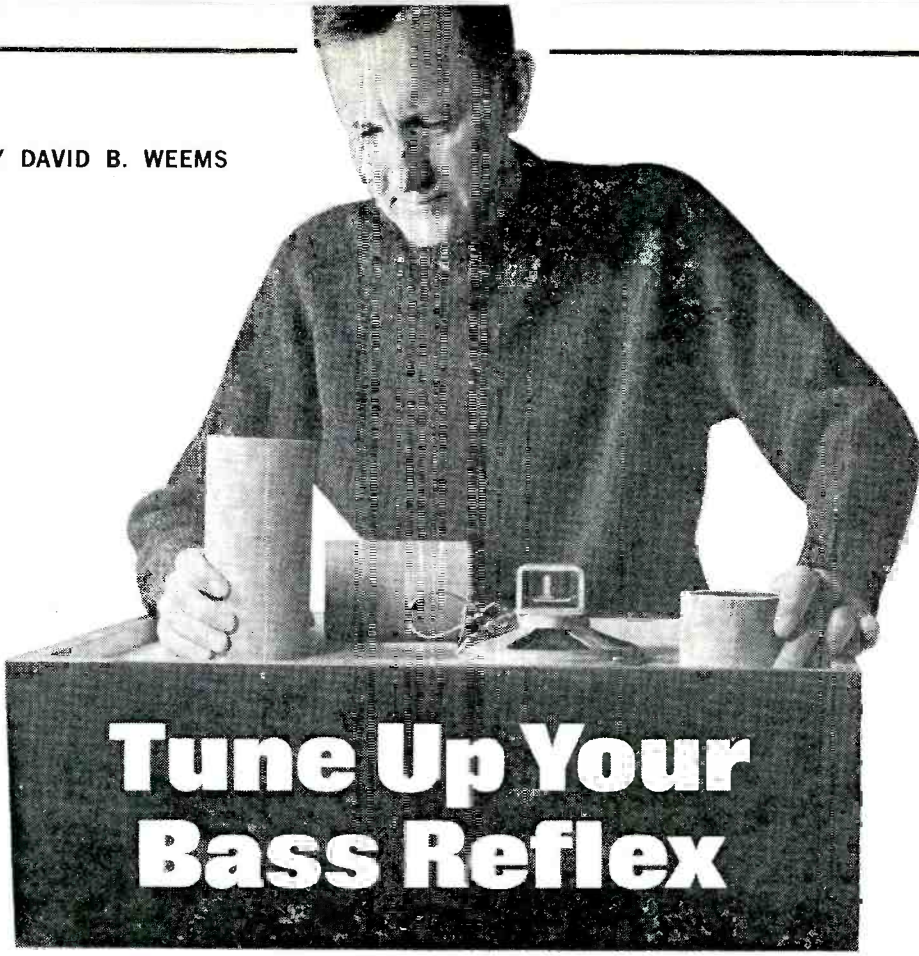
Approximately 52 footcandles are required to start the car, with 12 footcandles as a running minimum. The car should not be used in bright sunlight, as it will "run away" due to the amount of light striking the phototransistor. With artificial light, the problem is reduced.

As the average light level in a home is about 5 footcandles, the car can easily be controlled with a flashlight. A typical 2-cell flashlight has to be held about 3 to 6 feet away from the phototransistor to start the motor, but it will keep it running for about 15 feet. –30–



In the toy sports car at left, Q1 is bent to face through the rear window. In this toy, as in the station wagon shown above, the collector tab of the npn power transistor is soldered to the battery negative connector and the emitter lead is wired to a solder lug which fits between the battery case (negative) and its connector. The lug side facing the connector is insulated with tape. This puts the transistor in series with the battery, switch, and motor. The photo-transistor collector is soldered to the motor frame (positive), the emitter connects to Q2's base, while the base lead of Q1 and the collector lead of Q2 are removed to avoid accidental contact.

BY DAVID B. WEEMS



Tune Up Your Bass Reflex

Smooth out that bass response by matching the enclosure to the speaker

WHAT IS THE weakest link in any stereo system? Chances are in favor of it being the speakers. Fortunately, you can optimize this important hi-fi component by making some simple speaker enclosure refinements. One of the most rewarding investments is the small amount of time needed to "fine tune" a bass reflex enclosure to match its particular speaker.

About the "Boom Box." The primary purpose of any enclosure is to prevent the out-of-phase back wave of the speaker from cancelling the sound wave at the front of the speaker. A tuned bass reflex does this and more. It inverts the phase of the low frequencies over a broad audio band and the radiation from the port reinforces the sound from the front of the speaker cone. A properly tuned condition exists when the resonant frequency of the box occurs at the same point as the resonant frequency of the speaker. This point will dampen speaker motion and knock down the resonant peak. The result is a speaker system of high efficiency and extended low-frequency range. Mis-tuned enclosures generally sound awful—hence the name "boom box." If you know what test results to look for, or even how to listen carefully, you can expect to realize a better-sounding system.

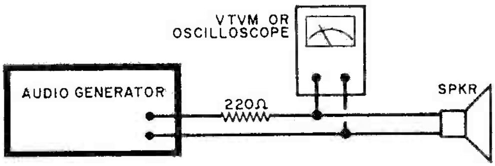


Fig. 1. Resonant frequency of speaker in free air is indicated by peak VTVM or oscilloscope reading.

The first step in matching an enclosure to a specific speaker is to find the free air resonance of the speaker. A "no equipment" method will be explained later, but typically, an audio generator and an a.c. voltmeter (any VTVM) wired as shown in Fig. 1 are used. The output of a glide-tone frequency test record fed through a hi-fi amplifier may be substituted for the audio generator. A run from 200 Hz down to 20 Hz will locate speaker resonance by a peak in the voltage across the voice coil. (See Fig. 2.) Let's call this frequency "f_r" to identify it.

After finding f_r, you have a choice of several procedures. The traditional approach is to adjust the area size of the port or the length of the duct—if one is used—to produce equal peaks in the impedance curve of the mounted speaker (see Fig. 2). The theory of the equal double hump is all right, but trying to obtain it may give you problems the textbooks don't mention. Usually when the trough of the impedance curve is centered on f_r, the amplitude of the humps will not be equal. Some reference books suggest that the peaks should be equally distant from f_r. Test curves sometimes show the trough at f_r, but the lower peak may be closer to f_r than the upper peak.

One test by the author resulted in reference-produced tuned box frequencies of 40, 58 and 85 Hz. The "distances" of 18 Hz (58 minus 40 Hz) and 27 Hz (85 minus 58 Hz) were clearly unequal, but the ratio of 58:40 (1.45:1) was approximately equal to the ratio of 85:58 (1.47:1). A double check of authoritative texts uncovered one expert who mentioned equal ratios rather than equal distances! Which expert do we believe? The author's enclosure produced the equal ratio condition when the trough was centered at f_r and seemingly confirmed the equal ratio theory.

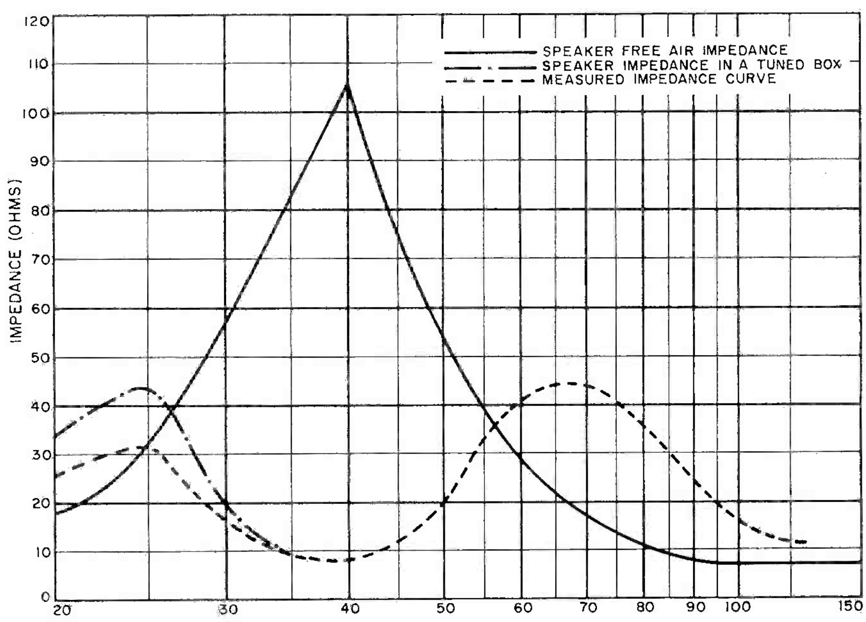


Fig. 2. Experimental results with speaker having free air resonance of 40 Hz. Enclosure was tuned to provide peaks at 66 and 24 Hz. Ratio 66:40 and 40:24 is important.

The Easy Way. There once was an easy way to tune a bass reflex enclosure. You followed the dimensions shown in a published chart that was based on speaker size. Perhaps speakers were more uniform in those days, but hi-fi enthusiasts would have probably done better if they had tuned by ear. Which brings us to the highlight of this story. You can actually tune a bass reflex by ear with the proper technique. The method is especially useful for enclosures in the construction stage. All you need is a test record.

First, locate the free air resonance (f_r) of your speaker. If you don't have a VTVM, you can probably hear the rise in audible output at resonance. Or sprinkle a little talcum powder on the cone and watch for maximum vibration. If you are using an audio generator, you can read the frequency directly. If you use a frequency test record, locate the point of resonance by a stopwatch or the sweep second hand on a wristwatch, counting the seconds from a frequency mark on the record.

When you construct your bass reflex enclosure, cut a hole that will hold the tuning duct (if it is a compact box) and cut various lengths of tubes to try. However, before making your speaker cutout, drill a 3/16-inch hole in the center of the proposed speaker location. Mount the front panel and install the back in your enclosure, giving particular attention to see that both are sealed against air leakage. Mount a small 5 or 6-inch speaker (any functional small speaker) over the 3/16-inch hole (see Fig. 3). The gasket of the speaker should make firm contact with the panel, and the screws should be tightened uniformly to seal the gasket without deforming the speaker.

Now, using the same glide-tone source, feed the output from your amplifier, tape recorder, or audio generator to the small speaker. By listening carefully at the port, you will hear an increased output at the resonant frequency of the enclosure. Insert tubes of varying lengths and note the resonant frequency with each tube. Each tube should be inserted in the hole at least far enough to be flush with the inside of the front panel. If the desired resonance (f_r) happens to be located between those obtained

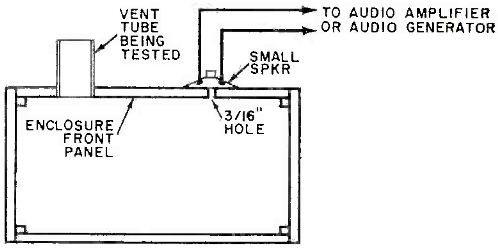


Fig. 3. To tune enclosure, fasten a speaker over small hole and vary length of cardboard vent tube.

with two tubes, you can cut off the longer tube a little at a time until f_r is reached.

Note that you do not have to have an accurately calibrated audio generator for this method. In fact, you don't even have to know the value of f_r.

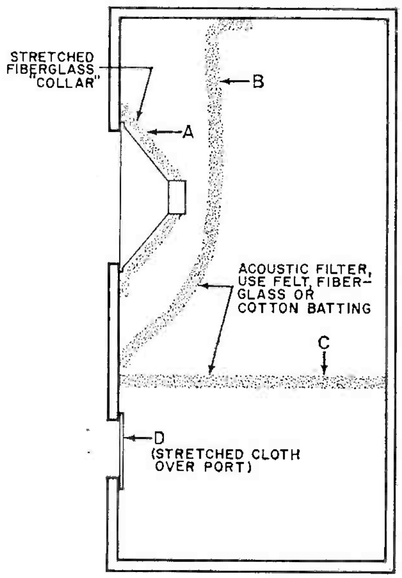


Fig. 4. Acoustic filter material may be added to the enclosure to provide sufficient damping. Top, bottom, and at least one side should be padded.

Does It Work? Skeptics may see some discrepancies, such as the possibility that the duct and the small speaker located outside the enclosure will give different results to those obtained later when the duct and a large speaker are mounted inside the enclosure.

To investigate these questions, an enclosure with a cubic volume of 2.5 cu. ft. was tuned to a 12-inch speaker with a free-air resonance of 38 Hz. After con-

BASS REFLEX TROUBLE SHOOTING CHART

SYMPTOM	POSSIBLE CAUSE	PROBABLE CURE
Numerous impedance peaks	Panel vibration	Brace enclosure walls with 1" x 2" wood strips. Glue and screw strips to walls. Or, glue sheets of Celotex to panels
Tuning peaks move unpredictably with each change in port area size or duct length	Air leak	Use more screws to hold back and front panels perfectly rigid. If necessary, add gasket. Check other enclosure joints and caulk if in doubt
Peaks in impedance curve are not equal when trough of curve is at speaker free air resonance	Test equipment defect	Use ratio method of fine tuning enclosure
Values in Design Chart produce enclosure resonance significantly above speaker free air resonance	Mistaken measurement. Double check enclosure measurements. Wrong enclosure shape	Double check for panel (front or rear) vibration or air leaks. Decrease port area or try longer tube on ducted enclosure
Enclosure resonance is well below speaker free air resonance	Double check chart, or re-check measurement	Increase port area or shorten length of tube on ducted enclosures. If port area must be increased above maximum (see Speaker Data table) the enclosure can be partially filled with solid material (bricks, sand bags, etc.)

SIMPLIFIED DESIGN CHART FOR BASS REFLEX ENCLOSURES

VOLUME	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
6 cu. ft.	9	12	25	12	18	32	20	28	36	28	40		56	75							
5 cu. ft.	7	9	20	10	14	28	15	20	24	20	30	40	36	50							
4 cu. ft.	¾		2	7	10	20	11	15	20	14	20	24	26	36		45	80				
3½ cu. ft.	1		3	¾		1½	8	11	16	12	16	20	20	28		32	45				
3 cu. ft.	2		4	¾		2	5	8	12	9	12	18	15	22		26	36		40	80	
2½ cu. ft.	2		5	2		4	¾		2	5	8	12	12	16		20	28		30	40	
2 cu. ft.	4		8	2		5	1		3	¾		2	7	10		12	18		18	25	
1½ cu. ft.	7		10	4		8	3		5	2		4	¾		2	8	11		14	20	
1 cu. ft.							6		8	4		7	2		4	1		2	5	10	
		35			40			45			50			60			70			80	

FREE AIR RESONANCE OF SPEAKER (f_r)

A — *Approximate port area in square inches for rectangular port (length to width ratio—4:1)*

B — *Approximate port area in square inches for square or circular port*

C — *Maximum port area in square inches for increased bass output. This tunes enclosure above speaker resonant frequency, but is permissible if resonance is below 50 Hz*

To use design chart, find fr as described in text, and determine enclosure volume (use inside dimensions). Locate intersection of volume row and fr column, and read length of 3"-inner-diameter tubing to try (or port area in sq. in. if intersection is in unshaded portion of chart). Tune enclosure as described in text.

sulting a design chart, three 3-inch diameter tubes were cut to lengths of 2½, 5 and 7½ inches. The cabinet was prepared in the prescribed manner and tests run. The resonant frequencies of the empty enclosure were:

2½″ tube	37-38 Hz
5″ tube	33 Hz
7½″ tube	27 Hz

These results were about as expected, the two longer tubes had been selected for use in the event of an upward shift of resonance. Next, the front panel was cut out for the 12-inch speaker and the speaker was installed. The 2½-inch duct was installed inside the enclosure. An impedance curve showed:

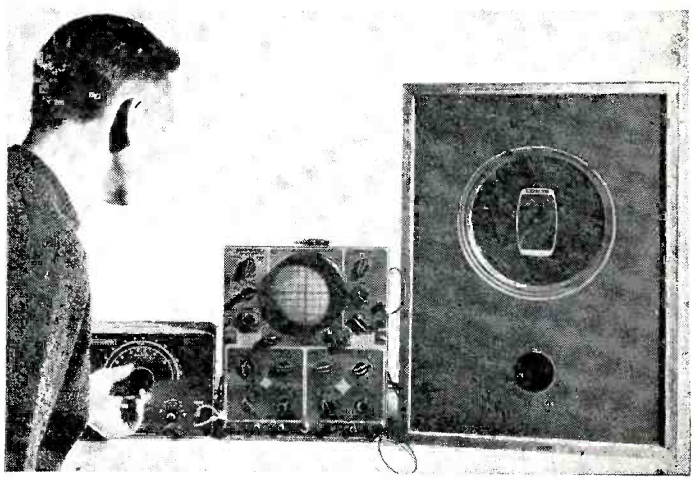
Upper peak	78 Hz
Center of trough	39 Hz
Lower peak	20 Hz

Both the position of the trough and the ratios of the upper peak:trough, and trough:lower peak, indicated that the tuning was successful. The shift of resonance from the empty box condition was insignificant.

Some speaker systems may show detuning effects more than the one tested. Remember that any change in tuning due to speaker volume will result in an enclosure tuned to a frequency slightly above f_r. This is a condition recommended by some hi-fi experts, particularly for systems that resonate below 50 Hz. It results in smooth bass with increased output at the usually needed bass frequencies. Conversely, tuning the box to a frequency below f_r can extend the frequency range downward but at the expense of increased bass distortion and lower output above f_r.

Other Problems. There are some factors that have more effect upon sound quality than minor errors in tuning. The amplitude of the upper impedance peak often presents a danger zone, even in a well tuned enclosure. Increased output there may produce boom unless sufficient damping material (felt, fiberglass or cotton batting) is added to the interior. The most efficient use of such material is to suspend it in the air behind the speaker (see B, C, Fig. 4), or stretch it tightly over the speaker (A, Fig. 4). If necessary, damping may also be applied at the port by stretching a layer of cloth across the opening (D, Fig. 4). A final check of damping may be made by connecting a 1.5 V flashlight battery to the speaker terminals via a s.p.s.t. switch. When the "bong" of the undamped enclosure changes to a "click" at the "make" or "break" of the circuit, the system is damped. Padding also reduces the reflection of mid-range frequencies bouncing around inside the cabinet back to the cone.

Another danger is panel vibration, which shows up on an impedance curve as multiple peaks and robs you of true bass response. All except the smallest enclosures should be constructed of ¾-inch plywood fastened together by glue



After mounting speaker inside its enclosure, again connect a VTVM or oscilloscope and an audio generator to it to determine whether or not the enclosure is correctly tuned.

and screws. Large panels should be braced by 1″ x 2″ cleats. It is also recommended that large panels be sandwiched to some other material (such as Celotex) to provide extra sturdiness and remove any tendency to vibrate or resonate.

A more subtle problem is air leaks. A few loose screws in the back of a large enclosure will not only allow vibration of the back panel, but also fail to seal it airtight. Generous use of screws plus a gasket of felt or thin foam rubber will insure proper sealing and tuning.

Of course, if you are starting out to design your own enclosure, you have other decisions, such as size and shape. Before stereo, most enclosures were large, and the dimensions shown on design charts were based on a port area equal to the effective cone area of the speaker. Almost any volume can be tuned to any reasonable resonant frequency, but in a compact enclosure the port area cannot possibly equal the cone area of a 12-inch speaker. A reduced port area means reduced port output, so while we can tune a compact enclosure to match a large woofer, it will produce less bass than a larger enclosure with a larger port. In fact, the optimum volume for the 1969 speaker is likely to be a moderate size enclosure. If in tuning you find that the port area must be greater than the effective cone area of your speaker, your cabinet is too large.

The shape of your enclosure and the location and shape of the port can also affect performance. Avoid "extreme" enclosures, such as a cube where all three dimensions favor a single frequency. Also avoid a long shape where the long dimension is equal to 1/4 any reproducible frequency or as much as three times as long as the shortest side. Very shallow enclosures should be used only where demanded by lack of space. Typical depth:width:height dimension ratios are 1:1.42:2 or 1:1.5:2.5.

SPEAKER DATA

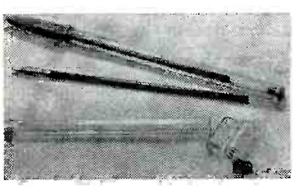
ADVERTISED SPEAKER SIZE	APPROXIMATE EFFECTIVE DIAMETER	APPROXIMATE CONE AREA
15″	13″	130 sq. in.
12″	10″	80 sq. in.
10″	8″	50 sq. in.
8″	6″	30 sq. in.
6″	5″	20 sq. in.

Port area is never greater than speaker cone area.

Don't be afraid to experiment. The easy tuning method is a perfect way to begin. Finally, believe your ears if they prefer a different size port or duct. And you don't have to feel guilty about it because hi-fi history tells us that in conflicts between ears and instruments, later improvements in our measuring methods have usually vindicated the ear. —30—

BALL-POINT PEN BARREL DOUBLES AS INSULATING SPACERS

When the ink cartridge of your non-refillable ball-point pen dries up, don't throw the pen away. The plastic barrel can be cut down to make insulating spacers. Remove and discard the empty ink cartridge, pen point and plastic (or metal) end. Then, when you need spacers, simply cut the pen barrel to the desired lengths with a fine-toothed hacksaw. The dielectric strength of your fabricated spacers will compare favorably with the commercially available product. —*B. J. Thompson*



SPRAY-PAINT CAN CAPS KEEP YOUR WORKBENCH NEAT

Neatness counts on your workbench when you are building a project or servicing equipment. To help keep things orderly and make locating small parts like nuts, bolts, washers, resistors and disc capacitors easy, save the caps from empty spray-paint cans and use them as containers as shown in the photo. You can use each cap as is, or bolt several of them to a piece of wood to hold different sizes and types of parts.—*James E. Arconati*

CHAPTER 2

THEORY INTO PRACTICE

As mentioned elsewhere in this edition of the ELECTRONIC EXPERIMENTER'S HANDBOOK, some of our readers are anxious to convert their hobby into a career. These people utilize experimenting and project building as a means to learn more about the practical aspects of electronics. Unfortunately, some of them frequently find it difficult to translate theory into practice, and vice versa.

This chapter is a new departure for the HANDBOOK. It includes three lengthy articles, each of which devotes as much time to theory as to practical application. Two of the three are suitable as Science Fair projects and the third contains over a dozen ideas that are easily breadboarded for classroom or home study examination.

We hope that the addition of this material enhances the value of the HANDBOOK and serves to stimulate and make easier the transition between theory and practice.

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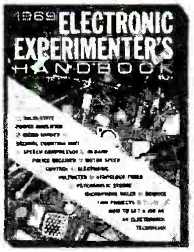

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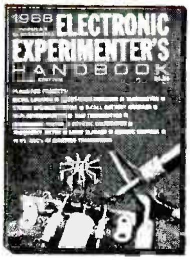

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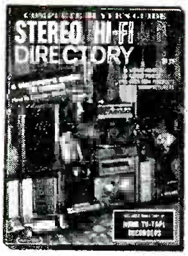

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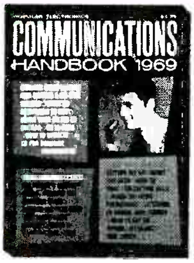

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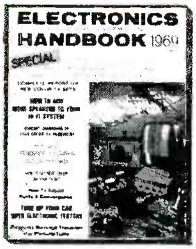

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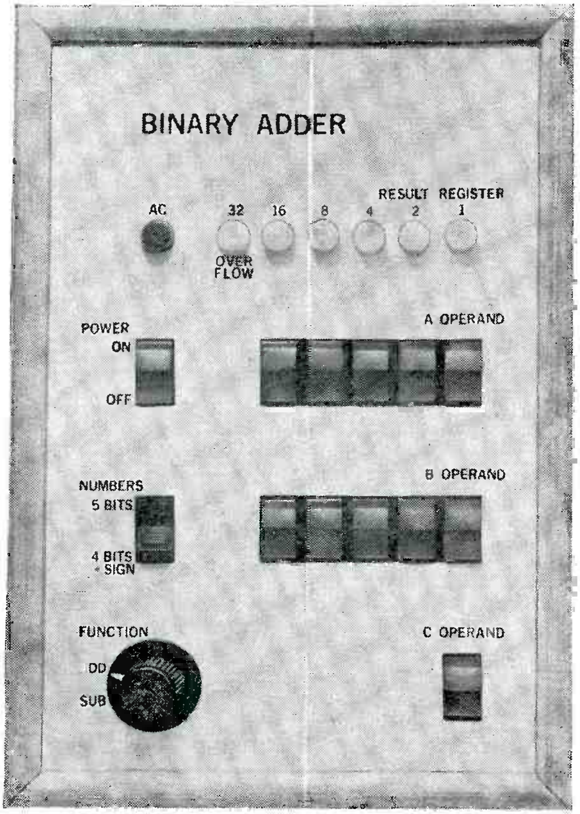


DEMONSTRATING BINARY COMPUTATION WITH THE *Binary Adder*

BY BARRY W. BEALS

SCIENCE FAIR OR CLASSROOM PROJECT ILLUSTRATES FUNDAMENTALS OF DIGITAL COMPUTER OPERATION

THE MODERN digital computer is an awe-inspiring sight and probably represents the most complex piece of equipment that most people have ever seen. However, there are two fascinating facts about a computer that the average individual is completely unaware of: first, all a computer can actually do is add, subtract, and remember (via a magnetic memory); second, the entire number vocabulary of the computer is limited to only two digits.

The choice of two digits becomes obvious when you consider that the entire vocabulary can be generated with a simple s.p.s.t. switch. One position (state) of the switch represents one digit, while the other position (state) represents the second digit. With the introduction of high-speed solid-state switches, operation at many millions of times per second is now possible.

The name of this two-digit arithmetic is "binary notation," with the *bi* representing the base 2. On the other hand, no pun intended, finger counting is called decimal notation (*dec*—to the base 10) because we count on 10 fingers, then repeat. Other values of notation are used in large-scale digital computers.

The "Binary Adder" discussed in this article is a very simple, low-cost digital computer that will not only teach you binary arithmetic and give you a good idea of how a modern digital computer works, but will also give you a good insight to the "new math" being taught in our schools.

HOW BINARY SYSTEM WORKS

The peculiarity of the binary number system lies in the fact that a serial arrangement of only two digits, "0" and "1," can be made to represent any number (units, tens, hundreds, thousands, etc.). Before delving into the following analysis of the binary number system, keep in mind that the use of these two digits is especially appropriate to computer technology and electronic calculation. Either "0" or "1" can be represented electrically in many simple ways: a voltage being present or absent; a switch being *on* or *off*; or any other function that can take either of two discrete stable states. Because one electrical switch can only "count" to 1 (e.g., 0, 1), several switches would be required to count to 2, 3. . .10, etc. This is the reason why binary numbers are usually represented in groups of several zero's and one's, with the length of the group depending on the values of the final number you require.

Looking at an array of binary digits, the right-most column represents either a zero or a one and is called the one's (or unit's) column—thus, five-digit binary number 00000 is zero, while 00001 is one. The second digit (or column) from the right is the two's position; thus, 00010 represents two. In combination then, binary 00011 represents three (one 2 plus one 1).

In similar fashion, the value of each binary digit to the left is twice that of the bit to its right. These "place values" in the binary system are therefore 1, 2, 4, 8, 16, etc. Table 1 lists these numbers and their corresponding binary representation. Note that the 1 symbol indicates that a place value is to be counted, while a 0 indicates that it is *not* to be counted.

TABLE 1: BINARY PLACE VALUES

Digit Position	Place Value	Binary Representation
1 (right-most)	1	00001
2	2	00010
3	4	00100
4	8	01000
5	16	10000

COMMONLY USED TERMS

Binary A numbering system using only two symbols (such as 0 and 1) to express any number by combinations of the symbols. Also referred to as a system whose successive digits are interpreted as coefficients of the successive powers of the base two.

Bit An abbreviation of binary digit. Equal to one binary decision, or the designation of one or two possible and equally likely values or states of information being stored. A bit may be conveyed by one binary code element or symbol.

Carry A signal or expression produced by an arithmetic operation when the sum of two digits exceeds the base of the numbering system being used.

Logic Circuit A set of switches (mechanical or electronic) that performs logical functions: add, subtract, etc.

Operand A result, parameter, argument, or an indication of the location of the next computer instruction.

Overflow The condition that arises when the result of an arithmetic operation exceeds the capacity of the number representation (e.g., readout).

Sign Bit When used, a bit (the left-most) in a binary number which tells you whether that number is positive or negative.

Truth Table A tabular means of identifying all the conditions that can arise in a given logical function. For each combination of inputs to the logic function, the table illustrates all possible outputs.

Two's Complement A means of representing negative binary numbers, obtained by inverting all the bits of the binary number (changing 0's to 1's and vice versa) and adding 1 to the result.

Using Table 1, the binary representation of any number up to 31 can be found. For example, the decimal number eleven can be broken up as eight plus two plus one, so that the binary equivalent is 01011 (no units of sixteen, one unit of eight, none of four, one of two, and one of one); decimal number seven is 00111; twenty-six is 11010; and thirty-one is 11111. To convince yourself of the ease with which the binary equivalent of a decimal number can be found, try the following:

(a) five ________
(b) twelve ________
(c) thirty ________

It is just as easy to convert a binary number back into a decimal number. You add up the values of the place values for each binary 1. Thus, 00110 represents four plus two equals six. Likewise, 11011 represents sixteen plus eight plus two plus one equals twenty-seven. Try these conversion examples:*

(d) 01001 ________
(e) 01110 ________
(f) 10011 ________

Binary Addition. Adding two binary numbers is also simple. For example, add 01001 (nine) to 10010 (eighteen):

```
  01001  (nine)
+10010  (eighteen)
  11011  (twenty-seven)
```

As in decimal addition, start adding the columns from the right to the left. In this example 1+0 is 1, 0+1 is 1, 0+0 is 0, 1+0 is 1, and 0+1 is 1. However, if the sum of any column exceeds 1 (example, 1+1), then a "carry" into the next column to the left is required. For example, add 01101 (thirteen) to 01101 (thirteen);

```
  11 1   carries
  01101  (thirteen)
+01101  (thirteen)
  11010  (twenty-six)
```

Proceeding from right to left in the above example, 1+1 is two, which is 10 in binary numbers. Therefore, the right-most column sum is 0 with a carry of 1. The carry of 1 plus the two 0's in the next column give a 1 with no carry. The third column again produces a 0 with a carry of 1. The fourth column presents an interesting situation. Here, the carry plus the two 1's gives a column sum of three. Since three is 11 in binary, the result is 1 with a carry of 1. Finally, the left-most column sum is 1. To help you understand binary addition, try:

```
(g)   00100
     +01010

(h)   00111
     +01110
```

The preceding examples show that a number of combinations can arise during binary addition. Table 2 lists each of these combinations and their outcomes. This table, called a *"truth table,"* shows the situation for a single digit of the binary number. The first two columns in each of the 8 lines show a digit from each of the two operands and the "Carry In" column indicates whether or not a carry *into* the position from the preceding one occurred.

To illustrate the meaning of the truth table entries, let's use it to add seven and fourteen in binary:

```
  00111
+01110
```

Starting with the right-most digit, we must add 1+0+no carry-in. Line 3 of the table covers this situation; the "Result is 1 and the "Carry Out" is 0. Thus, the addition so far has yielded:

```
                   00111
                  +01110
(partial total)        1
```

Working with the second column, we have 1+1+no carry-in. Line 4 of the truth table shows the "Result" to be 0 with a "Carry Out" of 1. Consequently:

```
(carries)            1
                 00111
                +01110
(partial total)     01
```

For the third column, use line 8 of the truth table—where the "Result" is 1 with a "Carry Out" of 1. So, the sum is:

```
(carries)           11
                 00111
                +01110
(partial total)    101
```

Line 6 covers the next situation, with the results being:

```
(carries)          111
                 00111
                +01110
(partial total)   0101
```

To complete the addition, use line 5 of the truth table (0+0+"Carry-In" of 1) to give the final result:

```
(carries)          111
                 00111
                +01110
                 10101
```

Answers to all problems are on page 87.

Negative Numbers. Up to now, we have been dealing solely with positive binary numbers. What about *negative* numbers? In decimal operations, we normally precede a number by a minus sign (−) to show that it is less than zero. However, in computers it is necessary to use an extra binary digit (or *bit*) to convey the sign of the number: 0 meaning "plus" and 1 meaning "minus."

It has been shown that a plus five would be written as 00101. Rather than use the left-most bit as the sixteen position, we will now use it as the sign bit (and having made that decision, we must cease to think of it as the "sixteen" digit, to avoid confusion). Thus, a minus five might be written as 10101. In this example, the magnitude of the number (i.e., the five) is represented the same way in both its positive and negative form—0101. This means of representing negative numbers is called the *true* form.

Obviously, this form is convenient to use—we simply append a sign bit (0 or 1) to the left end of a binary number. However, true-form negative numbers are not used in today's computers, since the circuitry required to manipulate them is unnecessarily complicated (and therefore slower and more costly). Rather, a complement form of manipulation is used.

Two's Complement Form. The *two's complement* form for negative numbers makes it possible to build computers in which *no* special provision has to be made for negative numbers. This form is obtained by inverting every digit of the number (that is, changing all 1's to 0's and all 0's to 1's) and then adding 1. For example, to find the two's complement representation of minus five:

(a)	plus five in binary	00101
(b)	invert every bit	11010
(c)	add 1	11011

The representation 11011 is minus five in two's complement form. As with true form, the left-most digit is used as the sign; here the left-most 1 indicates a negative number. Thus, 10010 and 11111 are negative numbers, while 01110 and 01001 are positive numbers.

Unfortunately, the numerical values of 10010 and 11111 are not apparent by inspection. To find the values of negative numbers, take the two's complement again. For example:

(a)	unknown negative number	10010
(b)	invert every bit	01101
(c)	add 1	01110

Since 01110 is plus fourteen, the value of 10010 is minus fourteen. Similarly, the value of 11111 can be found to be minus one. You will want to test yourself on these exercises—in each case, give the *value* of the binary numbers listed, remembering that the left-most bit is the sign of the number.

(i) 00111 __________
(j) 11001 __________
(k) 10011 __________

Binary Addition With Negative Numbers. As was mentioned earlier, the selection of two's complement form for negative numbers means that no special circuitry is required to manipulate them. In other words, the addition of positive and negative numbers is performed exactly as was shown above. For example, the addition of five and minus one would be:

carries	11111
five	00101
minus one	+11111
four	00100

In this case, the carry out of the left-most bit is simply discarded.

Interestingly enough, if the addition results in a negative total, no extra work is required either. For example, the sum of minus five and one is:

carries	11
minus five	11011
one	+00001
minus four	11100

That 11100 is minus four can be verified by inverting (00011) and adding 1 (00100).

A final example would be minus five plus minus one:

carries	11111
minus five	11011
minus one	+11111
minus six	11010

Again, the left-most carry is discarded.

Binary Subtraction. We have seen how binary addition works, that "carries" are produced in much the same way as in the decimal system, and we have defined a truth table that shows how to add two binary digits under all circumstances. Likewise, we could (but will not) develop the mechanics of binary subtraction, with rules for "borrowing," etc. In keeping with this straightforward approach, the older digital computers actually had separate circuitry for performing subtraction. But that is unnecessary.

Subtraction can be thought of as the addition of one number with the *negative* of a second number. That is, five minus one is the same as five plus (minus one); or, in general, "x−y" is identical to "x+(−y)." Therefore, today's computers (and the "Binary Adder" as well) perform subtraction by taking the negative of the second operand and then adding the two together. Since we are using two's complement negative numbers, we will perform subtraction by taking the two's complement of the second number, and then adding the two operands together. The subtraction of seven from ten proceeds as follows:

```
Step (a)    01010  (ten)
           -00111  (seven)

             11    (carries)
Step (b)    01010  (ten)
           +11001  (minus seven)
            00011  (three)
```

Likewise, ten from seven is:

```
Step (a)    00111  (seven)
           -01010  (ten)

              11   (carries)
Step (b)    00111  (seven)
           +10110  (minus ten)
            11101  (minus three)
```

Try the following example as an exercise.

```
    (m)     01100  (twelve)
           -00111  (seven)
```

After you have read the above text, you might want to gain a greater familiarity with binary arithmetic by creating a number of exercises and solving them using the methods demonstrated.

ANSWERS TO BINARY PROBLEMS

(a) 00101; (b) 01100; (c) 11110; (d) nine; (e) fourteen; (f) nineteen; (g) fourteen; (h) twenty-one; (i) plus seven; (j) minus seven; (k) minus thirteen; (m) change 00111 to 11001 and add to give 00101 (five).

TABLE 2: TRUTH TABLE FOR BINARY ADDITION

Line	A Operand Bit	B Operand Bit	Carry In	Result	Carry Out
1	0	0	0	0	0
2	0	1	0	1	0
3	1	0	0	1	0
4	1	1	0	0	1
5	0	0	1	1	0
6	0	1	1	0	1
7	1	0	1	0	1
8	1	1	1	1	1

BASIC ONE-BIT ADDER

The circuit used to perform binary addition of one digit from each of two operands is shown in Fig. 1. Each of the digits is represented by a d.p.d.t. switch and the result is read out on a neon lamp. To understand the operation of this circuit, refer to the extended truth table (Table 3).

Column 4 in Table 3 answers the question "Is the A Operand Bit different from the B Operand Bit?"—with 1 meaning yes, and 0 meaning no. Column 5 answers the question "Are both operand bits a 1?"

Using this table, you will see how the circuit in Fig. 1 performs binary addition—that is, how the Result and Carry Out are formed properly for all combinations of the A Operand Bit, B Operand Bit, and Carry In.

Result Generation. As shown in Fig. 1, switches S1(b) and S2(a) connect the B+ supply to the right side of the neon lamp when the switches are in opposite positions. Otherwise, resistor *R2* holds the right side of the lamp at ground potential, for all practical purposes. Thus, the right side of the lamp obeys Column 4 of Table 3, with ground meaning 0 and B+ meaning 1.

In Table 3, notice that the Result is a 1 only when Column 4 differs from the Carry In column. By wiring the left side of the neon indicator to the Carry In terminal, the neon lamp will light whenever the left and right side voltages differ (one at ground and one at B+).

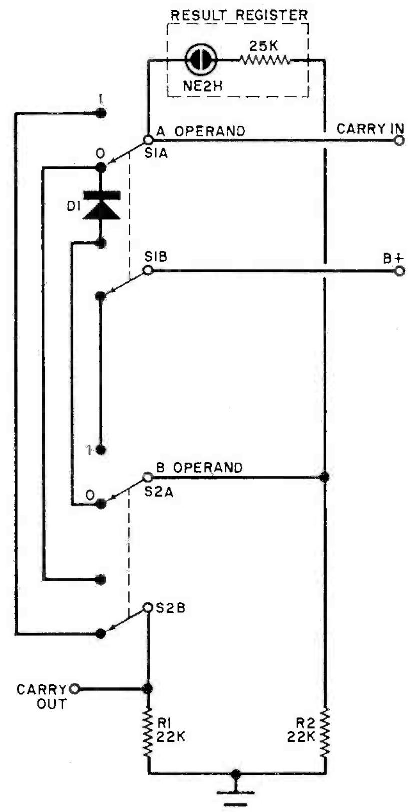


Fig. 1. This basic one-bit adder circuit shows how the Binary Adder operates.

Thus, the neon lamp displays the Result column under all circumstances.

TABLE 3: EXTENDED TRUTH TABLE

1 A Operand Bit	2 B Operand Bit	3 Carry In	4 A≠B	5 A&B=1	6 Result	7 Carry Out
0	0	0	0	0	0	0
0	1	0	1	0	1	0
1	0	0	1	0	1	0
1	1	0	0	1	0	1
0	0	1	0	0	1	0
0	1	1	1	0	0	1
1	0	1	1	0	0	1
1	1	1	0	1	1	1

Carry Out Generation. An inspection of Table 3 will reveal that the Carry Out signal is the same as the Carry In whenever Column 4 is a 1, 1 when Column 5 is a 1, and 0 otherwise.

Examination of Fig. 1 shows that: the first condition is met by switches *S1(a)* and *S2(b)*, which connect the Carry In terminal to the Carry Out terminal whenever these switches are set differently; the second condition is met by diode *D1*, which conducts the B+ supply voltage to the Carry Out terminal when the switches are both set at 1; and the third condition is met by the grounding of resistor *R1*.

Subtraction Circuitry. Binary subtraction is accomplished by adding the two's complement of the second operand to the first. The "invert" step of forming the two's complement is provided by *S3*, as shown in Fig. 2. The four poles of switch *S3* electrically invert *S2* by exchanging its connections to *S1*.

The "add 1" step required to complete the two's complement is accomplished by forcing a Carry In signal into the adder stage for the right-most digit position (which usually has no Carry In), thereby increasing the total by 1. This part of the operation is discussed more fully in the section below.

The C Operand Switch. This switch (*S5*) permits an extra 1 to be added to, or subtracted from, the A Operand and B Operand result. The wiring of this switch is shown in Fig. 3. For clarity, Fig. 3 does not show the wiring of the five individual adder stages (i.e., the wiring in Fig. 2). The Carry Out (CO) of each stage is wired to the Carry In (CI) of the next stage. The Carry In for the first stage (the right-most position, or place value one) is determined by the FUNCTION (ADD/SUB) switch (*S3*) and by the C OPERAND switch.

For the ADD function, the setting of the C OPERAND switch is identical to

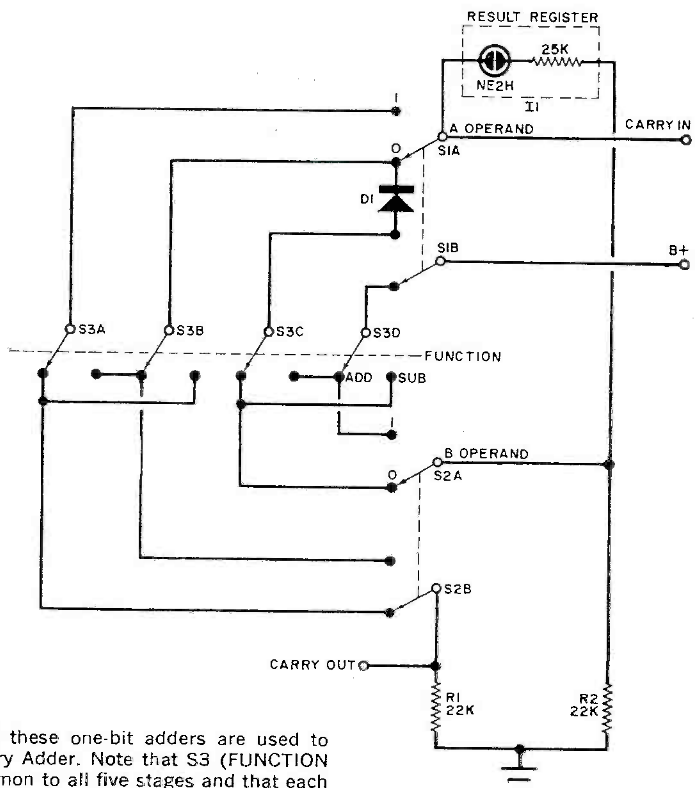


Fig. 2. Five of these one-bit adders are used to make the Binary Adder. Note that S3 (FUNCTION switch) is common to all five stages and that each stage uses four poles so that the five stages require a total of 20 poles on S3. Readout is via neon lamps.

the Carry In for the first adder stage. If the C OPERAND is set to 0, the Carry In is zero; if it is set to 1, then the Carry In is one, which will increase the sum by 1.

For the SUB(tract) function, the action of the C OPERAND switch is inverted by the wiring of *S3(f)*. That is, when the C OPERAND is in the normal (0) position, the Carry In is a 1 since *S5(b)* selects the B+ supply voltage in the 0 position.

This initial Carry In completes the two's complement operation by adding 1 to the A and inverted-B Operand total.

PARTS LIST

D1—Rectifier diode, 200 PIV, 500-mA (six required)
I1—Neon lamp assembly, NE2H and 25,000-ohm resistor (Allied Electronics 60 C 8700, six white required, 60 C 8698, one red required)
R1, R2—22,000-ohm, ½-watt resistor (12 required)
S1, S2, S4, S5, S6—D.p.d.t. rocker switch, 13 required (Burstein-Applebee 19A7207 or similar)
S3—24-p.d.t. rotary switch (IRC-CTS T239 or similar) 2 poles are not used.
T1—Isolation transformer, 117-volt a.c. to 117-volt a.c.
Misc.—Case (preferably wooden), front panel, decals, knobs, rubber feet, power line cable, etc.

On the other hand, if the C OPERAND switch is in the 1 position, then no Carry In will be present. As a result, the total will be 1 lower than the difference between the operands.

Numbers Switch. This switch (*S4*) enables you to use either signed or unsigned binary numbers as the A and B OPERANDS. With *S4* in the "4 BITS+ SIGN" position, the binary numbers represented by the A and B OPERAND switches and in the right-most five bits of the RESULT REGISTER are thought of as being signed numbers. For example, 01110 (fourteen) + 11110 (minus two) will be 01100 (twelve).

Notice that, with *S4* in this position, the right-most 5 bits of the RESULT REGISTER cannot contain the sum of all possible numbers that can be entered. For example, 01111 (fifteen) + 00011 (three) will display as 10010. But since the fifth bit is being used as the sign bit, 10010 should be read as minus fourteen, which of course is incorrect. In such a case (i.e., when the capacity of the RESULT REGISTER has been exceeded), the sixth (left-most) 32-OVERFLOW indicator of the register will light. This overflow indicator mirrors the situation that arises in large computers—when an operation produces a result that exceeds the register capabilities, an indicator is turned on so the computer programmer can test for overflow and take corrective action.

With *S4* in the "5 BITS" position, the binary numbers are thought of as having no sign bit, and the left-most bit of the operands simply represents a place value of sixteen. Thus, numbers in the range from zero (00000) through thirty-one (11111) may be entered, and they are always considered positive.

With the NUMBERS Switch in the "5 BITS" position, the left-most indicator in the RESULT REGISTER (32-OVERFLOW) has a dual meaning, depending upon the setting of the FUNCTION switch. For an ADD operation, that indicator is just another bit of the result and has a place value of thirty-two. For example, if 01111 (fifteen) and 10110 (twenty-two) are added, the result will show as 100101 (thirty-two plus four plus one equals thirty-seven).

With *S4* in the "5 BITS" position, and for a subtract operation, the left-most indicator is the sign of the result. For example, 01001 (nine) less 01011 (eleven) will display as 111110, which is minus two in two's complement form. Likewise, eleven minus nine will be 000010, or plus two.

As shown in Fig. 3, the wiring of the NUMBERS switch and the "32-OVERFLOW" indicator is simple. With *S4* in the "4 BITS+ SIGN" position, the indicator is connected across the last adder stage's Carry In (CI) and Carry Out (CO) terminals. Thus, it will light whenever the Carry In and the Carry Out of the "16" place value stage differ. Such a test is all that is needed to determine if the register capacity has been exceeded.

No special construction techniques are necessary to build the "Binary Adder." The easiest method is to drill the front

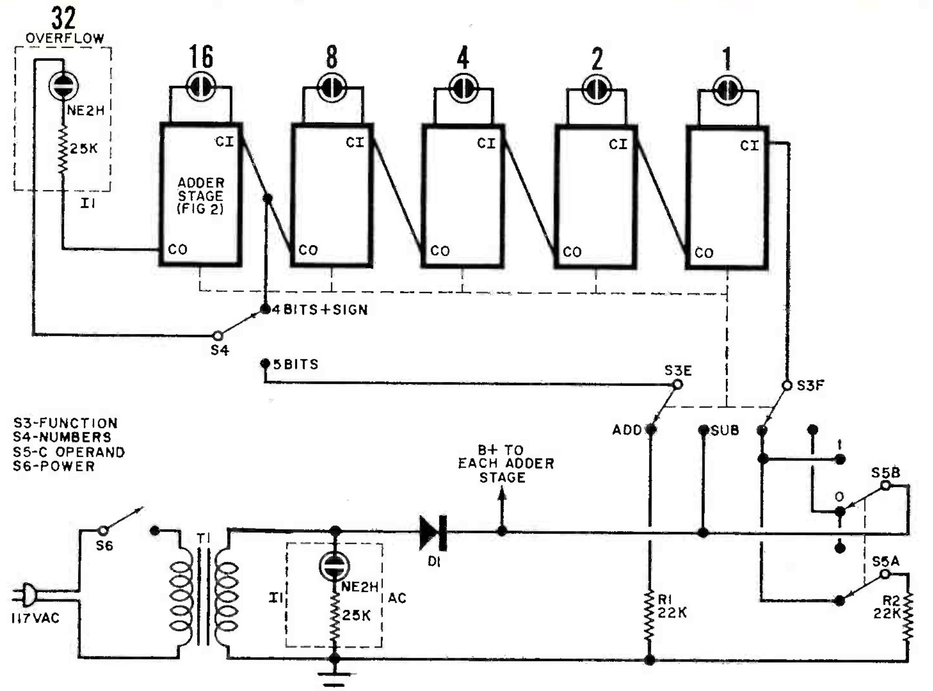


Fig. 3. To reduce illustration complexity, each of the five one-bit adders are shown in block form with only the Carry In (CI) and Carry Out (CO) of each stage identified.

CONSTRUCTION & APPLICATIONS

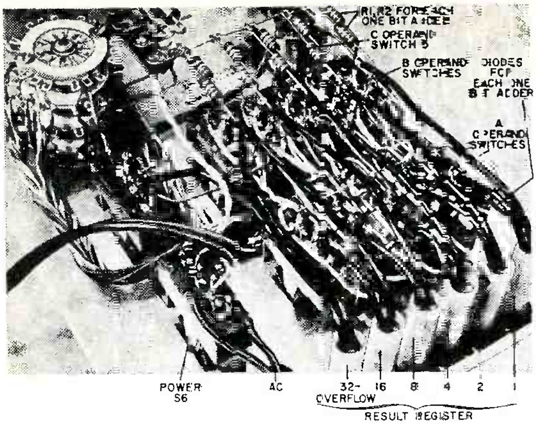
panel to accept the various switches and readout lamps before doing anything else. The author used the physical arrangement shown in the photo on page 83, although any other arrangement can be used, depending on the type of switches and lamps you use. A "nibbling" tool was used to make the cutouts for the switches, and dry transfer lettering was used for front-panel marking.

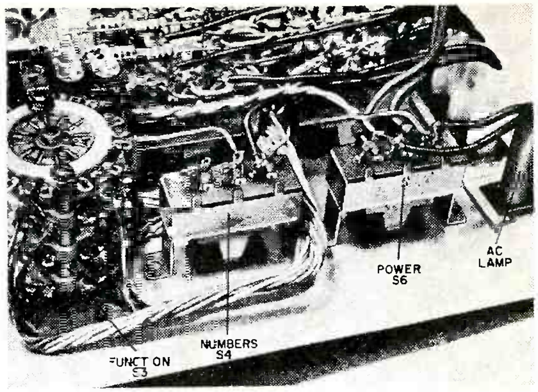
The only requirements for proper layout is that the six readout lamps (RESULT REGISTER) be installed in an equally spaced row across the upper end of the panel, with the "1" indicator at the right and the "32-OVERFLOW" lamp at the left. The five A OPERAND switches should be located sequentially under each readout bulb, starting at the right-hand side; the B OPERAND switches should be located directly under the A OPERAND switches; and the C OPERAND switch should be mounted directly under the right-hand column (see the photos on pages 83 and 92).

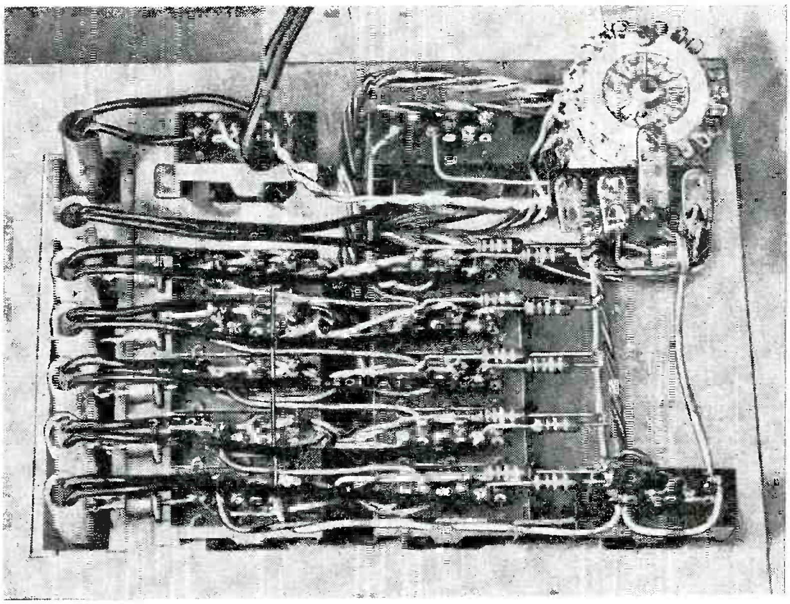
Each OPERAND rocker switch is mounted so that the switch is "off" when the side toward the user is "down." The positions of the other switches and the a.c. indicator lamp are not important. The power transformer and its associated rectifier can be mounted wherever convenient.

Once all components are properly mounted, wire the circuit point-to-point in accordance with Fig. 3. (This figure does *not* detail the repetitive internal circuitry of the five adder stages in Fig. 2 to avoid schematic complexity.) Make sure that all diodes are mounted with the correct polarity, and properly identify the terminals of the OPERAND switches. Note that a 22-pole, 2-position switch is required for the FUNCTION switch; you must very thoroughly and carefully identify the required contacts and use unduplicated color-coded wire to avoid mix-ups.

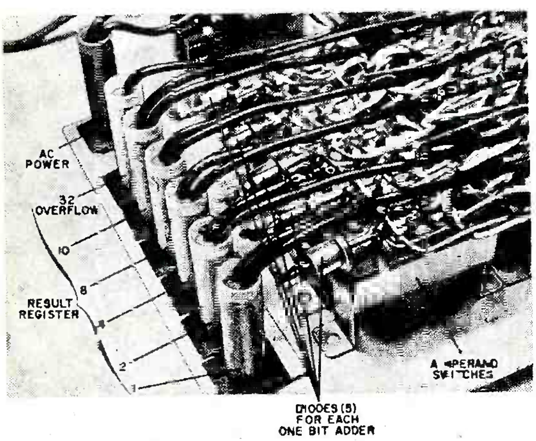
Initial Checkout. Once wiring has been completed and checked as to accuracy, the "Binary Adder" should be tested.

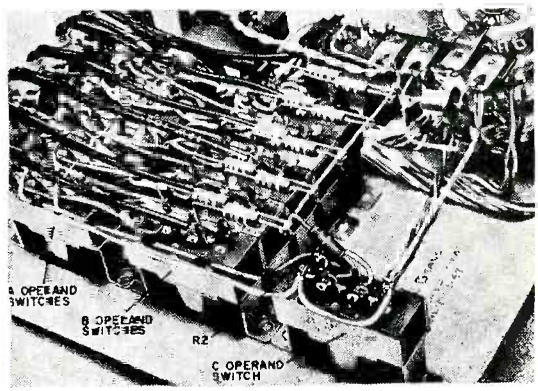






Overall interior view of the Binary Adder is shown at the left. The four photos surrounding this view identify the various components within the circuit. Note the alignment of each A and B Operand switch with its associated Result Register readout indicator.





Plug the unit into a source of 117-volt a.c. and turn the POWER switch ON—the red a.c. indicator lamp should come on. Place the NUMBERS switch (*S4*) in the 5 BITS position and the FUNCTION switch in ADD. With the A, B, and C OPERAND switches all set to zero (or down), the RESULT REGISTER indicator lamps should all be off.

Working with a single bit at a time, try the following operations:

	(a)	(b)	(c)	(d)
A OPERAND	0	0	1	1
B OPERAND	0	1	0	1
C OPERAND	0	0	0	0
RESULT REGISTER	0	1	1	0 plus carry out

"Carry Out" is indicated by the next light (to the left) coming on. For example, if the "2" digit position is being tested, Carry Out is signaled by the "4" lamp coming on. As a test of the carry circuitry, perform the following addition:

A OPERAND (21)	10101
B OPERAND (10)	01010
C OPERAND (1)	1
RESULT REGISTER (32)	100000

If the above tests are good, the subtract operation can be checked. Place the FUNCTION switch in the SUB(tract) position and perform the following operations:

	(a)	(b)	(c)
A OPERAND	11111	00000	00000
B OPERAND	11111	00000	00001
C OPERAND	0	1	0
RESULT REGISTER	000000	111111	111111

As a final check, place the NUMBERS switch in the 4 BITS + SIGN position and perform the following operations:

(a)

A OPERAND (+5)	00101
B OPERAND (sub. −6)	11010
C OPERAND	0
RESULT REGISTER (+11)	01011

(b)

A OPERAND (−16)	10000
B OPERAND (sub. +2)	00010
C OPERAND (sub. +1)	1
RESULT REGISTER	01101 + OVERFLOW

In the (b) example above, the expected result of −19 exceeds the limitations of the "Binary Adder" (which is restricted to the range of +15 and −16 inclusive) so that the OVERFLOW indicator lamp comes on, and the contents of the RESULT REGISTER are incorrect.

CONTROLS AND INDICATORS

NUMBERS Switch This s.p.d.t. switch changes the arrangement of the RESULT REGISTER indicator lamps. When it is in the "4 BITS + SIGN" position, the left-most bit is considered as the sign bit, so that the A and B OPERANDS may be positive or negative. When it is in the "5 BITS" position, no sign bit is used, so the left-most bit has the place value of sixteen; and only positive operands may be entered.

FUNCTION Switch This switch selects either an "ADD" or "SUB" (subtract) function.

A OPERAND Switches A set of five d.p.d.t. switches used to insert one five-bit binary number.

B OPERAND Switches A set of five d.p.d.t. switches used to insert a second five-bit binary number.

C OPERAND Switch A single d.p.d.t. switch with which a binary 1 may be added or subtracted from the total.

RESULT REGISTER Indicator Lamps A set of six neon indicator lamps which display the sum or difference of the "A, B, or C OPERANDS." A turned-off lamp indicates a binary 0, while a glowing lamp indicates a binary 1.

Using the "Adder." The following exercises can be done on paper first, then checked on the "Binary Adder." Place the NUMBERS switch in the 4 BITS + SIGN position. All numbers must be thought of as *signed* binary numbers.

To better appreciate the binary number system, and the "place value" concept, add a few simple positive numbers (2+2, 3+5, etc.), by first converting the decimal numbers to binary, then confirming the result on the "Binary Adder." Then add both positive and negative numbers (2+ minus 1, 7 + minus 8, etc.). Remember that the negative number must be represented by the two's complement.

For more experience in using the two's complement form, perform some subtraction: 8—(—2), 12—(—5), 4—(—6), —3—(—1), etc. Remember that negative numbers themselves must be in two's complement form, and that when you are performing the subtract operation, you must first find the two's complement of the second number, then add the two numbers together.

When working with the "Binary Adder," the complement function required to perform the subtraction is done automatically by the circuitry with the FUNCTION switch placed in the SUB(tract) position. —30—

WHAT HAS RESISTANCE, CAPACITANCE, INDUCTANCE, COUNTER-EMF, AND EVEN NEGATIVE RESISTANCE?

The Ubiquitous NEON LAMP

BY JIM KYLE

WHEN SIR WILLIAM RAMSAY and M. W. Travers in 1898 first distilled neon from 15 liters of liquid argon, they surely didn't know that they were lighting up the world with millions of garish electric signs. They probably didn't realize either that they had found the basis for the glow lamp—a device that eventually would be one of the important components in electronic curcuits.

The neon glow lamp is a relatively "old" device. In the 1940's it was principally used as a low-brightness indicator light. About the same time, its voltage-regulating qualities were recognized. Simple audio oscillators with neon lamps as the only active elements were built 15-20 years ago, but only within the past 10 years have designers begun to realize the number and scope of electronic circuits in which the neon lamp can perform a unique service that is reliable and economical.

As a computer element, the neon lamp performs a memory function and, as a bonus, gives visual indication of the stored information. The neon-lamp oscillator converted to a frequency divider is used in electronic organs to produce six-octave coverage from 12 master tone generators. In digital logic circuits, certain characteristics of the neon lamp make it an excellent on-off switch. Other new applications include improved voltage regulation, time delay and (in conjunction with photocells) control.

Basic Characteristics. The usual neon glow lamp consists of two electrodes (an anode and a cathode) in a miniature glass bulb filled with a gas which is usually *not* pure neon. Commercial neon almost always contains traces of both helium and argon; and mixtures are often used purposefully to achieve specific electrical characteristics.

Not all neon lamps have only two electrodes. Some lamps have a third electrode so that the device can be "triggered" with lower applied energy than is required by the conventional two-element lamps.

The gas within the lamp acts as an almost perfect insulator until a critical "breakdown" voltage is reached. This voltage ranges from 65 to 200 volts depending on such design factors as electrode spacing, gas pressure, gas mixture, etc. When the breakdown voltage is reached, the gas ionizes and becomes a relatively good conductor of electrical current. At this time, the voltage across the lamp drops to a level less than the breakdown voltage. Known as the "maintaining" voltage, this level ranges from 48 to 80 volts, depending on lamp design and is almost constant regardless of current flow in the lamp. These characteristics are shown in Fig. 1. If the voltage drops below the maintaining level, or if current flow through the lamps drops below the minimum, the gas deionizes and returns to its insulating condition.

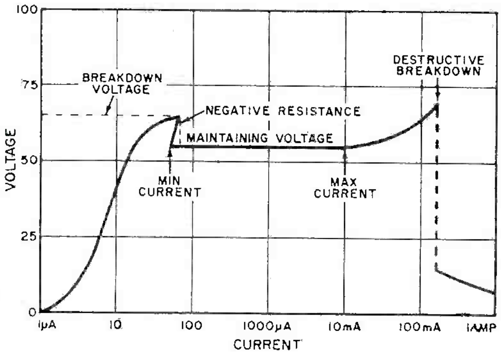


Fig. 1. Typical voltage-current characteristics of a neon glow lamp. The values apply to no specific type. Current flow before breakdown may be much less than indicated (note that the current scale is logarithmic rather than linear). Normal operating region is plateau between minimum and maximum current points indicated. Destructive breakdown changes characteristics so as to render neon useless.

At such times the resistance of the lamp is on the order of 1000 to 10,000 megohms shunted by 0.5 pF, which may be considered to be an open circuit. When the gas is ionized and the lamp is conducting, the resistance is between 1000 and 10,000 ohms. This million-to-one change in resistance is what makes the neon lamp an effective logic or switching element.

The neon lamp is a low-current device; normal operating currents range from 0.1 to 10 mA. Theoretically, a tube such as that whose characteristics are shown in Fig. 1 could be operated at currents up to 100 mA. However, destructive breakdown occurs very rapidly at high currents; and, for this reason, a resistor is always used in series with a neon lamp to limit the maximum current. The size of the resistor is not critical; the higher its resistance, the lower the current; and the lower the current, the longer the lamp life. However, with low current, light output is reduced and the time delay before breakdown (discussed in the next paragraph) is increased. The value of resistance actually used is thus usually a compromise with a range of 47,000 to 220,000 ohms being typical.

Since it takes a finite time for the gas in the lamp to break down and conduct, the neon lamp has a built-in time-delay characteristic. The delay ranges from several hundred milliseconds for slow lamps operated just at breakdown voltage to 4 microseconds for fast lamps driven at high voltage levels. The principal effect of the time delay is to set an upper frequency limit of about 200 kHz for the use of neons in oscillators, frequency dividers, and logic circuits.

The life of a neon lamp frequently exceeds that of the remainder of the equipment in which it is used. Average life rating is about 7500 hours. However, this is *on* time so that the actual life depends on the duty cycle of the circuit. Total life may run as high as 50,000 hours (6 years).

To sum up, the neon lamp has a constant terminal voltage when conducting, undergoes a million-to-one change in resistance between *off* and *on* states, remains *on* after being turned *on* by a brief pulse, and provides visible indications of its *on* state.

Neon-Lamp Oscillator. When a capacitor is charged and discharged at a fixed rate, it can be used in a circuit known as a relaxation oscillator. A neon lamp, a resistor, and a timing capacitor form one of the simplest of relaxation oscillators. See Fig. 2.

The capacitor charging rate is determined by the value of the resistor. When the voltage across the capacitor reaches

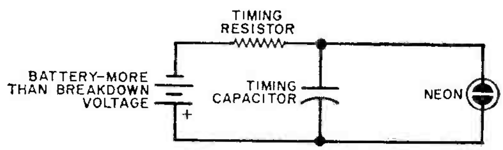


Fig. 2. Basic neon oscillator circuit includes only voltage source, resistor to establish current level, capacitor to be charged, and neon glow lamp. Resistor should have a value of about 100,000 ohms.

the lamp's breakdown rating, it is turned *on* and the capacitor discharges through this newly opened path.

When the capacitor voltage drops below the lamp's maintaining voltage, however, the neon switches *off* and the discharge stops. Thus, after the first cycle of operation, the voltage across the capacitor swings between the maintaining and breakdown voltages—normally a variation of about 10 volts.

The waveform of the oscillating voltage is essentially a sawtooth, and oscillators of this type were used as timebase generators in early oscilloscopes.

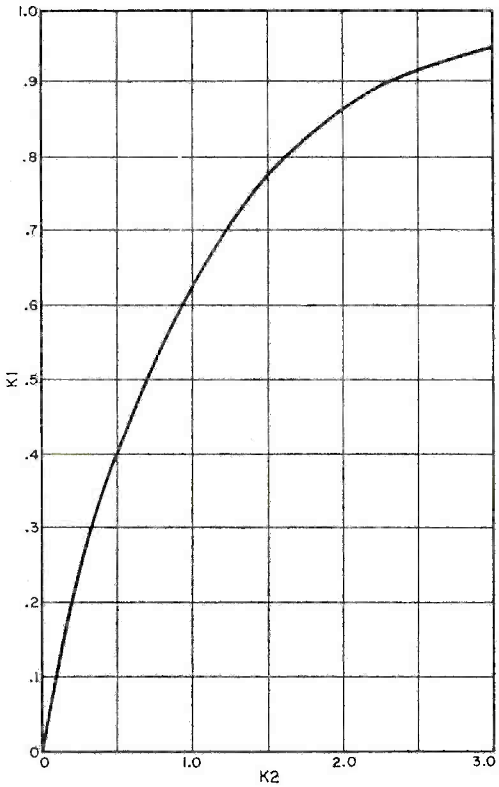


Fig. 3. Relationship of constants K1 and K2.

The frequency may range from as low as one cycle in 45 minutes to as high as 20 kHz.

The frequency of the neon-lamp oscillator is determined by the characteristics of all three components. For a high capacitance, a high resistance, or a large difference between breakdown and maintaining voltages, the frequency is low. The voltage level of the output is determined almost entirely by the difference between breakdown and maintaining voltages.

The actual design of an oscillator is not an exact process; but, since the circuit may be trimmed to the desired operating frequency by adjusting either the resistance or capacitance, the inaccuracies of the design procedure are of little importance.

The first design step is to calculate a constant, *K1*, which is defined as the difference between breakdown and maintaining voltage for the lamp to be used, divided by the difference between supply voltage and maintaining voltage. The value of *K1* should be less than 0.63 for best results. With *K1* calculated, Fig. 3 can be used to determine another constant, *K2*. The *RC* time constant of the resistor and capacitor can then be calculated from the equation

$$RC = K2/\text{frequency}$$

where frequency is in hertz. As a starting point use at least 470,000 ohms for *R1* and vary *R* and *C* as necessary to obtain the proper time constant.

To reach the desired oscillator frequency, it is always necessary to design the circuit to generate a higher frequency. Therefore, the first step in making a new design is to look up the desired frequency in Table 1 and base the design on the "Use Frequency."

Neon-Lamp Frequency Dividers. The circuit of Fig. 4 can be used as a frequency divider. With additional modifications, it can also be used to provide exact frequency division from 2 to 10, while simultaneously preventing the lower output frequency from being fed back to the input.

TABLE 1
Compensation For Ionization

DESIRED FREQUENCY (Hz)	USE FREQUENCY (Hz)
10 - 100	5% greater
200	215
300	330
400	460
500	600
750	900
1000	1250
1500	2100
2000	3000
3000	4800
5000	9000
7500	14.25 kHz
10 kHz	20 kHz
15 kHz	34 kHz
20 kHz	48 kHz

This application of the neon lamp is used widely in electronic organs. A single master tone generator for each of the 12 tones of the musical scale is constructed. Frequency dividers then scale each tone down an octave at a time to cover the desired musical range. Since at least 5 octaves are required for each of the 12

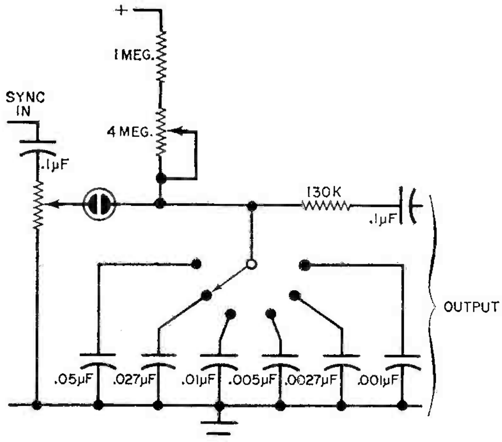


Fig. 4. Neon sawtooth oscillator with facilities to change frequency (six switched positions) and synchronize from external circuit. Supply voltage is usually 3 times breakdown level of the neon glow lamp. This circuit appears in some oscilloscopes.

tones—a minimum of 48 dividers—the simplicity and economy provided by the neon circuit are of great importance.

One stage of such a multiple divider circuit is shown in Fig. 5. This stage has an input at a frequency of 523.3 Hz and produces an output at 261.7 Hz, middle

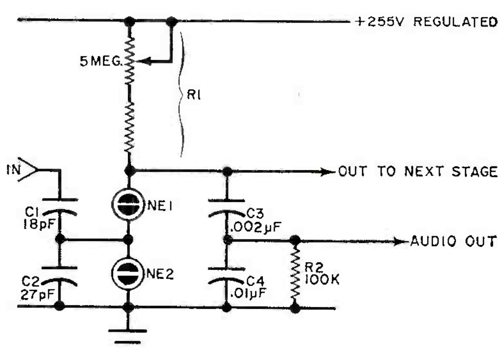


Fig. 5. This is a single stage of a frequency divider using neon glow lamps. Input capacitors aid in preventing reverse feedthrough and the output is chosen to produce a low source impedance. Resistor R1 is adjusted to bring frequency into synchronizing range so that circuit automatically produces integral submultiple of input frequency. This circuit is designed to divide by two; dividing by ten in a circuit very similar to this is often practical.

C on the scale. Here's how it works. The neon lamp of Fig. 6A is actually *NE1* and *NE2* of Fig. 5. It is the use of two lamps and two capacitors which prevents feedback of output signal to the input.

In the absence of any input signal, the circuit oscillates; the frequency of self-oscillation is adjusted by *R1* to be slightly lower than the desired output frequency. Each time the previous stage fires, a negative-going pulse is generated across *C1* and *C2*. The pulse amplitude divides across the two capacitors according to the ratio of their capacitances, so about 40% of the pulse is applied to *NE2*. Unless the neon is already about to fire (due to self-oscillation), the pulse will have no effect. If the neon is just ready to fire, the pulse will cause breakdown.

When *NE2* breaks down, the difference between its firing and maintaining voltages is applied to *NE1*, and it fires also. This causes *C3* and *C4* to discharge at a time determined precisely by the signal from the previous stage. The oscillation of this circuit is then locked at a frequency exactly half that of its input signal if the self-oscillation frequency is slightly less than half that of the input. Wave forms are shown in Fig. 6B.

The values shown for *C1, C2, C3,* and *C4* are not particularly critical, being determined in part by the specific frequencies involved. The ratios of their values, however, play an important role in circuit operation. In this application, it is essential that none of the low-frequency tone finds its way back into the preceding stage. Since *C1* is so much smaller than either *C3* or *C4*, any signal coming back from the next stage (by way of that stage's *C1*) will be attenuated by a volt-

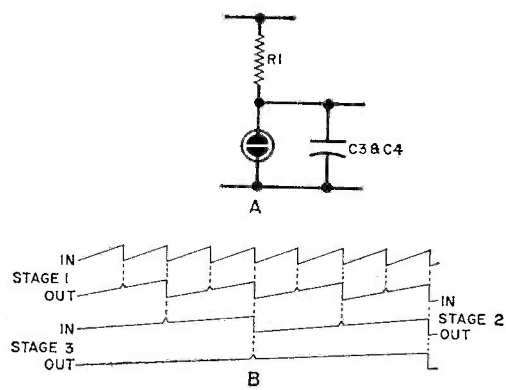


Fig. 6. Frequency divider operation is basically a relaxation oscillator as shown at A. Waveforms at B show how the divider operates. Input of one stage is output of previous stage. Output of third stage is only ⅛ the frequency of the input. Process could be repeated to produce low frequencies.

age ratio of approximately 500:1, or about 55 dB. The large value of *C4* also assures a low source impedance for each of the audio outputs, while the small values of *C1* and *C2* provide high-impedance drive for the neon circuit, to minimize loading of preceding stages.

Neon Lamps as Timers. The high leakage resistance of the neon lamp makes it particularly useful in timing circuits. While semiconductor devices are now being used in many timing applications, the neon lamp offers significant advantages. It can withstand much higher voltages and more severe environmental conditions; and when its life is exhausted, its failure is gradual rather than sudden.

While any type of neon can be used in timer circuits, best results are obtained with special lamps (such as Signalite's RT2-32-1A) which have a radioactive material inside the bulb to stabilize breakdown characteristics. Ordinary glow lamps may give erratic results in critical applications.

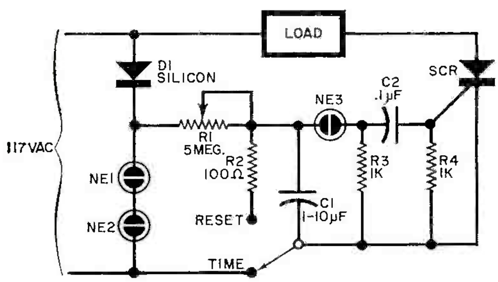


Fig. 7. In this practical timer circuit the output pulse is used to turn on the silicon controlled rectifier (SCR). Inexpensive SCR's may be used for loads up to 150 watts. Load receives pulsating d.c. and cannot be used with a synchronous motor or transformer. Text describes how this circuit works.

A practical neon timer circuit is shown in Fig. 7. The output of *NE3* is used to trigger an SCR at the expiration of the desired timing period.

With the switch on RESET, both the timer and the load are disconnected from the power line, and timing capacitor *C1* is discharged through resistor *R2*. When the switch is set to TIME, the time circuit is connected to pulsating d.c. provided by *D1* from the 117-V a.c. power line and regulated by *NE1* and *NE2*. The load circuit remains open since the SCR has not been gated *on*.

As soon as *S1* is set to TIME, *C1* begins to charge at a rate determined by adjustable timing resistor *R1*. With pulsating d.c. rather than steady current available, the charging of *C1* takes approximately three times as long as would be indicated by the *R1C1* time constant. When the voltage across *C1* reaches the breakdown point for *NE3*, the lamp fires, partially discharging *C1* through *R3* and producing a positive-going pulse across *R3*. This pulse is coupled through *C2* to the SCR gate, turning the SCR *on* and applying power to the load. Once the SCR is *on*, the timer circuit becomes superfluous although it continues to operate as a low-frequency oscillator. When power is removed from the load by switching to RESET, *C1* is discharged through *R2* and the SCR turns off. The circuit is then ready for another cycle.

Applications in Digital Circuits. Because of the difference between breakdown and maintaining voltages, neon lamps can be used in a number of digital circuits suitable for computers and computer-type devices. One of the simplest of these circuits is the neon flip-flop shown in Fig. 8.

Operation of this circuit depends upon the values of *R1*, *R2*, and *R3*, and the closeness with which the characteristics of the two lamps are matched. If *R1* is equal to *R2*, and *R3* is much larger, the circuit will operate as a flip-flop. When voltage is first applied, either neon lamp may turn on. As soon as one lamp fires, the voltage drop across *R3* lowers the voltage across the second lamp so that it

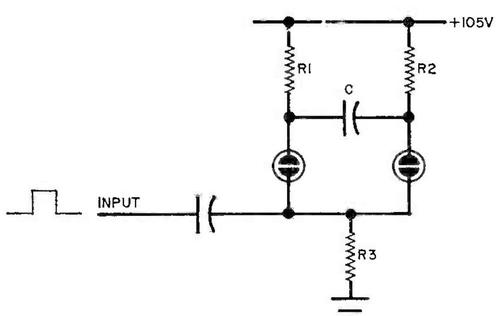


Fig. 8. Flip-flop circuit switches from one neon lamp to the other upon application of a positive-going pulse input signal. If resistor values are not proportioned properly, circuit may either oscillate or act as monostable (one-shot) multivibrator. Practical circuit is shown in next diagram.

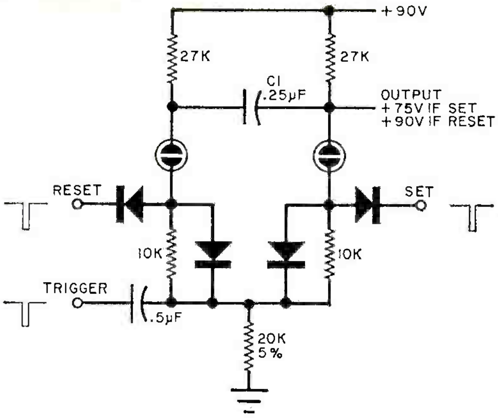


Fig. 9. This circuit could be used to construct binary counters or other digital circuits. Each of the flip-flops may be driven directly by output of preceding flip-flop. Use identical diodes, at least equivalent to 1N91. The 1N34 diode will not work.

can't fire. The capacitor is charged to the voltage developed across *R1* or *R2* (whichever is carrying current). Now a positive input pulse, greater than the difference between breakdown and maintaining voltage, temporarily reduces the voltage across the *on* neon, turning it *off*. The charge on the capacitor is then sufficient to turn the other lamp *on* and the status of the circuit is reversed.

While a single flip-flop of this type demonstrates the simplicity of the basic circuit, some modifications are necessary to allow several to be connected in series for any practical counting applications. Such a modified circuit is shown in Fig.

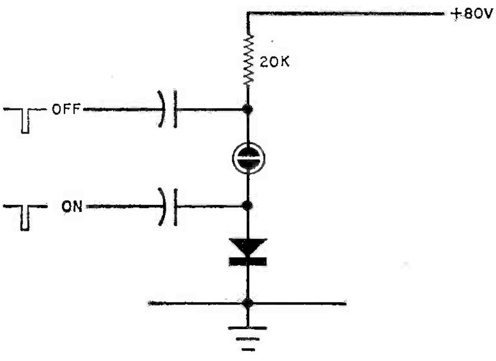


Fig. 10. Single neon-lamp memory circuit is turned on by negative-going pulse at lower input or positive-going pulse at upper input. Circuit turns off with opposite polarities. Supply voltage and resistor value are relatively critical; once turned on, lamp must remain on after pulse has decayed.

9. By permitting easy current flow in one direction but inserting resistance in the other, the diode-bypassed resistors increase the sensitivity of the circuit, so that the major portion of the triggering pulse is delivered to the neon which is *on*. When this neon turns *off*, *C1* turns the other *on*. The diode-gated set and reset inputs permit control of the starting condition of the flip-flop.

A single neon lamp can perform a digital memory function, since a higher voltage is required to turn it *on* than is required to maintain it, once fired. Such a single-bit memory circuit is shown in Fig. 10. Here the supply voltage is between the maintaining and breakdown voltages of the lamp so that it will re-

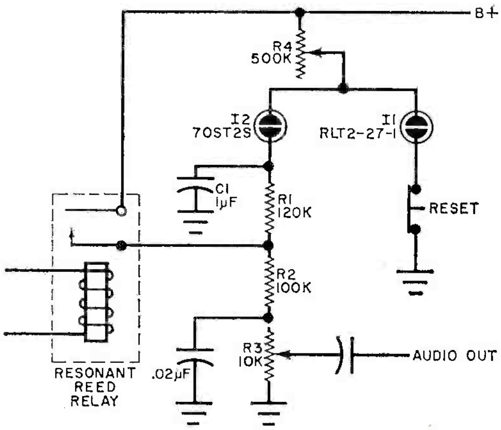


Fig. 11. Practical use of the neon-lamp memory appears in E.F. Johnson "Tone Alert". Neon lamp I1 is visible to operator, lamp I2 is hidden inside metal case of the unit. When call is received, I1 is turned on and stays on until reset switch is operated. Lamp I2 is in audible warning circuit.

main *off* when voltage is initially applied. To turn the neon *on* and thus store a single information bit, a negative-going pulse at least equal to the difference between maintaining and breakdown voltage is applied to the *on* input. This pulse adds momentarily to the supply voltage, bringing it above breakdown and firing the neon.

A memory circuit based on this principle, but using a second neon to provide a starting condition, is employed in E. F. Johnson, Inc.'s "Tone Alert." The basic circuit is shown in Fig. 11.

The Tone Alert is a selective calling system used in CB and Business Radio transceivers. In use, the receiver/speaker is muted until a special audio tone signal is received and the reed relay vibrates at its resonant frequency. Rather than turn on the speaker, the Tone Alert reed system applies B+ supply to the memory circuit.

In the memory circuit, neon lamp *I1* has a breakdown rating of 155 volts minimum while the maximum breakdown rating of *I2* is 120 volts. Thus, when the circuit is first energized, *I2* will always fire first. The maintaining voltage of *I2* is too small to permit *I1* to fire. Since *I1* is the "call received" indicator, the operator knows that no call for him has been received.

When a call comes in and the vibrating reed applies B+ voltage to the junction of *R1* and *R2*, both terminals of *I2* receive essentially full supply voltage and the voltage across it goes to zero. Lamp *I2* switches *off* and *I1* immediately comes *on*, indicating that the call has been received. At the same time, a portion of the square wave produced by the vibration of the reed relay is picked off by *R3* and applied to the receiver's audio circuits to indicate audibly that the call is being received.

If the operator is not present, the audible indication will not be answered. However, when the operator returns, *I1* will still be glowing to inform him that a call came in during his absence. When he answers the call, the "Reset" switch breaks the ground lead of *I1* and extinguishes the indicator. Lamp *I2* then fires, returning the circuit to its initial condition.

Voltage Regulation. The maintaining voltage of a neon diode is almost constant over the full operating range of current. With proper design, the voltage can be held to within 0.5 volt—and even an indicator neon will hold voltage constant within 5 volts under most circumstances.

This fact makes the neon lamp an excellent source of reference voltage for any type of voltage-regulator circuit. For low-current operation, the lamp can be used in the same manner as a VR tube. Such an application is shown in Fig. 12. Here, a neon lamp regulates the screen voltage for a crystal oscillator to provide improved frequency stability.

For moderate-current applications, the circuit of Fig. 13 can be used. The 6U8A tube specified is capable of providing up to 20 mA to a load, and output voltage may be set to any value between 75 and 150 volts. Regulation is to within 1.5 volts under worst conditions; when output voltage is set to 75 (best case), voltage drops by only 0.5 volt at maximum

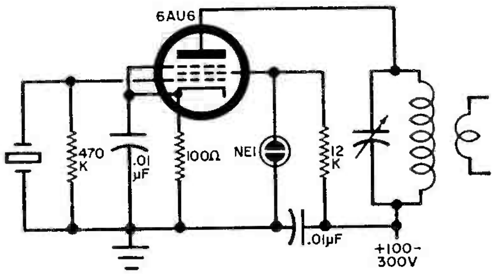


Fig. 12. In a crystal oscillator circuit such as this, the constant maintaining voltage of the neon lamp is used to regulate the screen voltage on the 6AU6, thus providing improved frequency stability.

load. For slightly more current, a 6JT8 may be substituted with modification of the pin connections, or separate 6AU6 and 6AQ5 tubes may be employed.

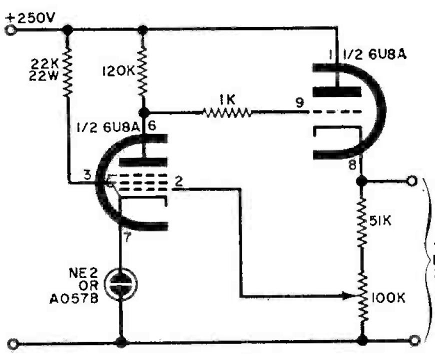


Fig. 13. Here the neon lamp holds a constant voltage on the anode of the first stage of a 20-mA regulated supply. The output is adjustable from 75 to 150 volts due to the feedback to the screen grid. Regulation 0.5 volt for the 75-volt output.

An unusual precision voltmeter which makes use of a neon lamp as its voltage reference is diagrammed in Fig. 14. This circuit's requirements are critical when it comes to the neon; the Z82R10 Signalite unit specified provides a reference voltage across *R2* of 1 ±0.012 volt. Resistor *R1* must be initially adjusted to provide calibration, but the circuit then maintains its accuracy indefinitely. The unknown input is applied to voltage divider $R3$ and compared to the accurate reference. When the null indicator (an inexpensive 50-0-50 μA FM tuning indicator, zero-center) indicates zero, the input voltage is equal to the ratio of the total resistance of $R3$ to the resistance between its rotor and ground. If a 10-turn indicator and an accurate 10-turn potentiometer are used, voltage can be read directly. The 39,000-ohm resistor avoids damage to the null indicator in initial stages; when the null is approached, $S1$ shorts out this resistor to provide maximum sensitivity.

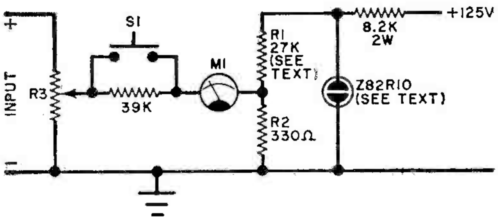


Fig. 14. The neon lamp specified here provides a reference voltage across R2 of 1 ± 0.012 volt. This is compared to the input in the null-indicating meter, making a highly accurate precision voltmeter.

Miscellaneous Applications. The list of ways in which neon lamps can be used (in addition to the general circuit applications already discussed) is virtually endless. Some specific circuits designed for various purposes are described here.

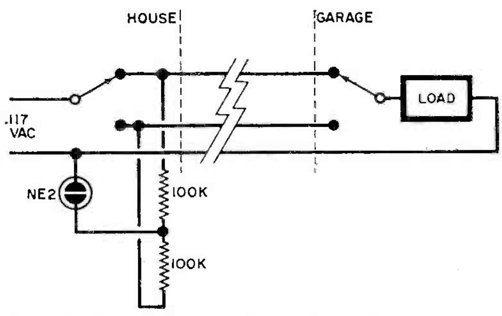


Fig. 15. In a circuit designed to indicate when a remote load is energized, the neon lamp is lit only when switches at both ends are connected to the same side of the power line. The neon indicating circuit can be repeated at load end of the line.

If you have three-way switches in your home or business, you may frequently have wondered whether the circuit they control is *off* or *on*. Since the *off* position is determined entirely by the position of the remote second switch, there's no direct way of determining the position of this switch. But one neon, used as an indicator, together with two resistors, provides a pilot light which may be installed at either end of the circuit. A bonus is the fact that the condition of the bulb or device operated by the switches is also indicated.

The circuit is shown in Fig. 15. It may be duplicated at both switches if desired although the illustration shows only one. Operation depends on the neon's requirement for breakdown voltage before firing. When both switches connect to the same line, both the load and the neon are across the 117-volt circuit and both are on. One of the resistors limits neon-lamp current while the other is disconnected. When the switches are on opposing lines, the load is *off*. Should the load circuit form a voltage divider which permits only half the line voltage to be applied to the lamp; this is insufficient to fire it and it remains dark indicating that the load is *off*. Should the load circuit open, as in the case of a burned-out light bulb, one of the two resistors is disconnected and the neon lamp lights.

Thus, if the neon is *on* and stays *on* when the switch is operated, the load circuit is open. If the neon is *on* but goes off when the switch is operated, the circuit is complete but *on*. If the neon is *off*, the circuit is complete and the load is *off*.

Another neon-indicator circuit provides indication of the sequence in which four s.p.s.t. switches are operated. This circuit, shown in Fig. 16 and requiring a dozen neon lamps, can become the basis of a game to test individual reaction time or can also be applied to more serious problems.

All switches are single-pole single-throw with locking action. The first switch to close causes all three lamps connected to it to light. Each of these three is in parallel with one lamp of another switch, and the supply voltages for these other lamps are reduced to below the breakdown point. Thus, the second switch permits only two lamps to light. This reduces voltage for a second lamp associated with each of the remaining switches, so that the third switch lights only one lamp. Similarly, the final switch cannot light any indicators.

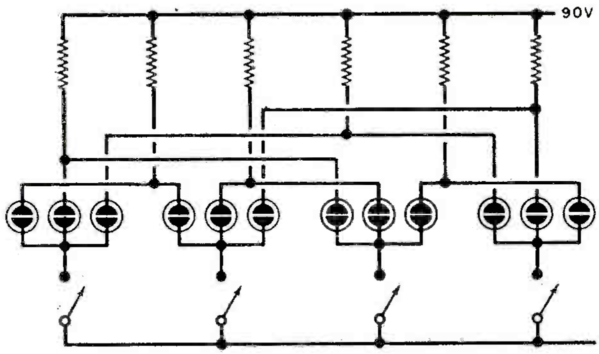


Fig. 16. In this sequencing circuit, when only one switch is closed, three lamps associated with it are lit. Subsequent closing of another switch lights only two of its lamps due to lowered voltage drop across one resistor. Last switch lights no lamps.

Resistor values are not critical—anywhere from 10,000 ohms to 1 megohm should suffice—and neon lamps need be matched only to the extent necessary to assure that none of them breaks down at a level less than the maintaining voltage of any of the others.

An inexpensive VTVM capable of indicating either 9 or 12 volts with an accuracy of 0.2 volt, yet having no moving parts is shown in Fig. 17. While a zener diode is shown for voltage reference, it could be replaced by a third neon lamp and voltage divider if desired. In operation, both plate-circuit lamps glow; and, if the input voltage is correct, both glow with equal brightness. If the input voltage is higher than desired, the HI lamp glows brighter; and vice versa.

The final circuit is a safety tester to check leakage current of a.c.-operated devices. According to Consumers' Union, a leakage current of 100 μA r.m.s. is acceptable, 100 μA to 1 mA is dangerous, 1 to 5 mA shows that repair is needed, and greater than 5 mA is unacceptable. The circuit, shown in Fig. 18 tests for 200 μA, 1 mA, and 5 mA with three different probes. The battery and voltage divider maintain voltage across the neon just below the breakdown level. The

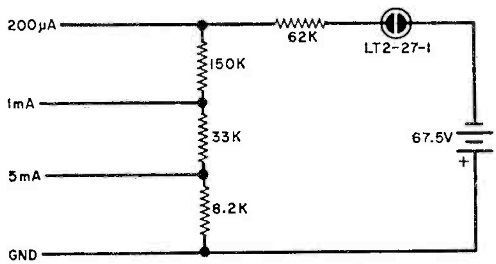


Fig. 18. To check a.c.-operated devices for safety where leakage currents are concerned, this simple circuit uses one neon lamp in series with a 67.5-volt battery. Three separate probes are used. If lamp lights when the 5-mA probe is used, leakage is too high and device is considered unacceptable.

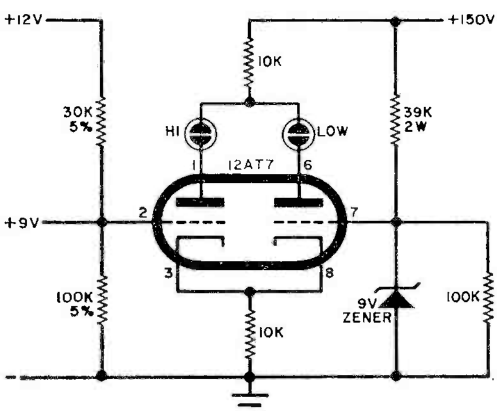


Fig. 17. Inexpensive VTVM has two lamps that glow with equal brightness if the 9- or 12-volt input is correct. If input is high, HI lamp glows brighter, and vice versa. Third neon could be used to replace zener diode as voltage reference if desired.

ground (GND) lead is fastened to the ground point against which leakage is to be checked, power is applied to the device to be tested, and the probes are touched to the device case one at a time, starting with the 5-mA probe.

If leakage current exceeds the probe rating, the voltage developed across that part of the voltage divider by the leakage current brings the neon-lamp voltage above breakdown and it fires; otherwise it remains dark and the next more sensitive probe can be tried. If the lamp remains dark for all three probes, leakage current is well within bounds.

Summing Up. Neon lamps have far more uses than most of us suspect. Those given here, although extensive, are only a small sampling chosen to illustrate the variety of possible applications. -30-

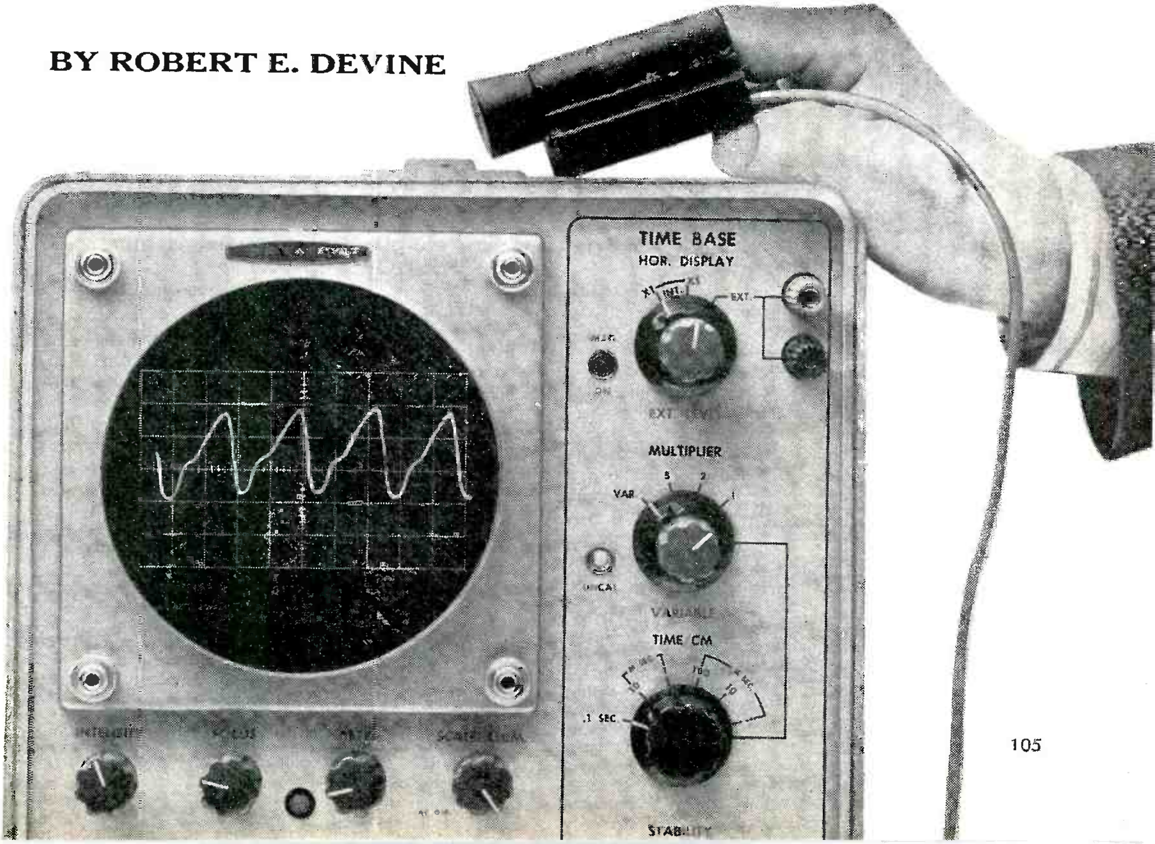
your own little PHOTOPLETHYSMOGRAPH

Unusual project shows heart action and blood flow

Hundreds of times each day, in the leading hospitals of the world, surgeons perform miraculous feats of surgery made possible by daring innovations in technique and an array of the finest equipment money can buy. An important member of the surgical team is the anesthetist. He leans heavily on modern medical electronic instrumentation, and can now keep his full attention on the unconscious form before him while the important heart data is supplied to him aurally. This information comes in the form of a soft rhythmic "bleep" emanating from an electronic monitor. If the *bleep* should falter, the signal can be switched from an audible to a visual presentation. The anesthetist would then be able to study the heartbeat waveform displayed on the face of his small, battery-operated oscilloscope.

This heartbeat signal originates in a photocell transducer that has been slipped over one of the patient's fingers. It has the rather formidable name of photoplethysmograph, usually abbreviated to PPG. The "plethysmo" portion of the word is derived from the Greek "plethore," meaning "to be full." Basically, the transducer measures the blood volume flow in the finger to which it is attached. This is an excellent indication

BY ROBERT E. DEVINE



PARTS LIST

B1—22.5-volt battery
B2—1.5-volt battery
I1—Pilot bulb #222, or "grain-of-wheat" bulb
J1—Three contact polarized socket
P1—Three contact polarized plug
PC1—Photocell sensitive to approximately 7350 Angstroms (Clairex CL903L or similar)
R1—5600-ohm, ½-watt resistor
R2, R3—10,000-ohm, ½-watt resistor
S1—D.p.s.t. switch
Misc.—Block of wood or opaque plastic approximately 2½" x 1½" x ½", thin metal plate, battery holders, length of 2-conductor flexible shielded cable with three-pin polarized plug (from transducer to bridge), length of phono cable with two-pin polarized plug (from bridge to preamp or scope), finger support (see text), connector for scope or preamplifier (optional), 25,000-ohm potentiometer (optional, see text), terminal strips, hardware, etc.

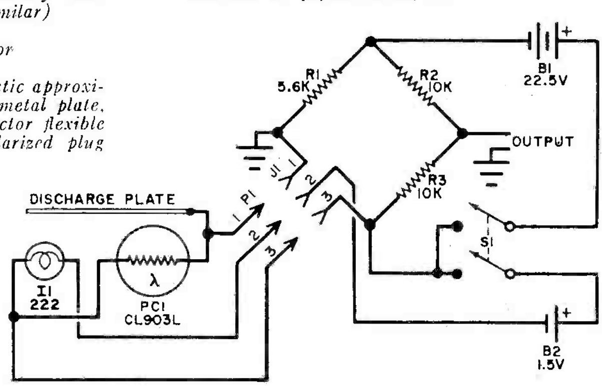


Fig. 1. The PPG circuit is a simple bridge with photocell PC1 as the variable arm. The plate bleeds off static electricity. The shield of the transducer cable is the common ground lead and is connected to pin 1 of P1. The output cable is a shielded single-lead microphone cable.

of how efficiently the heart is working. If the patient's condition warrants it, this pressure pulse monitor will accompany the patient to the recovery room. The PPG is also used in intensive care hospital rooms. Its signal can be carried by cable to a central observation point where it may be monitored continuously by either visual display or an audible signal. The electronic vigil will watch-and-warn for that critical 200 seconds—the period between the instant the heart ceases to pump, and death. The heart must be restarted during this critical interval to save the patient's life.

The actual waveform generated by the pressure pulse has a frequency of only one or two hertz—much too low to be heard by the human ear. In an aural setup this signal triggers an electronic tone generator whose frequency has arbitrarily been selected to be something "easy to listen to." The important information conveyed by the *bleep* is the tempo and regularity of the heartbeat. On the other hand—when the waveform is displayed on an oscilloscope, all the above information, plus other physiologically significant events, can be extracted from a visual observation of the waveform.

If you have a good oscilloscope, you

PARTS LIST

B1—22.5-volt battery
C1—12-μF, 20-volt tantalum capacitor
C2—75-μF, 6-volt electrolytic capacitor
J1—Two contact polarized socket
Q1—N-channel FET (Motorola MPF103 or similar)
R1, R4—2-megohm
R2—470-ohm
R3—7500-ohm } *all resistors ½-watt*
S1—S.p.s.t. switch
S2—S.p.s.t. momentary contact switch
Misc.—Metal case 4" x 2¼" x 2¼", transistor socket, battery holder, length of shielded flexible cable (from amplifier to scope), terminal strips, hardware, etc.

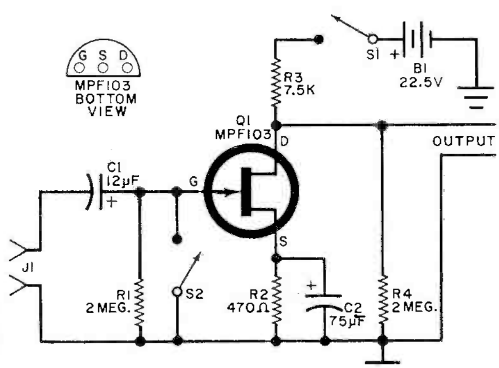


Fig. 2. Output level of the bridge is very low and this special preamplifier may be required. Capacitor *C1* is made of tantalum foil.

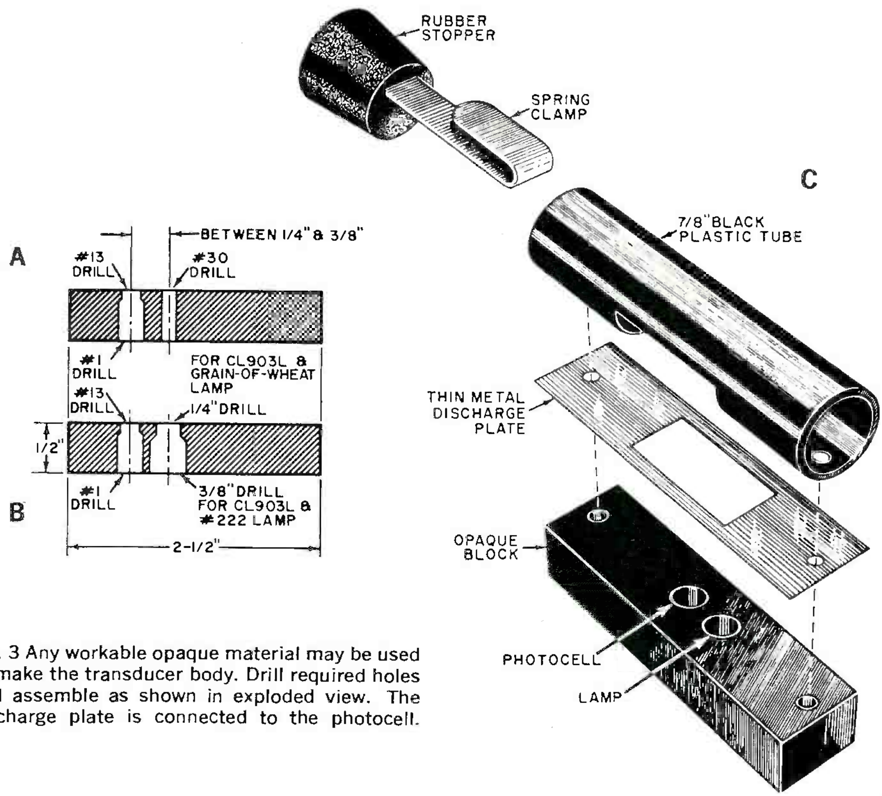


Fig. 3 Any workable opaque material may be used to make the transducer body. Drill required holes and assemble as shown in exploded view. The discharge plate is connected to the photocell.

can reduce the cost of building your own PPG to approximately six dollars. Construction time should be just a few hours.

Construction. The PPG is divided into three cable-connected sections: the finger-mounted transducer assembly, the measuring bridge, and a FET signal preamplifier (optional). The circuit for the transducer and bridge is shown in Fig. 1 and the schematic for the FET preamplifier is shown in Fig. 2.

To make a transducer, a piece of opaque plastic or wood approximately 2½" x 1¼" x ½" is drilled to accept the photocell and lamp as shown in Fig. 3. There are two methods of drilling the holes for the light source. Fig. 3(a) shows the drilling requirements for a grain-of-wheat lamp, while Fig. 3(b) shows the drilling for a #222 lamp. In both cases, the hole for the photocell remains the same size. Each unit should be submerged within the opaque block so that they do not "see" each other unless

HOW IT WORKS

The PPG takes advantage of the fact that tissues of the human body are relatively transparent to the red part of the light spectrum (near infrared region from 7000 to 8000 Angstroms), while the blood is not.

When you place your finger across the gap separating the reddish light source and the photocell, your flesh will provide a path for the light rays to reach the photocell from light source. With each systole, or contraction of the heart muscles, the amount of blood in your peripheral extremities increases as the blood vessels momentarily dilate. Since blood is opaque to the red light, this reduces the amount of light reaching the photocell during the pressure pulses. The change in light causes the photocell to change its resistance with each pulse.

The photocell is connected in a bridge circuit (see Fig. 1) with $R1$ being its opposite bridge element. Equal value resistors $R2$ and $R3$ provide a mid-point pickoff for the output signal. Each time the photoresistor changes its resistance value, an output signal is generated by the bridge.

Because the bridge output is a low-level, low-frequency signal, the FET preamplifier shown in Fig. 2 may be used to increase the signal level to a point usable by some scopes. This preamplifier is a conventional FET stage having the required very high input impedance so as not to reduce the low-frequency coupling ($C1$) at these one-to-two-Hz subaudible frequencies.

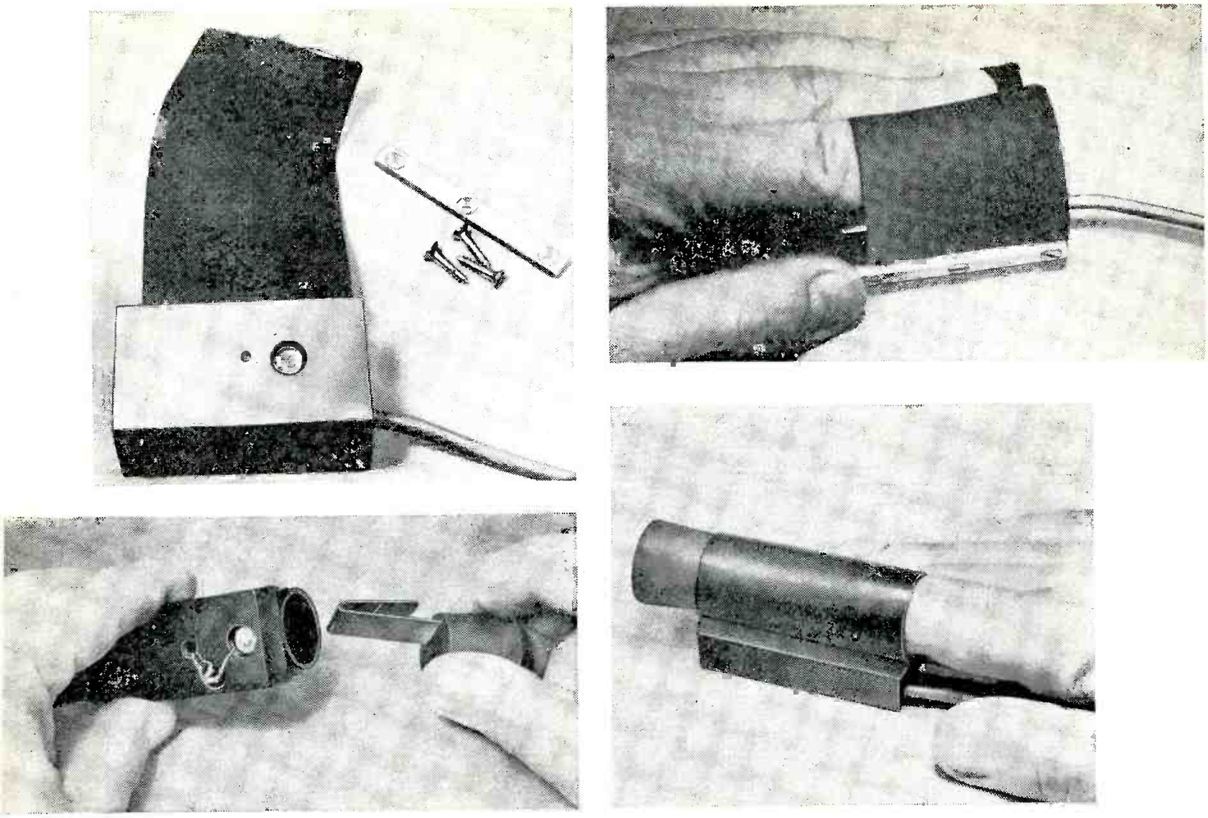


Fig. 4. Two preferred methods of assembling a transducer are shown. In the upper two photos, an elastic cloth has been used to secure the finger and block off outside light. The photocell and light source are visible through the holes in the metal plate. The two lower photos show tube transducer.

a finger is so placed as to make a reflective bridge between photocell and lamp.

To remove any static electricity charge, a thin metal plate covers the top of the opaque block with a cutout over the lamp and photocell holes. This is shown in Fig. 3(c). The metal plate is connected to the ground lead of the transducer-bridge cable.

A light shield surrounding the finger and the photocell is recommended. Use a black (opaque) plastic tube that can be bolted to the opaque block, with a cutout as shown in Fig. 3(c). To make sure that the finger correctly bridges the *I1-PC1* gap, make up a clamp using a rubber stopper and a home-made spring. The stopper should be a tight fit in the end of the plastic tube. The spring clamp is inserted so that when a finger is placed in the tube (fingernail up), the clamp will force the finger down to bridge the *I1-PC1* gap. An alternative construction method is to use a piece of opaque, elasticized cloth attached to both sides of the opaque block. This cloth forms both a finger support and a light shield. Figure 4 illustrates both types of finger transducers.

The photocell, lamp, and ground plate are wired to a short length (three feet) of two-conductor shielded cable. This cable is terminated in a polarized three-pin plug.

Building The Bridge. The author built his bridge circuit in a 5" x 4" x 2" metal box, as shown in Fig. 5, although any other similar container would suffice. The bridge elements (*R1, R2,* and *R3*) are supported on a pair of three-terminal strip assemblies. The two batteries are mounted on the sides of the box, the on-off switch (*S1*) is on the upper surface of the box, and the three-pin polarized connector to accept the output from the transducer is mounted on one end of the box. All wiring is point to point. The bridge output is taken via a length of phono cable, with the center lead going to the bridge, and the braid connected to the ground. This cable is terminated in a two-pin polarized plug for connection either to an oscilloscope or to the FET amplifier.

If the output of the bridge is used to feed a d.c. scope, the d.c. component of the bridge output can be removed by replacing *R2* and *R3* with a 25,000-ohm potentiometer. The output is then taken from the arm of the potentiometer which is adjusted to produce a zero voltage output (to ground) with no signal to the photocell.

Preamplifier. The approximate bridge output amplitude of a PPG signal is 0.05-volt peak to peak. Your scope should have a vertical sensitivity of at least 10 mV per cm (25 mV per inch) at one to two Hz. However, if your scope does not have this sensitivity, the FET preamplifier (schematic in Fig. 2) should be built.

This amplifier has two characteristics that may cause you some trouble. The first is that the tantalum input capacitor (*C1*) acts somewhat like a diode—it has a high resistance in one direction and a low resistance in the other. The second is the very long time constant of *R1C1*. Although this is a nuisance, it is important in passing the very low frequencies required by the PPG.

When using the PPG the output is at a d.c. level, transducer modulated about 25 mV in both directions. It is important that *C1* present its high-resistance side to this d.c. voltage, otherwise *C1* will bias the gate of *Q1* enough to make the amplifier inoperative. If you get no output from the amplifier (with an input signal from the bridge), reverse the capacitor end-for-end or reverse the battery powering the bridge. *DO NOT* reverse the battery supplying power to the FET.

The aggravating long *R1C1* time constant means that it may take anywhere from ten to fifteen seconds to charge *C1*. During this interval, the charging current passing through *R1* can bias the FET to pinchoff—the equivalent of cut-off in a bipolar transistor or vacuum tube. Therefore, after placing your finger in the transducer, you might have to wait fifteen seconds before the amplifier commences functioning and the signal appears on the CRT. To partially eliminate this delay, a momentary-contact switch (*S2* in Fig. 2) is connected across *R1*. With this switch closed, *C1* will charge in a fraction of a second. When you release this switch, the amplifier should function immediately.

The amplifier is built in a 4" x 2¼" x 2¼" metal box as shown in Fig. 6. Short leads should be used, as excessive capacitance between the output and input leads may lead to instability. Also, a good quality transistor socket is used to mount *Q1*. Since the signal of interest is in the millivolt range, the circuit should be shielded and good r.f. wiring techniques should be used to keep stray 60-Hz a.c. to a minimum. The input two-pin connector must match the plug coming from the bridge circuit, making sure that like leads are in contact—that is, hot lead to hot input, and ground braid to ground. The output of the preamplifier is a length of shielded microphone cable, with a double banana or coaxial termination plug suitable for attaching to your scope.

Using the PPG. Connect the transducer to the bridge, the bridge to the FET

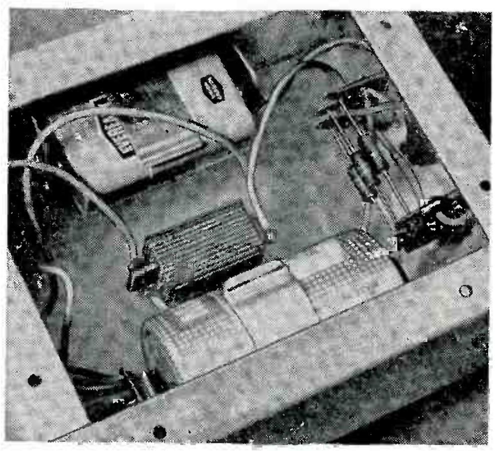


Fig. 5. The bridge circuit—excluding photocell and light source—is assembled with point-to-point wiring.

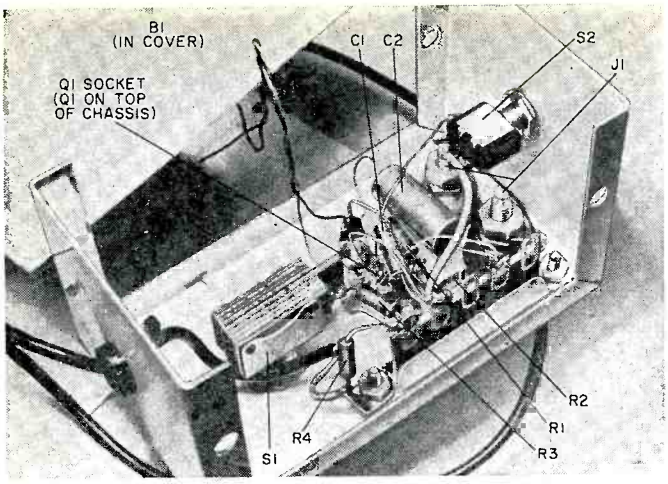


Fig. 6. Use point-to-point wiring when assembling the FET preamplifier. The circuit must be shielded to avoid electrical noise pick-up. Author mounted capacitor loading switch S2 on end plate of metal box and power switch S1 on top panel.

WHAT DOES THE PPG DISPLAY?

The photoplethysmograph (PPG) when connected to an appropriate oscilloscope displays pulsations of blood in the vascular system. These pulsations originate in the action of the heart and the PPG shows their amplitude, frequency and waveform.

Blood pressure (PPG amplitude) is displayed in three phases: "systolic," during contraction of the heart when arterial pressure is maximum; "diastolic," when the heart is expanding and pressure is low; and "mid-point," or mean, which occurs between the two extremes and is called the pulse pressure.

There is no normal PPG amplitude although there is a direct correlation between blood pressure and the peak response displayed by the PPG. Blood pressure of the subject varies according to age, physical condition, emotional state, etc. It also varies in different parts of the vascular system. The large arteries have higher pressure while the capillaries at the finger tips have a moderately low pressure.

The frequency rate of the pulse display is also variable—from an abnormal low of 50 pulses per minute to a high of 150, or more, pulses per minute. The velocity of the pulse wave through the vascular system is about 7 meters per second, although the actual blood flow is around 0.5 meters per second. If you attempt to correlate the actual heart beat and the PPG display, you will see a displacement due to the time lag in the flow of the blood through the arteries.

Because of the many variables, a strict interpretation of the PPG display is best left to the professional. However, as indicated in the article text, the PPG offers an opportunity to examine blood flow in the human body and the reaction of the heart to stress or emotional upset and physical exertion.

preamp (if used), and the preamp to the d.c. scope vertical input. If the preamp is not used, connect the bridge output directly to the oscilloscope. Make sure that the polarity of each signal lead is correct. Turn on the scope and adjust for a very slow horizontal sweep rate—one every two seconds is a good place to start—otherwise, set the sweep to as slow a rate as possible with your particular scope. If your scope has provisions for hooking an external capacitor to the horizontal sweep circuit, select a capacitor that produces a sweep time between one and 10 seconds. Capacitance values depend on the particular scope.

Set the scope vertical gain high, as the signal to be observed will be of low amplitude. Turn the bridge on-off switch *on* and check that the transducer light bulb goes on simultaneously. One interesting aspect of the transducer is that the brightest light source does not necessarily produce the strongest output signal. Some commercial PPG's use a rheostat in series with the light bulb so that light intensity can be controlled. Starting with maximum brightness, the lamp is gradually dimmed until a point is reached where the amplitude of the output signal peaks. The explanation for this behavior becomes clear when you recall that the PPG photocell is most sensitive in the *red* region of the visible light spectrum. A light bulb at full brilliance is putting too much of its energy in the blue spectrum, where the cadmium selenide photocell used in this project is "blind." This is why the *I1* is operated at approximately half voltage.

Insert a finger into the transducer light shield so that the ball of your fingertip rests comfortably across the two holes containing the light bulb and photocell. If you use either the spring clip or elastic band finger retainer, make sure that it does not push down too hard on your finger, as this will cut off the blood flow to the fingertip and reduce the output signal.

If you are using the FET preamplifier, close the capacitor switch for a couple of seconds, and adjust the scope vertical position until the trace is centered on the screen.

Do not wiggle your finger while making PPG measurements, as this will cause the trace to dart up and down the scope face.

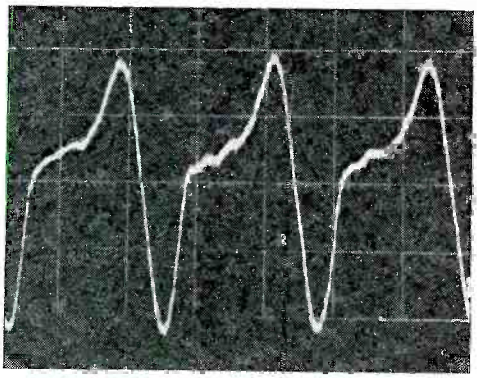


Fig. 7. Typical PPG displayed waveform. The trace shows fuzziness due to electrical noise pick-up.

After the trace settles down, you will see it assume a waveform similar to that shown in Fig. 7. (The waveform seen on the scope face on the cover is an approximate three-second time exposure.) The upward trace (downward if you have reversed the battery in the bridge circuit) is caused by an increase in blood volume due to a momentary dilation of the blood vessels. This in turn is caused by a pressure wave originating in the heart with each heart beat. This sharp contraction of the heart is called "systole" in medical terms. Naturally, the upward pulse trace will occur somewhere between 60 and 120 times each minute, corresponding to your heart rate. Variations in rate or amplitude, which represent an increase or decrease in blood volume, are evident and recognizable.

To observe the action of the heart, stand up, hold your hand at heart level, and observe the trace. Then raise your hand as high as you can (wait for the trace to settle if it should flick off the scope face), and note the difference in the amplitude of the pressure wave. You can also lie down with the transducer at heart level, note the waveform, then raise the hand as high as possible.

While observing the waveform, grasp the wrist of the hand attached to the transducer and start squeezing—gently at first, then more firmly. The amount of pressure required to flatten the scope trace will depend on your blood pressure. A pneumatic cuff and mercury manometer may be used with the PPG to determine your actual blood pressure.

You know that the tempo of your heartbeat will increase with exercise (such as a few quick, deep-knee bends), but what happens to the shape of the waveform? Try it and see. Also, try holding your breath after inhaling deeply—you might find that your pulse rate will accelerate at first, then decelerate, then speed back up again. There will be surprising changes in the amplitude of the pulse wave.

Emotions also have a powerful effect on blood circulation. If you experience stress, anger, or fear, your peripheral blood vessels will constrict and lessen the blood flow. It is difficult to duplicate these strong emotions under artificial conditions. However, be alert and you may note changes in the PPG waveforms that correspond to changes in the subject's emotional state.

Other, more practical uses, can also be demonstrated. The PPG can be used as an indicator of whether or not blood flow has been cut off in an arm while practicing with a tourniquet or using "pressure points" in practicing first-aid procedures. You can even apply the PPG transducer to a leg (connect the transducer to a toe) and check for the proper application of pressure points used to stop leg bleeding.

Cigarette smoking causes cutaneous vasoconstriction—reduction of blood flow in the skin. Smokers may observe this effect by taking a few deep "drags" on a cigarette while monitoring a PPG scope trace. –30–

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CHAPTER 3

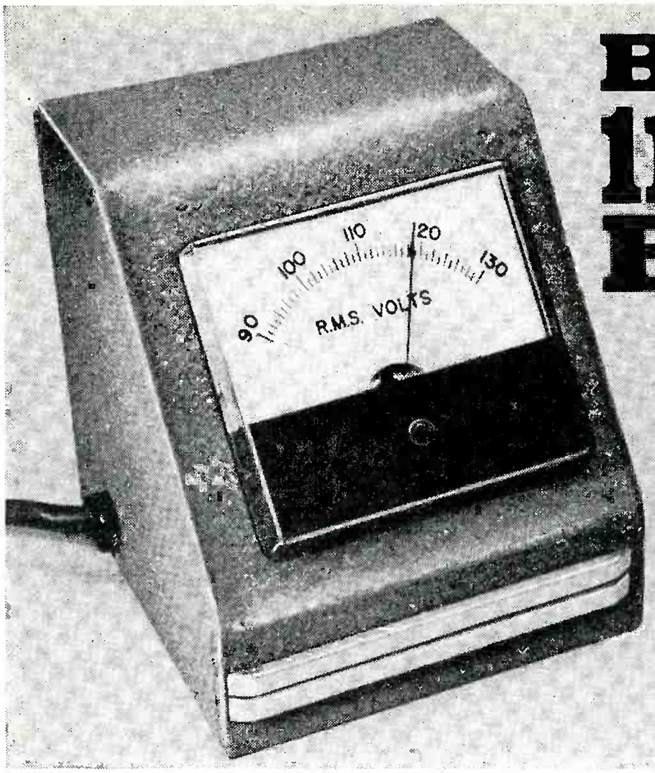
LAB & TEST EQUIPMENT PROJECTS

It would be a poor experimenter that didn't build some of his own test equipment. In fact, many experimenters feel that constructing a test equipment project is a greater challenge than duplicating the usual run-of-the-mill household project. The leeway, or slack, in a household project must be eliminated from test equipment and performance must be on the nose.

This edition of the HANDBOOK contains a variety of test equipment projects ranging from the precision millivoltmeter (page 117) to a simple continuity tester (page 124). There is also a 3.6-volt d.c. power supply (page 134) designed for integrated circuit experimentation and a clever idea on how to measure a.c. wattage loads using very unsophisticated equipment (page 131).

All of the test equipment projects have been tested by the HANDBOOK staff and found (where applicable) to approach the accuracy of professional gear costing from two to five times as much as the price of the individual components alone.

114	117-VOLT PLM	F. Forman and E. Nawracaj
117	MILLIVOLTMETER FOR THE LAB	Frank H. Tooker
124	"SONCON" CONTINUITY TESTER	Neil Johnson, W2OLU
126	ACCURATE LOW-VOLTAGE CALIBRATOR	Frank H. Tooker
127	TRANSISTOR TEST ADAPTER FOR YOUR VTVM	A. A. Mangieri
131	MEASURE A.C. AMPS & WATTS WITH YOUR VOM	Neil Johnson
134	IC EXPERIMENTERS' 3.6-VOLT POWER SUPPLY	Frank H. Tooker



BUILD 117-Volt PLM

BY F. FORMAN AND E. NAWRACAJ

Power **L**ine **M**onitor uses expanded scale for a.c. house voltage read-out

WHEN YOUR a.c. line power is used to supply critically balanced test equipment, some erroneous results can be blamed on variations in the line voltage. While most of us rely on the power company to keep the voltage at a nominal 117 volts, it should be monitored because variations of −15 volts and +10 volts are not uncommon.

To check the voltage, it is always possible to use a standard VOM, but trying to read 117 volts on a cramped multi-scale meter is often difficult. A solution is to build a 117-volt PLM, the expanded scale voltmeter that indicates only between 90 and 130 volts, eliminating interpolation between the fine divisions on a VOM meter scale. All you need to make this device is a 0-1 milliammeter and a few spare parts.

The schematic for the voltmeter is shown in Fig. 1. Basically, it consists of a half-wave rectifier with filter (*D1* and *C1*) and a bridge circuit with the milliammeter in the middle of the bridge. One leg of the bridge is a zener diode, *D2*, which maintains a constant voltage drop of 33 volts. Potentiometer *R4* in a second leg is adjusted so that with a 90-volt line input, the drop across *R4* is just 33 volts to match the drop across the zener diode. In this case there is no flow through the meter.

When the line voltage goes up, the drop across *R4* increases while the drop across *D2* stays constant. Thus, current flows through the meter and it indicates a voltage higher than 90 volts. Potentiometer *R5* is adjusted to limit the maximum (130-volt) reading on the meter. Diode

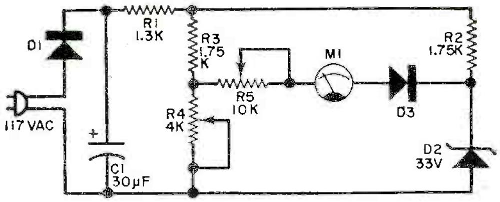
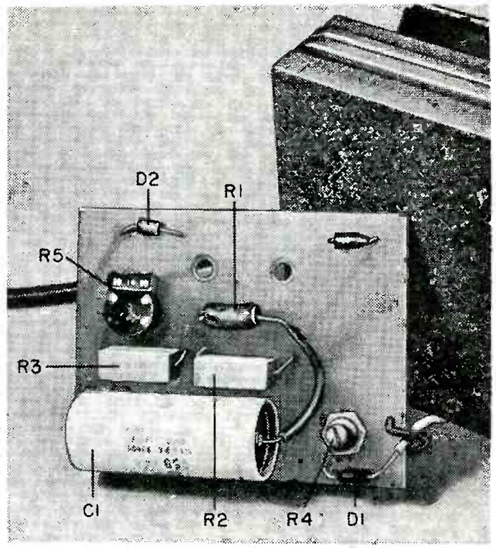


Fig. 1. The circuit is a voltage-sensitive bridge with one leg a zener diode stable reference source.

PARTS LIST

C1—30-µF, 200-volt electrolytic capacitor
D1, D3—Silicon rectifier diode, 1-ampere, 200-volts PIV
D2—Zener diode, 33-volts, 1-watt
M1—0-1 mA meter
R1—1300-ohm, 5-watt resistor
R2, R3—1750-ohm, 5-watt resistor
R4—4000-ohm, 5-watt potentiometer
R5—10,000-ohm, ¼-watt potentiometer (printed circuit type)
Misc.—Meter housing, line cord, new meter scale (see text), miscellaneous hardware.

The printed board is available etched and drilled for $2.00 from Edward Nawracaj, 3914 West 47th St., Chicago, Illinois



Every component is mounted on PC board and then the board is attached to the meter by the meter lugs.

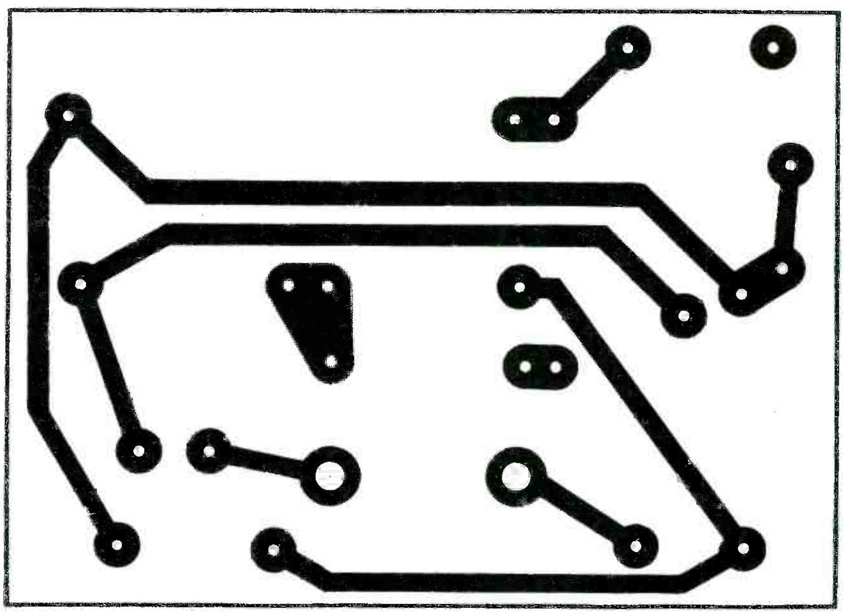


Fig. 2. Full-size drawing of the PC board designed by the authors. Component arrangement can be seen in the photo above and in Fig. 3. The diameter of the large holes should be adjusted to suit the milliammeter lugs used in your project. Some meter lugs are this diameter, but others are somewhat larger.

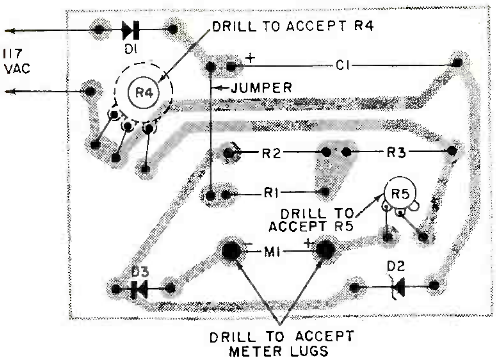
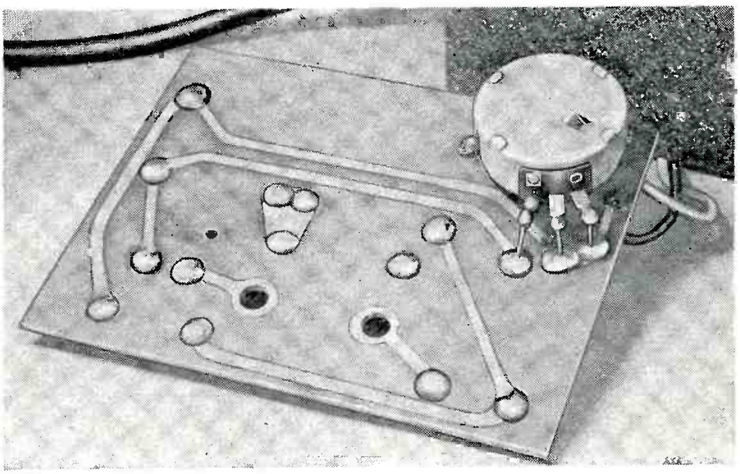


Fig. 3. Component installation on the PC board. A wire jumper connects R1 and the positive side of capacitor C1. This jumper is visible in the photo on the facing page. Alter the diameter of the holes for the meter lugs and potentiometers to fit snug.

Method of mounting potentiometer R4 is seen in this photo. Two shaft nuts enable the potentiometer to stand away from the foil side of the board. Short lengths of bare wire connect the potentiometer lugs to PC board copper foil.



D3 prevents a reverse flow through the meter.

Construction. The complete 117-V PLM circuit is assembled on a printed circuit board, shown full size in Fig. 2. After the board has been fabricated and drilled, mount the components as shown in Fig. 3. The next step is to alter the meter face.

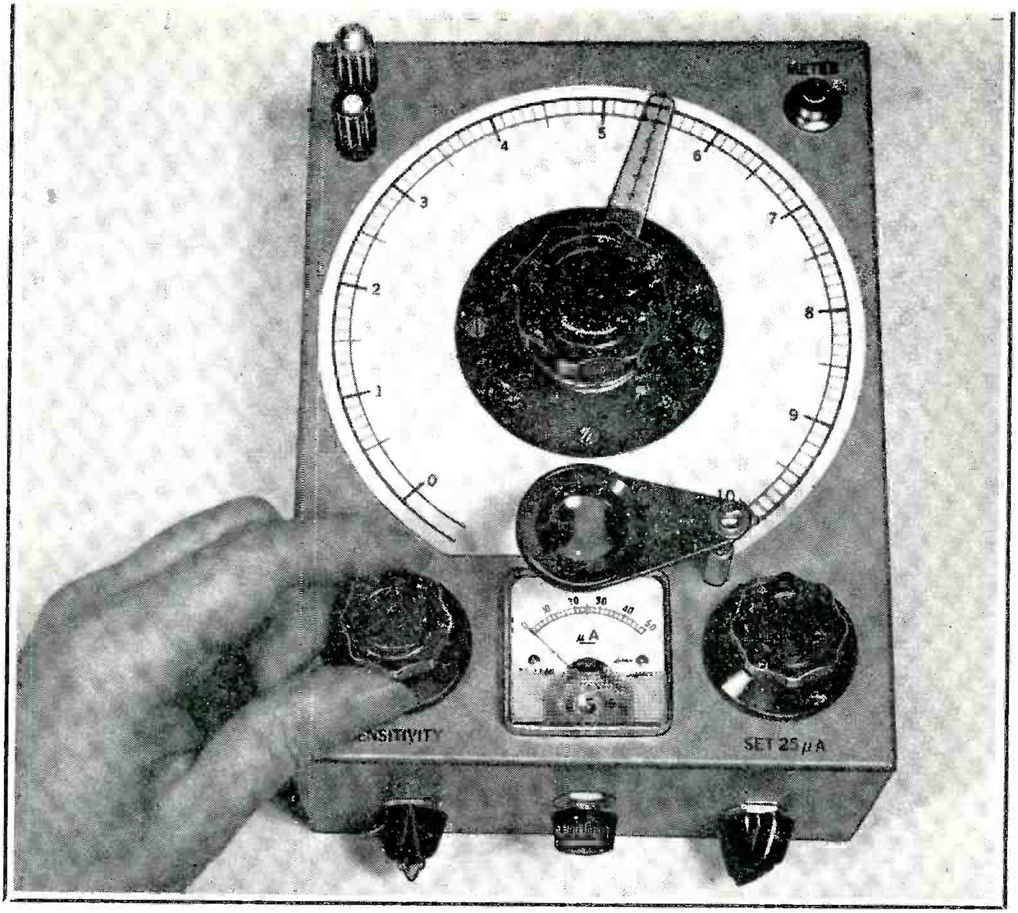
Gently remove the meter scale and either repaint it or make up a new one. Divide the scale into four equal segments marked 90 (old zero on the meter), 100, 110 (center), 120, and 130 (full scale). If desired, the major segments can be marked off into 10 equally spaced minor segments to indicate one volt increments. Mark the 117-volt reading in red.

After the meter is reassembled and the circuit has been calibrated, the printed circuit board can be mounted and supported by the meter lugs.

Calibration. Make a temporary connection between the meter lugs and the appropriate terminals on the PC board. To calibrate the device, you will need a Variac and an accurate a.c. voltmeter covering the range between 90 and 130 volts.

Set the Variac to exactly 100 volts and gradually adjust potentiometer *R4* until the meter indicates 100 volts. Increase the Variac input to 130 volts and adjust *R5* until the meter reads 130. Repeat the process until the meter reads exactly the same as the Variac over the entire range between 90 and 130 volts.

After calibration, cement the potentiometer shafts in place to prevent them from being accidentally disturbed. Remove the Variac source from the input and remove the temporary wiring on *M1*. Secure the PC board to the meter lugs using the nuts provided with the meter. —30—



Millivoltmeter for the Lab

D.C. READINGS DOWN TO 5 mV AT 5000 MEGOHMS PER VOLT

BY FRANK H. TOOKER

VOLTAGE MEASUREMENTS below 1 volt d.c. cannot be made easily or accurately with the average VOM, VTVM, or TVM. Usually they involve estimations (sometimes plain old guesswork) and results can be considerably in error.

Described in this article is a D.C. Millivoltmeter designed with emphasis on precision measuring, in which accuracy and input impedance both play important roles—especially in very low-current or high-impedance circuits. It measures from 1 volt down to 5 millivolts with an accuracy of ±1% in addition to the calibration accuracy, which is 2 to 3%. Input resistance is about 5000 megohms/volt.

Reading a millivoltmeter of this kind takes a little longer than just glancing at a meter scale. The scale is over a foot long—the equivalent of a large meter with the customary 90-degree deflection. Accuracy is independent of both the linearity of the meter movement and the linearity of the amplifier.

Power consumption for this millivoltmeter is about 70 milliwatts and the cost is about $35. Considering these economic factors and the meter's accuracy and input resistance, it's easy to see that it is

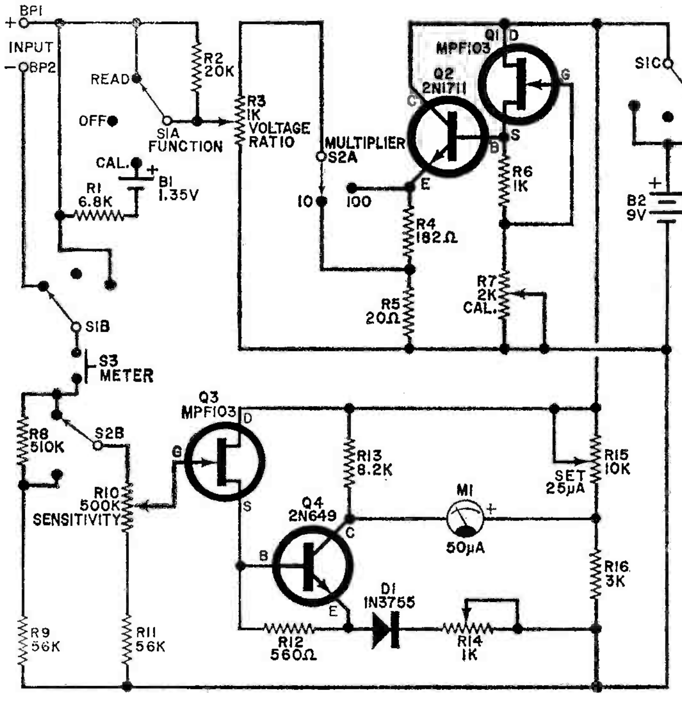


Fig. 1. This voltmeter uses a two-transistor precision voltage regulator (Q1 and Q2) and a two-transistor voltage difference amplifier (Q3-Q4). These precision circuits permit voltage measurements down to 5 mV with accuracy of 1%.

PARTS LIST

B1—1.35-volt mercury cell (Mallory RM1R or similar)
B2—9-volt alkaline transistor battery (Mallory MN1604B or similar)
BP1—Binding post, red (E.F. Johnson 111-102 or similar)
BP2—Binding post, black (E.F. Johnson 111-103 or similar)
D1—1N3755 diode
M1—50-μA miniature microammeter (Lafayette 99T5049 or similar)
Q1, Q3—Field-effect transistor (Motorola MPF103)
Q2—2N1711 transistor
Q4—2N649 transistor
*R1—6800-ohm, 2% resistor**
*R2—20,000-ohm, 2% resistor**
R3—1000-ohm, 5% wirewound potentiometer (Clarostat 58C1)
R4—182-ohm, 1% precision resistor
R5—20-ohm, 1% precision resistor
R6—1000-ohm, 2% resistor
R7—2000-ohm miniature wirewound potentiometer (Mallory VW or similar)
R8—510,000-ohm, 5% composition resistor
R9, R11—56,000-ohm, 2% resistor
R10—500,000-ohm, molded composition potentiometer (Ohmite CU or similar)
R12—560-ohm, 2% resistor
R13—8200-ohm, 2% resistor
R14—1000-ohm, miniature printed circuit type, wirewound potentiometer (Clarostat U39 or similar)
R15—10,000-ohm, miniature wirewound potentiometer (Mallory VW or similar)
R16—3000-ohm, 2% resistor
S1, S2—3-pole, 2-to-3-position, non-shorting, phenolic, rotary switch (Centralab PA-1007 or similar)
S3—S.p.s.t. normally open, miniature push-button switch
*Misc.—8" x 6" x 3½" aluminum cabinet, 5:1 vernier drive mechanism (National type AVD-250 or similar), large fluted knob, small fluted knobs (2), pointer knobs (2), miniature knob, magnifying glass**, battery holder, battery terminal clip, white posterboard for dial, sheet plastic laminate, plastic material for pointer, aluminum-alloy rods 1¾" long by ¼" diameter (2), PC boards or perf boards, 2-terminal strip, plastic cement, rivets, screws, nuts, washers, wire, solder, etc.*
**Select for ± 1% accuracy. All 2% resistors are ½-watt, metal glaze IRC RG20 or similar.*
***A number of different magnifying glasses are available from Edmund Scientific Company, Barrington, N.J. 08007.*

ideal for the circuit designer, technician, or advanced experimenter.

Construction. The circuit for the D.C. Millivoltmeter is shown in Fig. 1.

Since meter *M1* is a conventional 0-50-μA microammeter, rather than one with a center zero, it is operated with a virtual zero at the midscale position. It is necessary to mark this center position on the dial. Remove the transparent plastic dial cover from the meter specified in the Parts List and, using dry transfer (or a ball-point pen, if necessary) make a short vertical red line at the exact midpoint on the scale (25 μA). Then replace the dial cover, making certain that the projection on the mechanical zero adjustment properly engages the slot provided for it in the arm of the meter movement.

The D.C. Millivoltmeter is assembled in an 8″ × 6″ × 3½″ metal cabinet. Layout of the face and front panel is given in Fig. 2. After all machine work and lettering are complete, cut a 5⅝″ diameter piece of heavy white posterboard for the dial for potentiometer *R3*. The center hole to clear the projecting part of the vernier drive and the four small holes for the screws which mount the mechanism have the same dimensions as those of the dial center plate shown in Fig. 3. Also cut a transparent pointer with a fine indicator line down its center to mount on the shaft. It should be about 2¾″ from the tip of the indicating end to the center of the opening for the shaft of the drive mechanism. Using a #60 drill, make a tiny hole centered on the indicator line a short distance in from the tip of the pointer. Calibration points on the dial will be located by pricking through this hole with a needle so it is

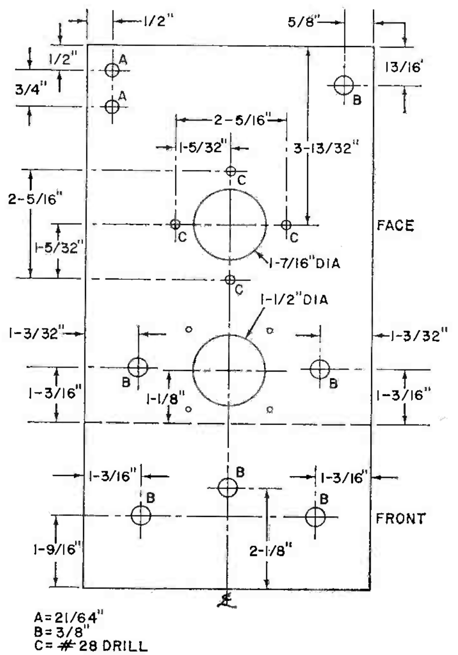


Fig. 2. To duplicate the author's model, follow this front-panel and face layout.

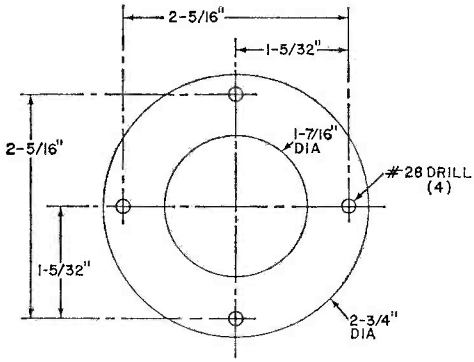


Fig. 3. The dial center plate supports the vernier drive and it can be seen in the photo on page 117.

important that the hole be centered accurately on the pointer's indicator line.

Dial Calibration. Mount the dial, the dial center plate, the pointer, potentiometer *R3*, and the vernier drive mechanism on the face of the cabinet. The potentiometer is mounted on the plate shown in Fig. 4, which is separated from the drive mechanism by a pair of metal rods 1¾″ long by ¼″ diameter, tapped for No. 6-32 screws at each end. The rods engage two of the mounting screws of the drive mechanism. Be sure that all these parts

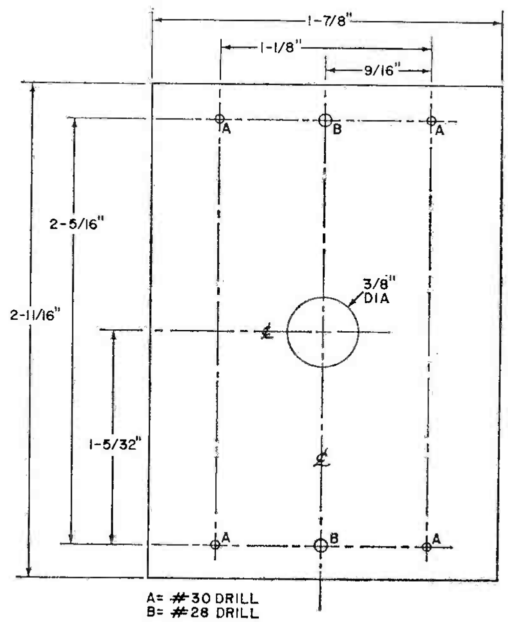


Fig. 4. Potentiometer R3 is mounted on this plate which, in turn, supports the two component boards.

BASIC PRINCIPLES

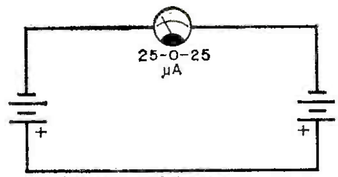
The D.C. Millivoltmeter works on somewhat the same principle as a bootstrap transistor amplifier as far as its input resistance is concerned. Its ability to make low-level measurements with high accuracy can be best understood by reference to the circuit shown here.

At (A) there are two voltage sources, represented as batteries, with a 25-μA zero-center microammeter between them. The batteries are connected with positive pole to positive pole so that, if the microammeter were not in the circuit, they would simply be in parallel.

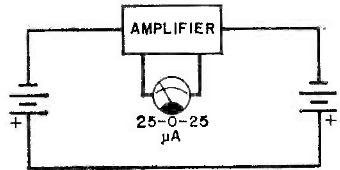
If the two batteries have exactly the same voltage, the potential of one exactly nulls or balances out the other. With no potential difference in the circuit, no current flows and there is no indication on the microammeter. If the voltage of one battery is slightly higher or lower than the other, current flows in the circuit and the ammeter indicates the imbalance by deflecting either to the left or the right.

The smallest difference in potential that a particular meter can indicate depends on the meter's sensitivity. Obviously, for maximum accuracy in measuring potential, we want a highly sensitive meter. In an instrument such as the millivoltmeter described here, the effective sensitivity of the meter can be increased by increasing the magnitude of the potential difference before applying it to the meter. This is done by interposing an amplifier between the source of the potential and the meter as shown at (B).

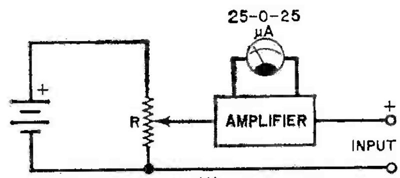
The fundamental circuit of the D.C. Millivoltmeter is shown at (C). A precisely calibrated potentiometer is connected across a stable, highly accurate voltage source (battery). The potential on the arm of the potentiometer is then used as a reference or standard. When the circuit is perfectly balanced so that no current is flowing, the ratio of the resistance of the low end of the potentiometer to the total potentiometer resistance can be multiplied by the battery voltage to determine the exact potential



(A)



(B)



(C)

at the slider. Thus, if the battery is exactly 1.0 volt and the slider is set at the mid-position, the voltage at the slider is exactly 0.5 volt. The dial on the potentiometer, therefore, can be calibrated in terms of voltage or voltage ratios.

Now if a voltage of 1.0 volt or less is applied to the input terminals and the potentiometer is adjusted to obtain a null as indicated by the meter, the potential at the slider of the potentiometer is equal to the unknown input.

Theoretically, since there is no current flow in the potentiometer when the circuit is balanced, the circuit resistance is infinite. Thus the millivoltmeter is entirely nonloading. In a practical setup, it is impossible to know when the circuit is absolutely balanced, but we can get close enough to be able to say that the effective input resistance is in the thousands of megohms per volt.

align accurately so that the mechanism operates smoothly from one end of the potentiometer's rotation to the other. Binding at any point may result in an error in the calibration of the dial.

Using an accurate resistance bridge, determine the exact electrical center of the potentiometer's resistance. With the pointer and the potentiometer aligned, mark this setting at the top center of the dial as the "5" calibration point. Divide the mid-resistance value by 5 and, using this value and the bridge, carefully locate the "1," "2," "3," and "4" points to the left of the middle and the "6," "7," "8," "9," and "10" points to the right.

With this part of the calibration complete, remove the dial from the face of the cabinet and ink in the points.

Using a divider, locate the mid-points of the spaces between the principal calibration points. Ink these points in and then divide each interval into 5 equal spaces. Locate 5 of these divisions also below the "1" calibration point. Letter the dial as shown in the photo and, for permanent protection, cover the entire dial surface with a thin plastic laminate. Cement the dial to the cabinet face and, when the cement has hardened, replace the dial center plate, the vernier drive, etc. Then, using the resistance bridge once more, check that the halfway point of the potentiometer's resistance is at exactly the same point as the "5" calibration point on the dial.

Assembling the Components. Most of the small components, including the transistors, are mounted on two circuit boards secured with No. 4-40 screws to a pair of U brackets (Fig. 5) riveted to the potentiometer plate. Layout of the boards is straightforward and not critical. Some of the other small components may be mounted on them if desired. In the author's prototype, these are mounted on unused terminals of the rotary switches. Perf board layout may also be used. Details of a suitable bracket and contacts for the mercury cell are given in Fig. 6.

Locations of the larger components are shown in the photos. It is recommended that this arrangement be followed since it provides maximum convenience in the use of the instrument.

The instrument shown in the photos is equipped with a small magnifying glass, which has a spring-loaded mounting so that it can be turned to a position over the center of the meter scale or swung away, as needed. Using the magnifier, the slightest deflection of the meter needle in the vicinity of the virtual zero can be seen. A glass having a diameter

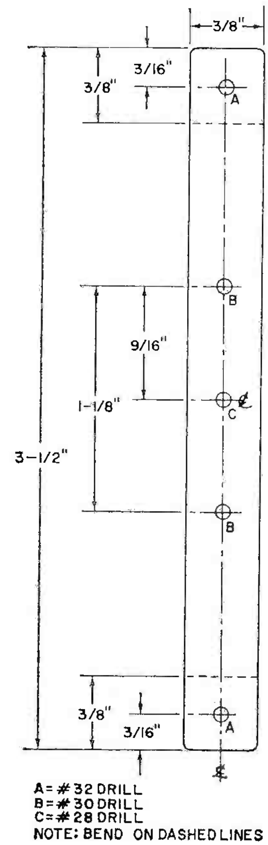
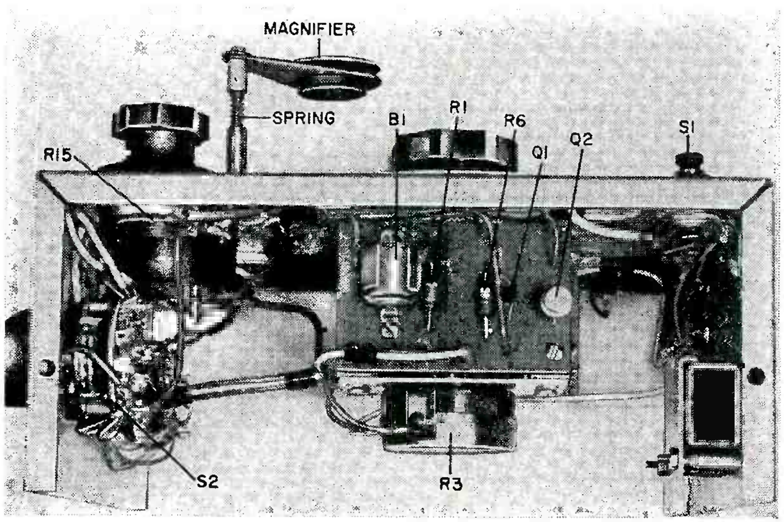


Fig. 5. A pair of these U-brackets is used to support the two electronic assemblies.



Both the magnifier and its associated spring are optional but should be used for finding exact meter null. This view also shows the location of most of the other components

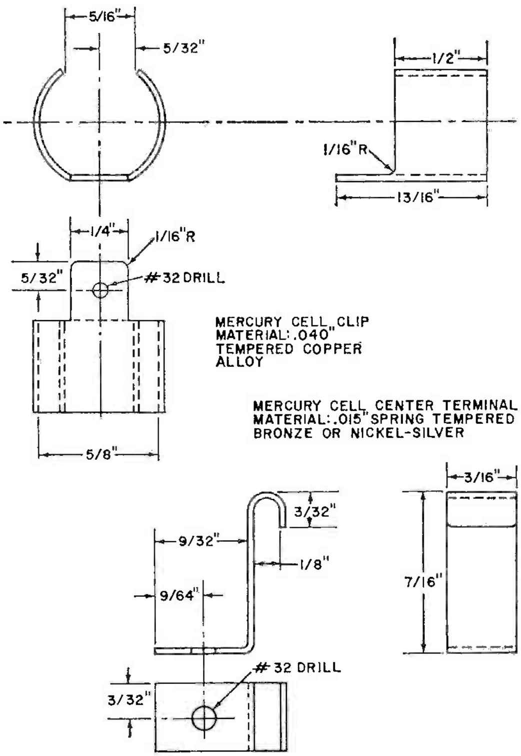


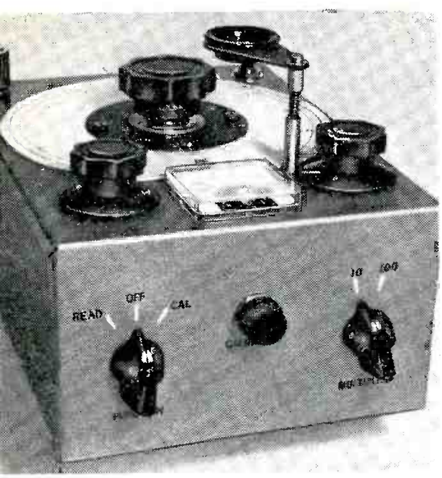
Fig. 6. Bracket and contact assembly for mercury calibration cell B. It mounts on one circuit board.

of about ¾″ and a focal length of 2″ is satisfactory. Adjust the spacing between the glass and the meter scale for best magnification of the virtual zero area without blurring or distortion.

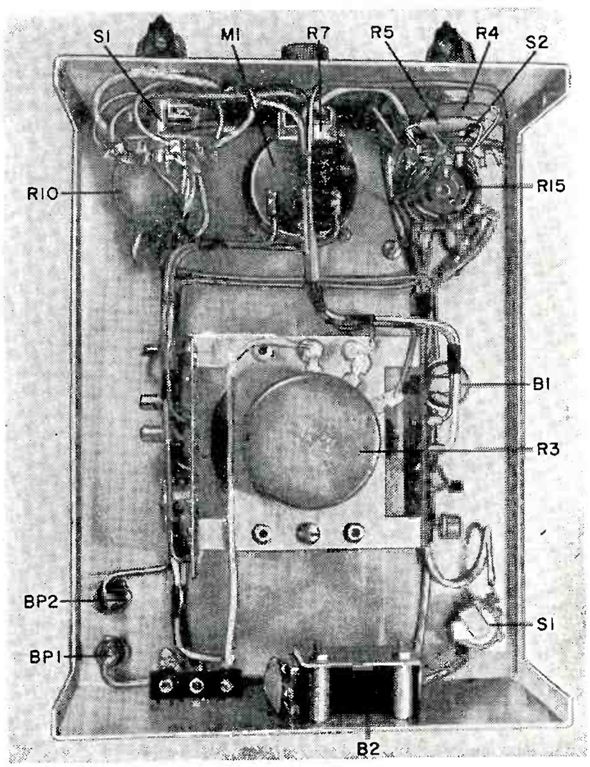
Initial Adjustments. Wire the instrument completely except for one of the leads to the meter (*M1*) which should be left temporarily disconnected. Install mercury cell *B1* and battery *B2*.

Set CALIBRATE control for minimum resistance. Place potentiometer *R14* and the SET 25 μA control (R15) at about midposition. Connect a d.c. VTVM (or a TVM) between the lead to the positive terminal of *M1* and the negative terminal of the battery. Set FUNCTION switch *S1* to READ and note the indication of the VTVM carefully. Connect the VTVM between the lead to the negative terminal of *M1* and the negative terminal of the battery, and adjust potentiometer *R14* until the VTVM reads the same value noted previously. Set *S1* at OFF, disconnect the VTVM, and secure the lead of *M1* that had been left off before.

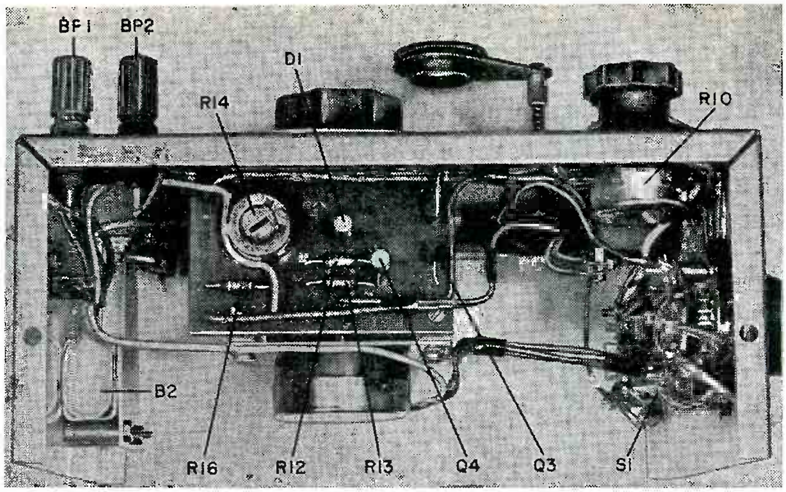
Set *S1* to READ and adjust potenti-



The various controls are handily grouped at the front of chassis for maximum operating convenience.



Underchassis view shows location of all major components and the two U-bracket-mounted perf boards.



Plenty of room, coupled with the lack of heat-producing components, allows the circuit to remain stable for long periods of time. This greatly improves accuracy.

ometer *R14* until *M1* reads midscale (at the red mark).

Set MULTIPLIER switch *S2* at 100. Connect the VTVM across the two outer terminals of calibrated potentiometer *R3* and with *S1* still set at READ, adjust the CALIBRATE control until the VTVM reads exactly 1.0 volt.

Disconnect the VTVM. Set *R3* to "10" on the calibrated scale. Check the center-scale reading of *M1* and, if necessary, adjust the SET 25 μA control to center the needle on the scale. With the MULTIPLIER switch still set at 100, set the SENSITIVITY control at minimum resistance. Switch *S1* to CAL and, holding down the METER pushbutton, adjust the CALIBRATE control so that the center reading on *M1* is restored. Advance the SENSITIVITY control in steps and adjust the CALIBRATE control as needed until, with the sensitivity at a maximum, pressing and releasing *S3* repeatedly pro-

(*Continued on page* 152)

HOW IT WORKS

Transistors *Q1* and *Q2* make up an accurate constant-potential source, supplying 1.0 volt and having an effective output resistance less than 20 ohms. The output voltage (at the emitter of *Q2*) can be set very accurately by comparing it to a built-in standard cell and adjusting CALIBRATE potentiometer *R7* to balance the circuit. Details of making this adjustment are given in the article.

The standard voltage used for calibration is obtained from mercury cell *B1* and resistors *R1* and *R2*. The resistance values are chosen to provide 1.0 volt across *R2*. The mercury cell is used only during calibration and then the current drain is only 50 μA so the life of the mercury cell in normal use of the D.C. Millivoltmeter is very long.

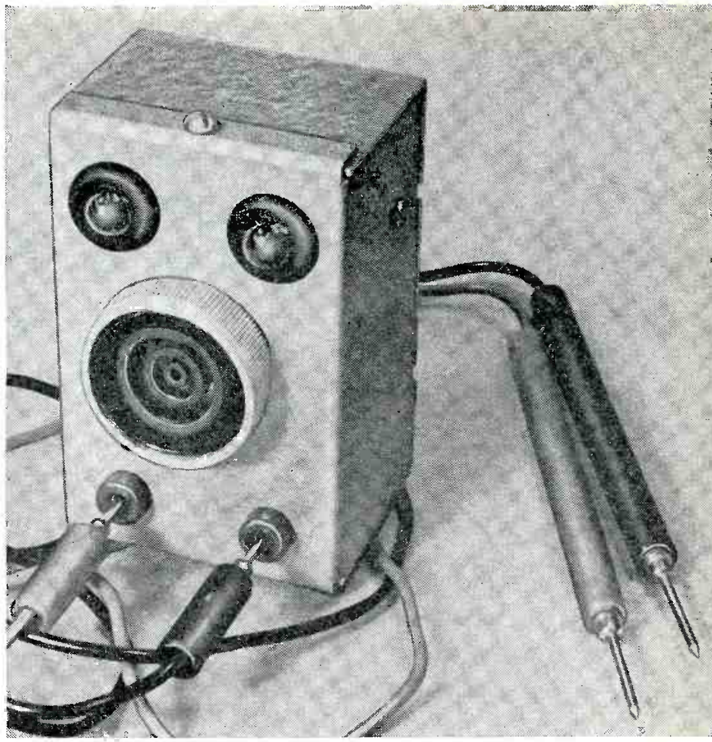
The reference voltage from *Q2* is applied to potentiometer *R3*, which takes the place of potentiometer *R* in the Basic Principles discussion. The pointer for the large dial on the top of the instrument is connected to the shaft of *R3* through a 5:1 vernier drive mechanism. The potentiometer used for *R3* must be carefully chosen and the dial must be accurately calibrated to achieve overall accuracy in the meter. Of a number of different moderately priced, readily available potentiometers checked by the author, the one called for in the Parts List was found to be the most suitable for this particular application.

The amplifier circuit for the meter (*Q3* and *Q4*) provides a deflection sensitivity of about 1.5 microamperes per millivolt of the error (potential difference). With a conventional 50-μA meter movement in *M1*, then, there is an error of about 3 degrees of deflection per millivolt of misadjustment. With care, potentiometers *R3* and *R7* can be set with an accuracy of about 1% at the 10-millivolt measuring level and above.

Two attenuators, one fixed and the other variable, provide a maximum attenuation ratio of about 100:1 at the input to the meter amplifier. The fixed attenuator, made up of *R8* and *R9*, provides a 10:1 attenuation and is set automatically by the MULTIPLIER switch *S2*. This gives the D.C. Millivoltmeter almost the same feel of adjustment on either measuring range.

The variable attenuator, *R10* and *R11*, provides sensitivity control. Pushbutton switch *S3* keeps the amplifier input circuit open until it is needed for obtaining a balance. Operating this switch on and off during the final phases of adjustment of balance aids in the accurate setting of the controls. Switch *S3* also allows continuous monitoring of the midscale zero setting of the meter as long as the instrument is turned on. Regardless of the setting of any of the other controls, the meter may be rezeroed at any time *S3* is depressed.

Potentiometer *R15* is used to set the midscale zero point on the microammeter.



"SonCon" Continuity Tester

Electrician's Helper You Can't Blow Out

by Neil Johnson, W2OLU

SOONER OR LATER it's bound to happen. You will be making a continuity test of an inoperative electrical appliance using your trusty old ohmmeter, when suddenly you will accidentally place the test probes of the ohmmeter across the power line. Poof, there goes the meter. The story gets even sadder when you have to fork over twenty bucks or so either for a new meter movement or a new VOM.

So, if you do any appliance testing, it will be worth your while to build the "Solid-State Continuity Tester." Not only will you get an audible indication of continuity (which means that you won't have to take your eyes off the job to look at a meter), but if you should accidentally place the probes across the power line, the tester will not be damaged.

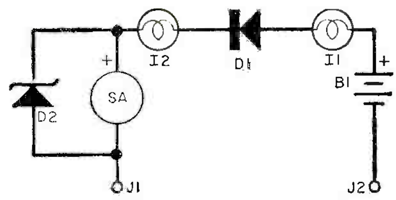


Fig. 1. SonCon circuit is a modern, burn out-proof version of the old-fashioned tester.

PARTS LIST

B1—9-volt battery
D1—Silicon rectifier, 1 ampere, 400 PIV
D2—Zener diode, 20 to 28 volts, 10 watts
I1, I2—Pilot lamp, 28 volts, tungsten filament (Type 313)
J1, J2—Banana jack
SA—Mallory "Sonalert" audible warning device, 6-28 volts d.c.
Misc.—Cabinet, test leads, grommets for lamp support, hookup wire, etc.

The continuity tester consists of a 9-volt battery in series with a "Sonalert" module. This module is a commercially available electroacoustic device which emits a shrill audio tone when its electrical contacts are supplied with from 6 to 28 volts d.c. The power line protective circuit consists of a pair of pilot lamps, a silicon rectifier diode, and a zener diode arranged in the circuit as shown in Fig. 1.

Some alert readers will recognize the similarity of this device to an old-fashioned buzzer-battery tester. However, a buzzer circuit requires about 75 mA to start operating, and any slight resistance in the circuit under test will prevent the buzzer from sounding. Furthermore, the sparks produced by an operating buzzer are a source of annoying radio-frequency interference (RFI), not to mention the possibility of an explosion if the device is operated within a gas-filled area.

The "Solid-State Continuity Tester," on the other hand, requires only 4 to 5 mA to operate, allowing the testing of even long, relatively high resistance lines (up to 1000 ohms). It has no moving parts to produce a spark (thus, no RFI), and its 2500-Hz tone is distinctive enough to be heard over most ambient noise.

If you should accidentally connect the test leads across the power line, imposing 117 volts a.c. across the input, the two pilot lamps will glow brightly, and the 2500-Hz tone will be modulated by the 60-Hz power line frequency—producing both a distinctive visual and audible alarm. Because the pilot lamps are tungsten filament types, they display a positive temperature coefficient of resistance; that is, the greater the current flow, the higher their resistance. This increased resistance lowers the voltage applied across the tone-generating module, and a zener diode connected directly across the module makes sure that the voltage breakdown of the module is not exceeded.

The complete circuit is constructed within a 2"-wide, 3⅜"-long, and 1½"-deep metal box, as shown in Fig. 2. Parts layout is unimportant, but do NOT use the metal chassis as a common tie point. The author affixed a belt clamp to the rear of the box so that he could carry the tester clamped to his belt, leaving both hands free to manipulate the test leads.

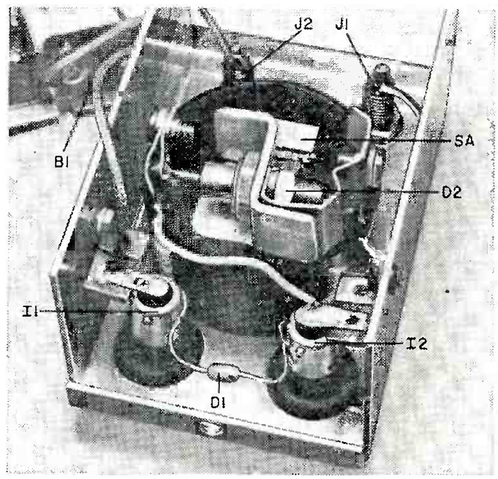


Fig. 2. Although the parts layout inside the metal box is not critical, the author suggests an arrangement similar to this. Note heat sink in zener diode.

The audible warning device is affixed to the front cover, and a pair of ⅜" rubber grommets support the two pilot lamps. The battery is strapped to the rear cover, and two test banana jacks are located at the front. —30—

ACCURATE LOW-VOLTAGE CALIBRATOR

NOVEL CIRCUIT
UNAFFECTED BY LOAD

BY FRANK H. TOOKER

HERE IS A D.C. VOLTAGE standard and calibrator circuit that can be used to check the accuracy of any voltmeter from a 1000-ohms/volt VOM to a vacuum-tube voltmeter or TVM.

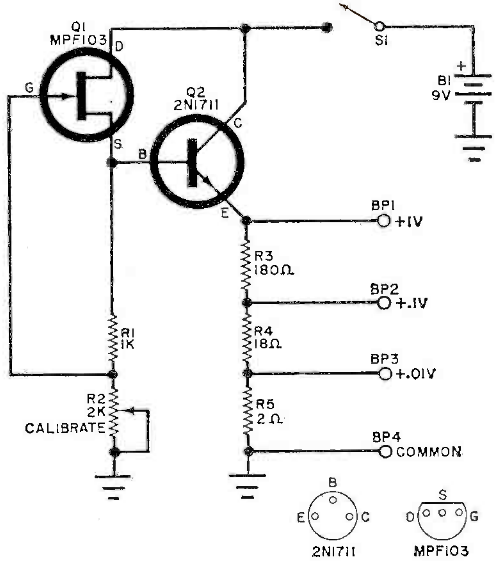
This standard is insensitive to variations in its own battery voltage. When the 9-volt battery potential has dropped to 5 volts under load, the accuracy of the standard is only affected 2%.

How It Works. As shown in the schematic diagram, field-effect transistor *Q1* is connected in series with resistor *R1* and potentiometer *R2* across the battery. The resulting current flow (about 700 μA) in *R1* creates a voltage drop which provides the gate bias for *Q1*.

Since *Q1* is reverse-biased, any decrease in its bias voltage causes an increase in source current which tends to restore the current flow in *R1* to its original value. Similarly, an increase in source current increases the gate bias and thus tends to decrease the source current.

Fundamentally *Q1* operates as a constant-current device and thus creates a constant voltage drop. The potential between the source electrode of *Q1* and ground is fixed despite wide variations in the value of the supply voltage.

The output resistance at the source electrode of *Q1* would be adequate for calibrating a VTVM or a TVM with a high input resistance, but it will not accommodate a VOM with a resistance as low as 1000 ohms/volt. The output of *Q1* is therefore current-amplified by transistor *Q2*, reducing the effect of loading by a factor of about 100:1. Simultaneously, the meter being calibrated or checked is presented with a terminal resistance no higher than 20 ohms. Thus, a high order of accuracy is maintained.

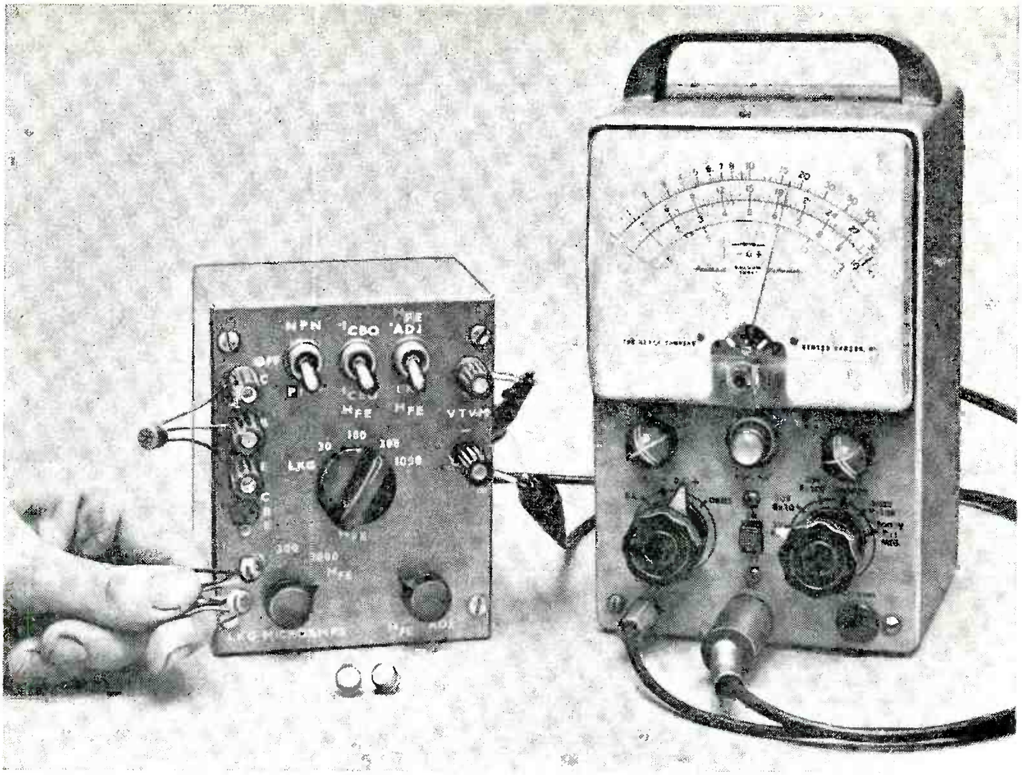


PARTS LIST

B1—9-volt transistor battery
BP1, BP2, BP3, BP4—Five-way binding post
Q1—MPF-103 field-effect transistor
Q2—2N1711 transistor
*R1—1000-ohm, 2%, ½-W metal-glaze resistor**
R2—2000-ohm, wire-wound miniature potentiometer
*R3—180-ohm, 2%, ½-W metal-glaze resistor**
*R4—18-ohm, 2%, ½-W metal-glaze resistor**
S1—S.p.s.t. switch
Misc.—Battery holder, battery terminal clip, suitable small cabinet, wire, solder, etc.
**IRC type RG20 or equal*

All resistors in this circuit should have a tolerance of 2% or better. Author used metal-glaze resistors (IRC-RG-20). Battery should be alkaline.

Calibration. The unit can be calibrated against any accurate voltmeter standard having at least 1000 ohms/volt resistance. Simply connect the voltmeter across the +1.0 V and COM terminals and adjust potentiometer *R2* until the meter reads exactly 1 volt. Lock the shaft of *R2* in place. —30—



Transistor Test Adapter for your VTVM

MAKE ACCURATE CHECKS OF IMPORTANT TRANSISTOR PARAMETERS OR, HOW TO TELL THE BAD FROM THE GOOD

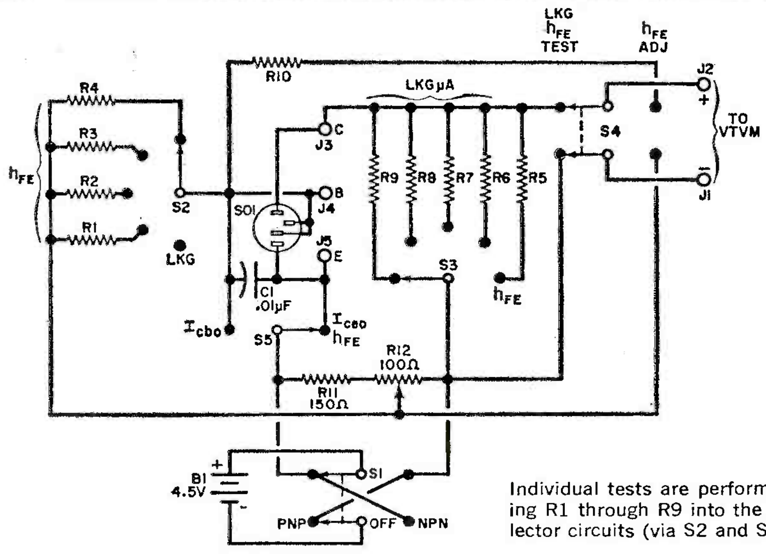
BY A.A. MANGIERI

WHILE a transistor tester is a desirable addition to any modern experimenter's test bench, it isn't necessary to invest a lot of money to obtain a good one. If you already own an 11-megohm-input vacuum-tube voltmeter that has a 1.5- or 3-volt d.c. range, you can build an adapter that will temporarily convert the meter into a transistor tester.

The VTVM/tester adapter combination will do the checking job just as well as—with an accuracy the equal of—most medium-priced full-fledged transistor testers. Yet the difference in price between the adapter (it costs about $6 to build) and a commercially available tester can represent a savings of $50 or more.

When the adapter is attached to your VTVM, you can measure the d.c. *beta* (h_{FE}) and leakage currents (I_{CBO} and I_{CEO}) of almost any transistor available. The power supplied by the adapter to the transistors under test is maintained at a safe 4.5-volt level.

Construction. The entire adapter circuit can be conveniently housed inside a



Individual tests are performed by switching R1 through R9 into the base and collector circuits (via S2 and S3) as needed.

ABOUT THE CIRCUIT

The circuit of the transistor test adapter simulates the most desirable forward and reverse biasing conditions for testing almost any transistor—whether it is *npn* or *pnp*. Range switch *S2* selects one of the base resistors *(R1* through *R4)* for proper base current during h_{FE} gain tests. Range switch *S3* selects from among resistors *R5* through *R9* to provide direct gain and leakage readings on a VTVM when connected to *J1* and *J2*. The values of *R1* through *R10* must be chosen on the basis of the range of the VTVM. The respective values have been computed and are shown in the Range Resistance Table on page 130.

Potentiometer *R12* is used during the tests to adjust base current to the correct level, taking into account normal battery aging. Switch *S1* applies battery power in the proper polarity during the tests, and *S5* is the test mode switch.

Switch *S4* is, in effect, a test-calibration switch; in the left position, it sets the adapter up for *TEST*, while in the right position it permits calibration (via *R12*) of base current.

Capacitor *C1* bypasses any stray a.c. induced into the base circuit of the transistor being tested. Resistor *R10* prevents battery short circuit in the event *J1* is shorted to *J2*. (For the 1.5-volt d.c. range, *R10*, which is equal to the input resistance of conventional VTVM's, reduces the meter's sensitivity by half when base current is adjusted. The sensitivity of the VTVM remains unaffected on the 3-volt range.)

PARTS LIST

B1—Three 1.5-volt "D" cell batteries
C1—0.01-µF, 200-volt disc capacitor
J1-J5—Insulated five-way binding post or banana jack
R1-R10—½-watt, 5% resistor—see Range Resistance Table for values
R11—150-ohm, ½-watt, 10% resistor
R12—100-ohm wire-wound potentiometer
S1, S4—D.p.d.t., center OFF, toggle or slide switch
S2, S3—Single-pole, five-position rotary switch
S5—S.p.d.t. toggle or slide switch
SO1—Elco No. 05-3301 saddle-mounting transistor socket
1—5" x 4" x 3" utility box
1—Keystone No. 175 single "D" cell battery holder
1—Keystone No. 176 dual "D" cell battery holder
Misc.—Knobs, hookup wire, solder, hardware

5" × 4" × 3" metal utility box if you follow the layout in Figs. 1 and 2. Start construction by fabricating the front panel, with the mounting holes sized according to the parts you use. Mount the parts in their respective holes. Then carefully label the positions of the controls, control designations, and the jacks. Take particular care to label *S2* and *S3* ("h_{FE}" and "LKG" range switches) so that they correspond to the ranges in the "Range Resistance Table" for your meter.

Wire the capacitor and resistors into the circuit, using Fig. 1 and the schematic diagram as guides. (You parallel a 10,000- and a 15,000-ohm resistor to obtain 6000 ohms; parallel 100,000- and 150,000-ohm resistors to obtain 60,000 ohms; and series-connect a 270,000- and a 39,000-ohm resistor to obtain approximately 308,000 ohms as needed.) Use insulating spaghetti on all resistor leads to prevent accidental short circuits. Then solder all connections.

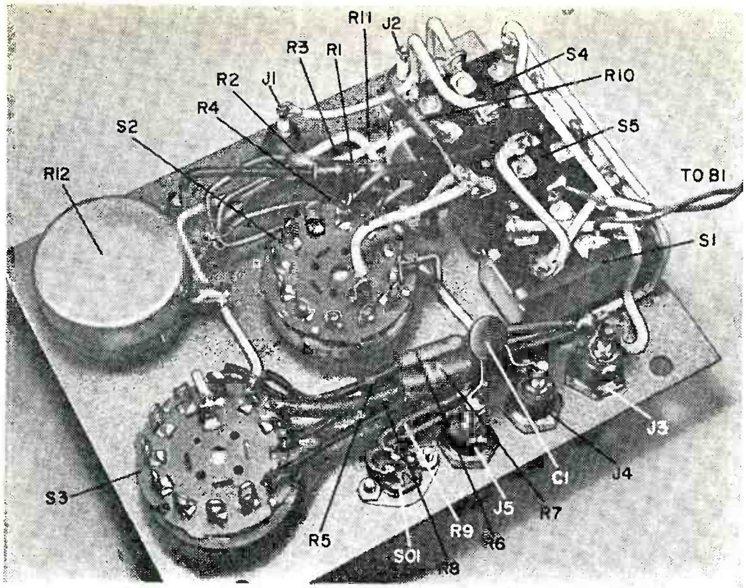


Fig. 1. All parts except batteries and holders should be mounted on the front panel of the metal box.

It will be necessary to nibble or file away parts of the bent-over edges on the body of the utility box (see Fig. 2) to allow the front panel to properly mate with the sides. Mount the battery holders on the rear of the box as shown, and solder hookup wires from *S1* ("NPN-OFF-PNP" switch) to the holders. Finally, insert the batteries in the holders, and secure the front panel in place.

Using the Adapter. Connect test cables from *J1* and *J2* on the adapter to the appropriate input jacks on the VTVM (see schematic diagram). Set the meter's FUNCTION switch to "plus d.c. volts" and the RANGE switch to either 1.5 or 3 volts—whichever your adapter is designed for. Then plug a test transistor into *SO1*, or connect its leads to *J3*, *J4*, and *J5* (collector, base, and emitter jacks or binding posts, respectively).

First, measure leakage currents I_{CBO} and I_{CEO}. (If you measure gain first, the meter reading obtained may be due to excessive leakage instead of base current.)

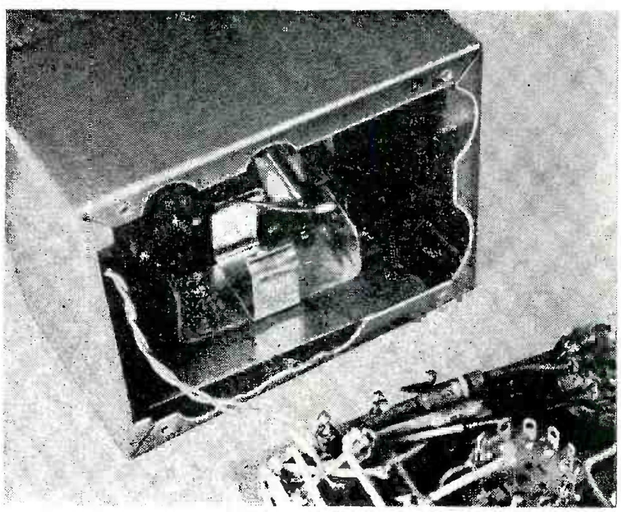


Fig. 2. It is necessary to nibble or file away portions of the bent-over edges on the body of the metal box to permit front panel and sides of box to mate properly.

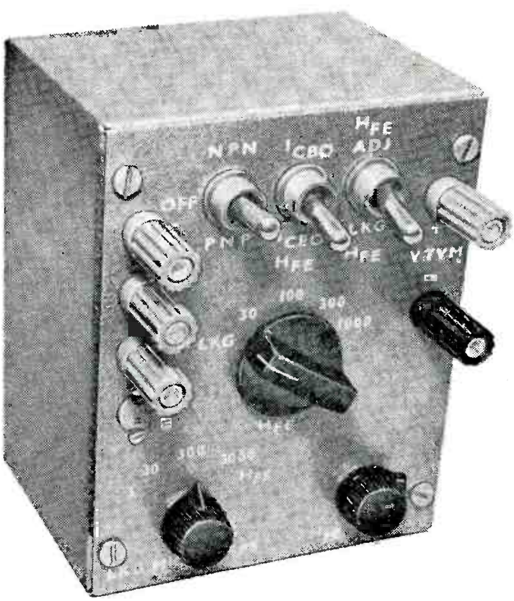
RANGE RESISTANCE TABLE				
FUNCTION	1.5-VOLT D.C. RANGE		3-VOLT D.C. RANGE	
h_{FE}	Resistance (in ohms)	h_{FE} Range Full Scale	Resistance (in ohms)	h_{FE} Range Full Scale
R1	10,000	50	6000*	30
R2	30,000	150	20,000	100
R3	100,000	500	60,000*	300
R4	300,000	1500	200,000	1000
R5	100		200	
LKG		Leakage Range (μA)		Leakage Range (μA)
R6	300	5000	1000	3000
R7	3000	500	10,000	300
R8	30,000	50	100,000	30
R9	308,000*	5	1,100,000	3
R10	11,000,000		1000	

See text

Table reflects differences in gain and leakage range multiplier resistors needed for 1.5- and 3-volt d.c. VTVM ranges. To obtain non-standard resistance values, connect two or more standard value resistors in parallel by following instructions given in the text.

To measure collector-to-base leakage current, set *S5* to "I_{CBO}," *S2* and *S4* to "LKG," and *S3* to the lowest range. Move *S1* to "NPN" if the test transistor is *npn* ("PNP" if *pnp*-type). The meter pointer will now indicate I_{CBO} in microamperes.

Next, determine the collector-to-emitter leakage current. To do this, set *S5* to "I_{CEO}," *S2* and *S4* to "LKG," and *S3* to any position that will give a good meter reading when *S1* is set to the appropriate position as determined by the type of transistor under test. Now, read I_{CEO} in microamperes on your meter.



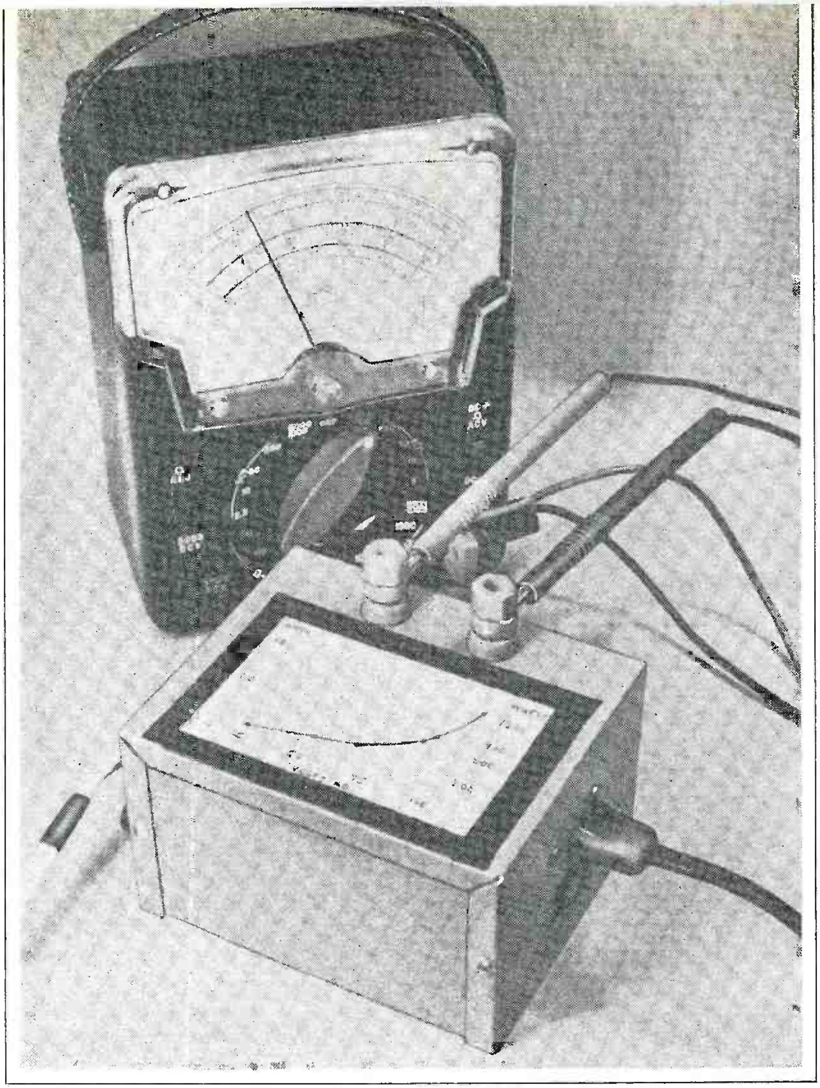
The finished transistor test adapter unit is compact and conveniently independent of line power.

Most low-power germanium transistors will show between 1 and 5 μA I_{CBO}, while I_{CEO} may be as high as 200 μA, depending on the gain of the transistor. Silicon transistors, on the other hand, have exceptionally low leakages and will often test out at less than 0.1 μA. In any case, check the readings you obtain against the figures given for that particular transistor in a transistor manual. If the readings obtained are higher than those listed, the leakage is excessive, and the transistor should be discarded.

To measure d.c. *beta*, set *S3* and *S5* to "h_{FE}" and *S2* to a mid-range—say, 300. Move *S1* to the appropriate position as described for leakage tests, set *S4* to "h_{FE} ADJ," and adjust *R12* for full-scale deflection of the meter's pointer. (If you are unable to obtain full-scale deflection, the battery is weak and should be replaced). Now move *S4* to its alternate position, and read the transistor's gain on your VTVM.

Next, open-circuit the base of the transistor by moving *S2* to "LKG." The meter pointer should drop to—or very near—zero if the transistor is good.

You may be able to measure gain on several different ranges, and the readings obtained may not agree with each other. Such discrepancies are normal and are due to the variations in tolerance among the resistors and to transistor nonlinearity. –30–



Measure A.C. Amps & Watts with Your VOM

BY NEIL JOHNSON

YOU CAN USE ANY FILAMENT TRANSFORMER IN MAKING LOW-COST 1200-WATT ADAPTER

FEW EXPERIMENTERS have facilities to measure the wattage or alternating current drawn by a piece of electrical or electronic equipment. The question of how many watts a certain piece of gear draws during operation goes unanswered. The main reason for this situation is that a broad-range a.c. ammeter or wattmeter is expensive.

However, most experimenters own a multimeter—VOM or VTVM. With the

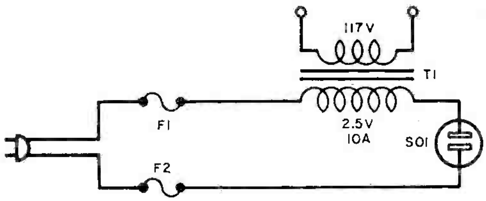


Fig. 1. Don't let simplicity of circuit fool you; it does a good job. Almost any filament transformer can be used as explained in text.

PARTS LIST

F1, F2—10-ampere fuse
SO1—A.C. outlet
T1—Filament transformer: primary, 117 volts; secondary 2.5 volts, 10 amperes (Allied Radio 54 B 3711 or similar—see text)
Misc.—A.C. line cord with plug, feedthrough grommet, binding posts (2), fuse holders (2), suitable chassis, test jig—see text

HOW IT WORKS

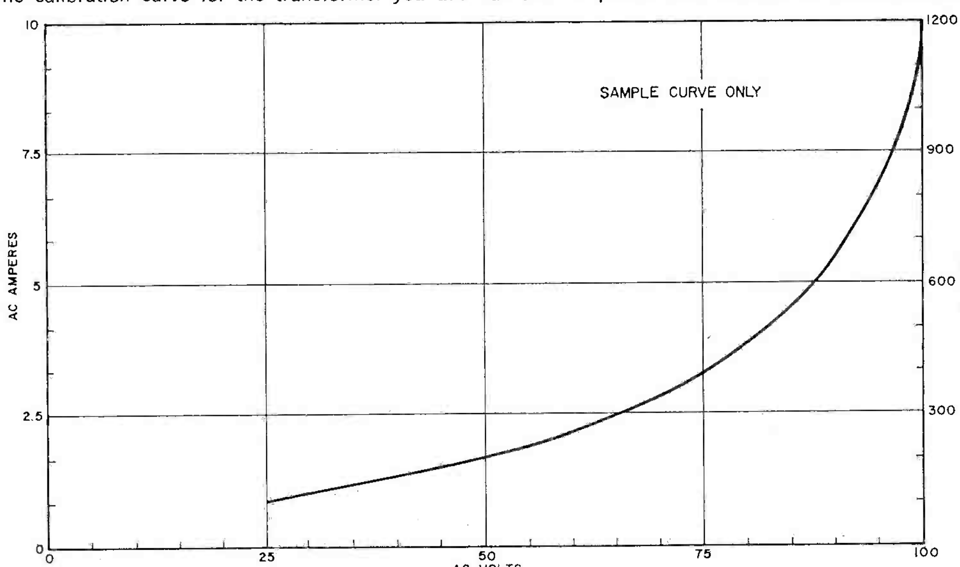
The heart of the adapter is a conventional filament transformer hooked up "backward." When a piece of gear is plugged into *SO1*, current proportional to the wattage of the load will be drawn through the low-resistance, low-voltage winding. This will induce in the 117-volt winding of the transformer a voltage that can be easily measured. The higher the voltage, the greater the current being drawn by the load.

There is a bonus with this type of current measurement. As the load applied to *SO1* is increased, there will come a point where the transformer core will saturate. This effect produces nonlinear output readings with the result that a larger meter scale differential exists between currents at the low end of the scale, and smaller at the high end. For example, a 1-ampere change at the 2-ampere point will move the multimeter needle a greater distance than a 1-ampere change at the 8-ampere point. This is desirable because, in the first case, the change is a significant 50%, while in the second case, the change is only 12½%. In essence, this is a form of "expanded scale" metering.

addition of a low-cost filament transformer, and a few other parts, you can convert your VOM into an a.c. ammeter or wattmeter. The ammeter adapter to be described here will enable your VOM to measure from an ampere, or so, to over 10 amperes a.c., or from a couple of watts to over 1000 watts.

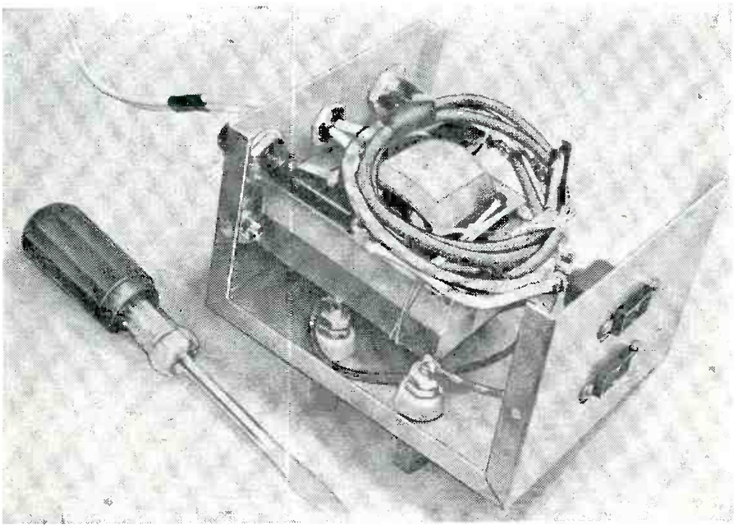
Construction. Although the transformer specified in the Parts List for the adapter has a 2.5-volt, 10-ampere secondary winding, you can use almost any filament transformer you happen to have at hand provided that the low-voltage winding can carry the current range you want to measure. For example, a 5-volt, 6-ampere filament transformer can be used if the load current being measured does not exceed six amperes (at 117-volt nominal line voltage, this amounts to about 702 watts). The only requirement, other than current-carrying capability, is that the filament winding have a low

Fig. 2. Actual-size graph that can be copied (without the sample curve) and glued to your metal cabinet. The calibration curve for the transformer you use can then be plotted and drawn in for future reference.



voltage rating so as not to introduce an excessive voltage drop and distort the true wattage reading.

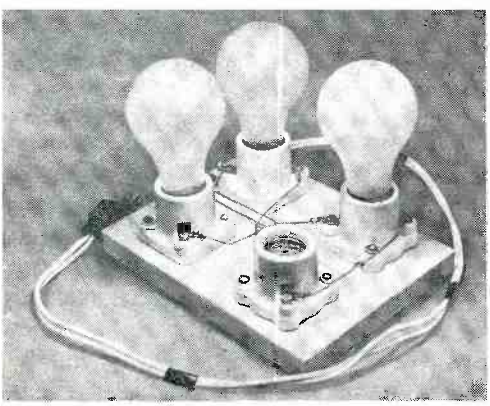
The schematic in Fig. 1 and the photo show one method of construction. (Almost any method will do.) Transformer *T1* is mounted within the metal box, the two input fuses (*F1* and *F2*) and a.c. line cord protrude from one end, while the a.c. outlet (*SO1*) is mounted on the other end. The multimeter binding posts, and the meter calibration graph, are affixed to the top of the box.



In the author's version, the filament transformer, two fuse holders, and the line cord grommet are on one wall, the output binding posts are on the middle wall, while a pair of a.c. sockets are mounted on the third chassis wall. Layout is not critical; any other will do as well.

Calibration. Temporarily make up a test jig consisting of four conventional electrical screw-in candelabra lamp sockets. Wire these sockets in parallel to a length of ordinary lamp wire terminated with a conventional electrical plug. Mate this plug with *SO1* on the ammeter adapter, then connect your VOM (set to its highest a.c. range) to the binding posts. Plug the adapter into the power line.

Bulbs of various wattages are used to create a wide load variation. Be careful of exposed line wiring.



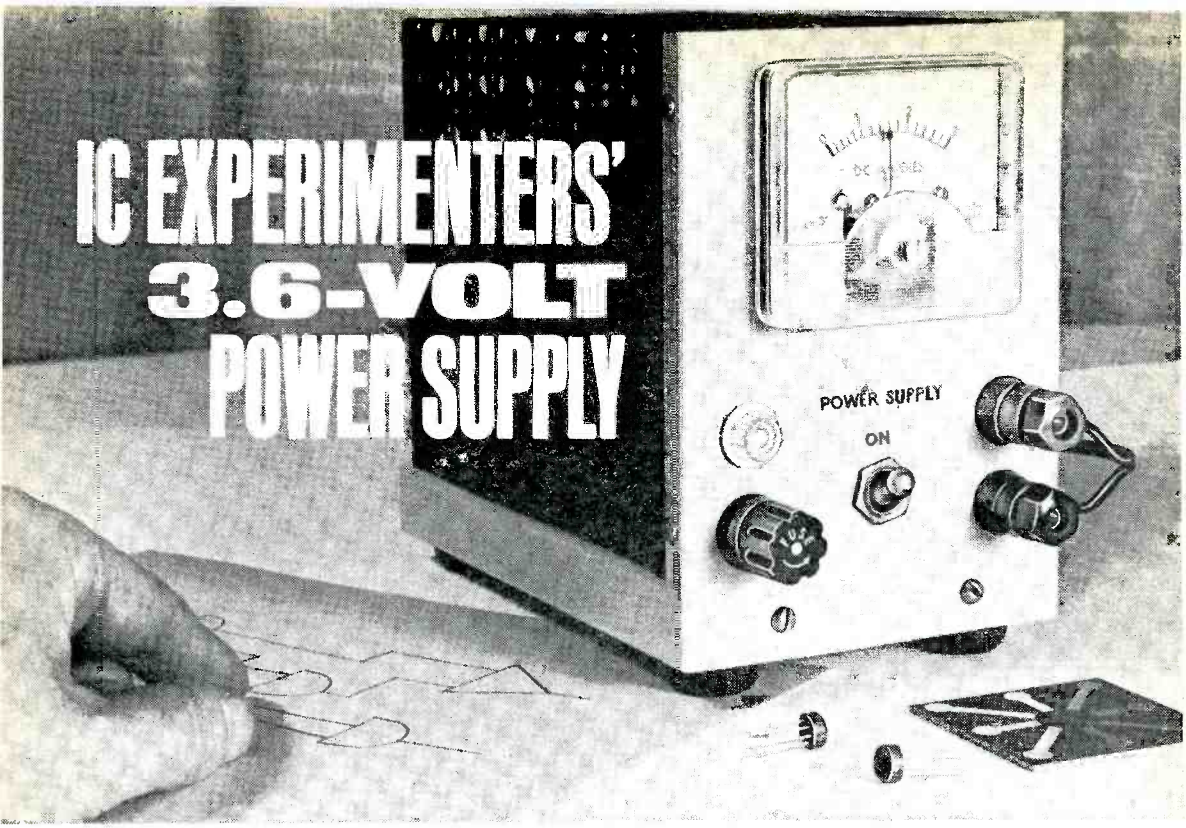
Start the calibration by inserting a low-wattage lamp into one of the sockets on the test jig. Adjust the VOM a.c. range switch until an easy-to-read indication is found on the meter scale. Record this value and the wattage of the bulb. Various wattage lamps, or combinations of lamps, can be inserted into the sockets of the test jig to produce a range of wattages.

As necessary, change the a.c. voltage range switch on the VOM. The wattages that produce the meter indications should be recorded. If electrical appliances are used for the very high wattages, remove the test jig plug from the adapter, and insert the appliance plug. These appliances usually have a nameplate calling out their wattages.

Calibration Curve. After a sufficient number of readings have been recorded, make up a calibration curve as shown in the graph (Fig. 2). To convert wattage

(*Continued on page* 151)

IC EXPERIMENTERS' 3.6-VOLT POWER SUPPLY



JUST THE THING FOR THOSE IC PROJECTS

BY FRANK H. TOOKER

LOW-COST integrated circuits are being used in an increasing number of home-built projects. For such applications, the experimenter needs a stable, low-cost, high-current 3.6-volt power supply. This voltage (3.6 volts) is the level required to operate most commonly available IC's.

The power supply described here will deliver up to 1.5 A at 3.6 V ± 150 mV continuously. The combined hum and noise at maximum output is 120 mV and the supply will run cool, even with 24-hour-a-day operation. A built-in ammeter indicates the current being drawn by the circuit under test.

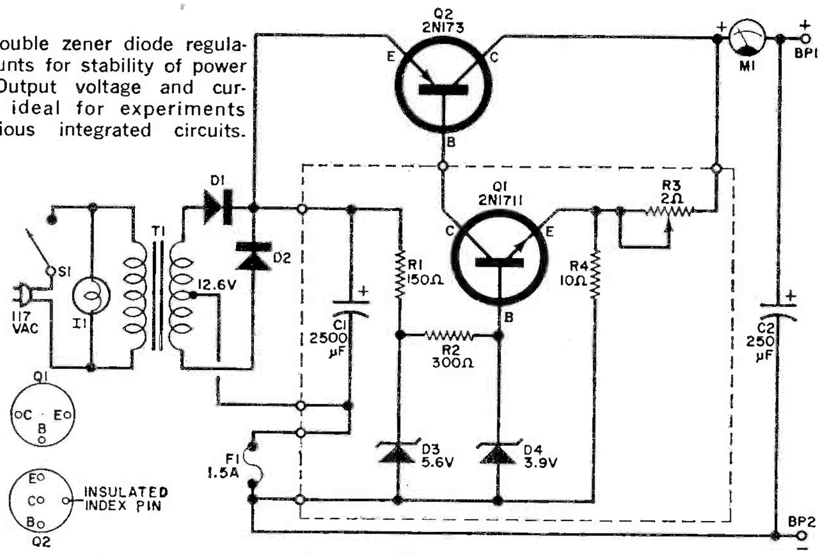
Construction. The components shown within the dashed box of Fig. 1 are mounted on a printed circuit board, such as that shown actual size in Fig. 2. A ⅜" hole must be drilled in the board for potentiometer *R3*. Once the PC board is made, install the components as shown in Fig. 3. After mounting all the parts, fit the radial heat sink over transistor *Q1*.

The rectangular heat sink that supports power transistor *Q2* and rectifier diodes *D1* and *D2* is drilled as shown in Fig. 4. When mounting the semiconductors on the heat sink, use mica insulating wafers—liberally coated with silicone grease on both sides—to insulate the semiconductors from the metal heat sink. Don't forget to use insulated mounting hardware for the transistor. The cathodes of the rectifier diodes, and the leads of the transistor should protrude through the flat side of the heat sink.

Connect the required PC board terminals to the semiconductors as shown in the schematic. Then secure the board to the flat side of the heat sink using four long insulated standoffs and the necessary hardware.

The author used a block of smooth wood for the base. This simplifies the mounting of the heat sink (using a pair

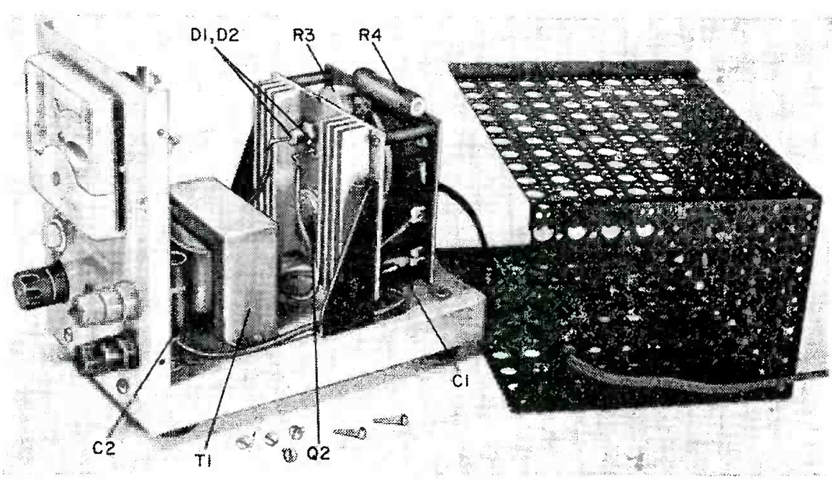
Fig. 1. Double zener diode regulation accounts for stability of power supply. Output voltage and current are ideal for experiments with various integrated circuits.



PARTS LIST

BP1, BP2—5-way binding posts, one red and one black
C1—2500-µF, 10-volt computer-grade electrolytic capacitor
C2—250-µF, 6-volt electrolytic capacitor
*D1, D2—2-ampere silicon rectifier diodes**
D3—5.6-volt, ¼-watt zener diode
D4—3.9-volt, ¼-watt zener diode
F1—1.5-ampere, 3AG fuse
M1—D.c. ammeter, 1.5 amperes minimum
I1—117-volt neon lamp and resistor assembly (Leecraft 32-2117 or similar), or 117-volt lamp
Q1—2N1711 power transistor
Q2—2N173 power transistor
R1—150-ohm, ½-watt resistor
R2—300-ohm, ½-watt resistor
R3—2-ohm, 5-watt wire-wound potentiometer
R4—10-ohm, 10-watt wire-wound resistor
S1—S.p.s.t. switch
T1—Filament transformer; secondary 12.6-volts @ 2 amperes, C.T.
Misc.—Rectangular heat sink 3" x 3⅜", fuse holder for 3AG fuse, 5-ohm, 10-watt resistor for calibration, wood for base, metal for front panel and heat sink brackets, silicone grease, heavy-duty screen, radial heat sink for Q1, line cord, rubber feet (4), insulated spacers (4), screws, wire, solder, etc.*

**Several mail-order suppliers are selling a heat sink with four silicon rectifiers (including mounting hardware) for about $2.00. Look in your latest catalog for this bargain. It is sometimes called "Battery Charger Kit."*



Protective screen was shaped by the author out of stock aluminum available at many hardware stores. Note the position of the 10-watt resistor R3 suspended above PC board.

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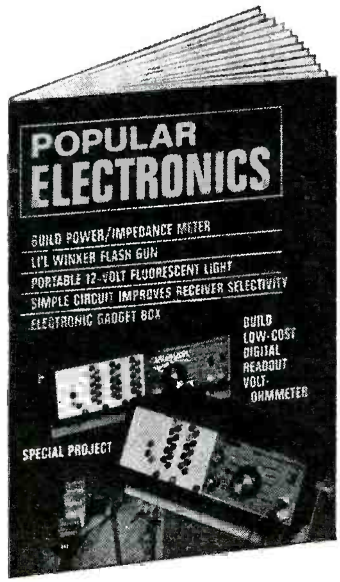

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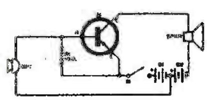

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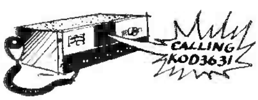

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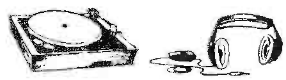

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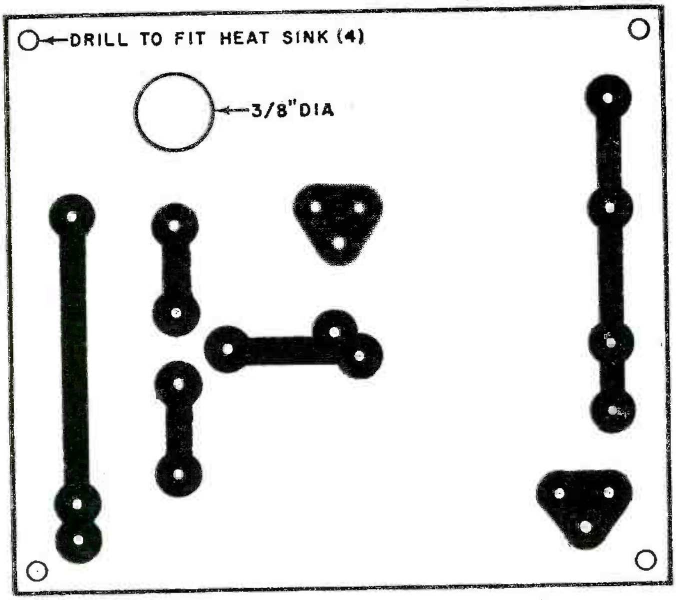


Fig. 2. Actual-size printed circuit board used to simplify wiring of the power supply. A slight change was made in this board compared to the one below in the photo. In this board zener diodes D3 and D4 are fed to individual holes, but in the board below the two diodes are inserted in the same hole. The ⅜"-diameter hole is to mount potentiometer R3. Board is mounted to—but spaced from—the heat sink as shown in Fig. 4.

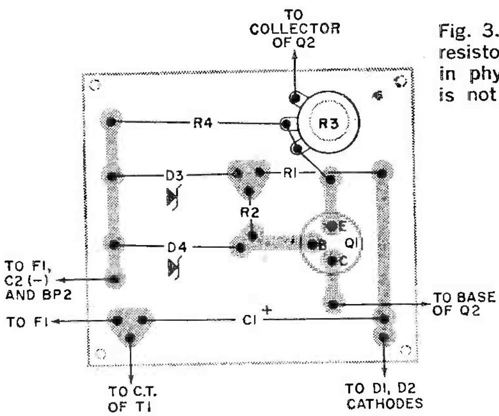
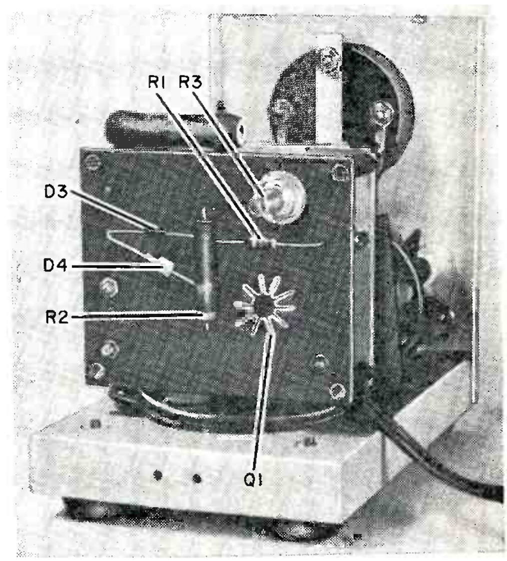


Fig. 3. Parts layout on the PC board. The 10-watt resistor R4 is suspended by its leads and is not in physical contact with the board. This resistor is not called out in photo, but is clearly visible.



Rear view of author's prototype. A piece of hard wood was used for the base to simplify mounting.

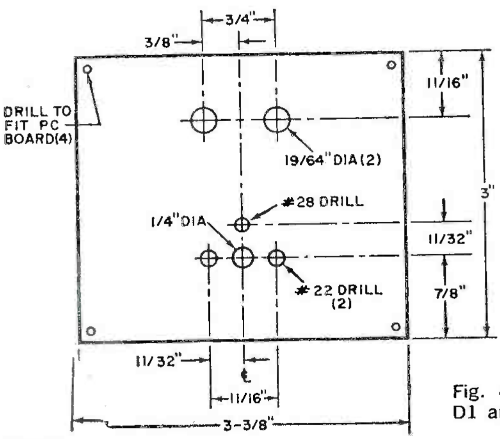


Fig. 4. Drilling instruction for heat sink. Diodes D1 and D2 mount in top holes, Q2 in holes below.

of brackets) and the affixing of both the front panel and the enclosing cage.

The front panel can be layed out as desired to accommodate meter *M1*, the two output binding posts *BP1* and *BP2*, power ON-OFF switch *S1*, and indicator lamp *I1*. It is suggested that a red binding post be used for the positive voltage output (*BP1*) and a black one for the negative voltage output (*BP2*). Both binding posts are insulated from the metal front panel.

The enclosure should provide sufficient ventilation for the heat sink.

HOW IT WORKS

The power supply is a series-regulator circuit using a zener diode as the voltage reference. In a supply of this kind (see Fig. 1), when potentiometer *R3* is set for minimum resistance, the output voltage of the supply is equal to the voltage drop across the reference zener diode (*D4*) minus the emitter-to-base voltage drop of control transistor *Q1*. In this case, as the voltage across *D4* is 3.9 volts and the drop of *Q1* is 0.6 volts, the output voltage of the supply will be 3.9—0.6=3.3 volts.

At breakdown voltage levels below approximately six volts, the dynamic resistance of a zener diode tends to increase. The higher dynamic resistance reduces the regulation accuracy and decreases the filtering efficiency unless steps are taken to prevent or reduce such effects. In this design, to reduce *D4*'s maximum load current (maximum base current of *Q1*) to less than 10% of its steady-state value at zero output from the supply, the gain product of the *Q1-Q2* combination has been made high. In addition, the voltage from the rectifiers and filter (*D1*, *D2*, and *C1*) is pre-regulated by *R1* and zener diode *D3* before it is applied to the *D4-Q1* combination. Thus, *D3* actually provides the greater part of the regulation, reducing the load on *D4*. Without *D3*, the wide voltage swing (about 2 volts) at the output of the rectifiers due to the variations in load requirements would result in a higher hum level and reduced regulation accuracy.

Operation. Once all wiring has been completed and checked over for any possible errors, connect a 5-ohm, 10-watt resistor across the output-voltage binding posts. Then connect a 5-volt d.c. voltmeter across this resistor. Turn on *S1* and observe that the front-panel indicator lamp (*I1*) comes on. Observe the voltmeter indication, and adjust potentiometer *R3* to obtain a 3.6-volt indication. Turn off the power, and remove both the 5-ohm resistor and the voltmeter from the output terminals.

The power supply will now deliver 3.6 volts for any load up to 1.5 amperes with exceedingly good regulation and very low ripple. —30—

THE BEST OF TIPS & TECHNIQUES

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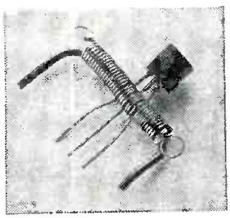
PROTECT MOSFET FROM ELECTROSTATIC DESTRUCTION

The very high input resistance of a MOSFET is due to a microscopically-thin film of glass deposited between the transistor chip and metal gate electrode. This film is so delicate that friction-produced electrostatic charges built up by allowing the MOSFET to slide around inside a plastic box—or even handling—without proper precautions will puncture the film. To protect a MOSFET from electrostatic destruction, the leads must be kept shorted together at all times except when the unit is in a circuit. Press the MOSFET leads between the coils of a small-diameter spring—while keeping the leads twisted or shorted together. It may be necessary to stretch the spring slightly, but the spacing of the turns must be kept less than the diameter of the MOSFET's leads to insure a short circuit. Then pass a length of copper wire through the spring, bending the ends at right angles as shown, to hold the MOSFET in place.



—*Frank H. Tooker*

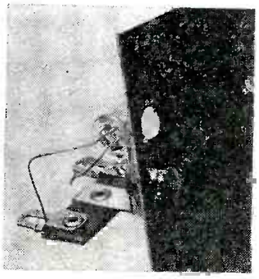
MAKE VECTOR-PIN INSERTER TOOL

You can make a Vector-pin inserter from a 3″-long soft aluminum rod. Drill a 0.111″ hole about 5⁄32″ deep in one end of the rod. After drilling the hole, slowly and carefully squeeze the drilled end in a vise. You should be able to slide the Vector pin into the hole easily but the tool should hold the pin firmly once it is in place. The blunt end of the inserter can also be used to remove pins from Vector board without damaging either the board or pins.

—*Stephen E. Maziarz*

INEXPENSIVE PILOT LAMP ASSEMBLIES

Looking for a low-cost, easy-to-mount indicator lamp assembly for your projects? Well, you can't get much less expensive than making an assembly from an NE-2 lamp, clear plastic cable clamp, and a two-lug terminal strip. The first thing you do is decide where you want to mount the lamp assembly; then drill a ¼" hole through the panel in that location. Next, slide the lamp inside the cable clamp, and place the assembly against the panel to determine where to drill the mounting hole. Then, after drilling the second hole, place the mounting lug of the terminal strip between the cable clamp and panel, and secure them in place with appropriate hardware. The terminal strip provides a convenient mount for the series dropping resistor needed for the lamp. For colored lamps, use colored plastic tape, placing a ½" length over the hole on the inside of the panel.



—*Donald R. Hicke*

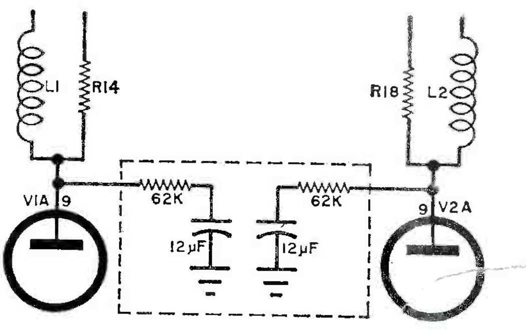
CLEAR UP CB AND HAM TVI

One cause of television interference (TVI) from many amateur radio and Citizens Band stations can be traced to the use of monitors or field strength meters. These devices employ diodes which rectify some of the r.f. and often generate enough harmonics to produce TVI radiation. Grounding the case of the monitor and moving it farther away from the transmitter will usually reduce—and possibly eliminate—the interference.

—*James E. Arconati*

LOW-FREQUENCY COMPENSATION FOR EICO MODEL 460 OSCILLOSCOPE

The transconductance of vacuum tubes changes between d.c. and low-frequency a.c. This effect is noticeable in EICO's Model 460 oscilloscope as a change in gain between d.c.



and a.c. signals, and a pronounced sloping of low-frequency square waves. The compensation network shown here will compensate for low-frequency losses in the Model 460. For best results, you might have to allow a slight variation in the value of the resistors for individual tubes. The easiest way to install the capacitors is to connect one lead of each to a ground lug held by terminal board TB-16, and the other lead directly to pin 9 on the respective tube sockets. —*Donald Stauffer*

PERMANENT MAGNET SERVES AS BULK ERASER

Need a bulk eraser for your recording tapes? If you do, but can't justify the cost since you will use it only occasionally, try doing the job with a small permanent magnet. To erase a magnetic tape with the permanent magnet,

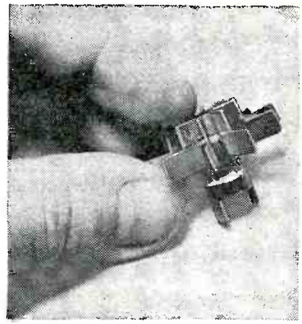
thread the tape on your recorder as you normally would if you were going to record or play back, and hold the magnet as close as possible to (but not touching) the tape. Then activate the "fast-forward" or "rewind" control, and the magnet will erase all tracks. —*Fred Blechman*

TUBE SHIELD MAKES LOW-POWER TRANSISTOR HEAT SINK

A tube shield can often be used as an inexpensive heat sink for transistors in projects where space is not at a premium. Most shields for 7-pin tubes can be simply snapped over the crown (raised part) of a TO-3 transistor case. The split type of tube shield shown in the photo is perhaps your best bet, however, since it is inexpensive and its expansion springlike action makes for a good all-around snug fitting. It will effectively dissipate heat build-up in low-and most medium-power transistors. For high-power transistors, a much larger and more efficient heat sink is normally required. —*Richard Oram*

TRANSISTOR HEAT RADIATOR EXTENDS NUVISTOR TUBE LIFE

If a Nuvistor tube could be operated at a lower ambient temperature its life might be extended. With this in mind, attach a transistor heat radiator to the top of the Nuvistor's envelope as shown in the photo.



The fins will provide a larger radiating surface, thus increasing heat radiation efficiency. Any heat radiator that will fit snugly over the Nuvistor will serve.

—*Richard Mollentine,* WAØKKC

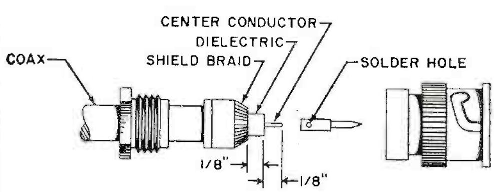
IDENTIFYING SPACE AGE RESISTORS

Anyone who has visited his local surplus parts supplier recently has probably come across precision "Space Age" or MIL type resistors. If precision metal film, these resistors can be identified by the curious coding stamped on them (such as, RN6049R9F). Unless you know how to interpret this code, you have to buy blind. However, it is relatively simple to identify some of these resistors. The first four digits in the code tell you the power rating—RN60, RN65, RN70, RN75, and RN80 indicate ⅛-, ¼-, ½-, 1-, and 2-watt units, respectively. Of the next four digits, the first three are the significant figures of the resistance value, and the fourth indicates the number of zeros. Inserting of the letter "R" in the midst of these four digits locates the decimal point for values less than 100 ohms. The last letter, "F," indicates that the resistor has a 1% tolerance. In the above example, the code is read: ⅛ watt, 49.9 ohms, and 1%.

—*Herman W. Frisch*

QUICK-CHANGE PROBE CONNECTOR

Quick-change capability can be built into a VTVM or other test equipment that uses a microphone connector for attaching test cables. Replace the mike connector with BNC coaxial cable fitting. The BNC fittings are shielded, assure positive electrical contact, and can be disconnected with a simple quarter-turn motion. To make the substitution remove the old mike connector and re-

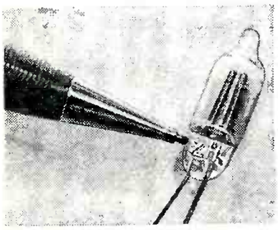


place it with a UG-1094A/U BNC connector. Replace the fitting on the test cable with a UG-88/ BNC connector (see drawing). Since the shorting switch in some VTVM probes can be erratic on the low resistance range, it is a good idea to make a straight-through test cable for this function, using a UG-88/U BNC connector, a length of RG-58A/U, and two alligator clips.

—*Robert N. Tellefsen, WØFMF*

IDENTIFY GE NEON LAMP TYPES AT A GLANCE

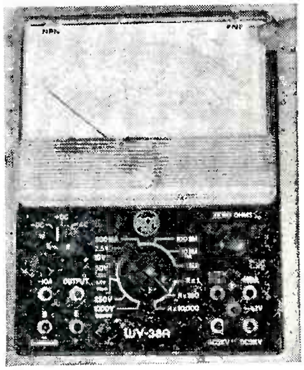
Have you been wondering how to identify the type of those miniature neon lamps you have gathering dust in your spare parts box? By carefully examining the glass bases of the individual lamps, you'll find the lamp number on one of the flat surfaces (see photo); the other flat surface has the initials "GE" stamped on it, indicating the manufacturer. Armed with these simple facts, you need never be in the dark about miniature neon lamps again.



—*Steve Horowitz*

OHMMETER "TELLS" YOU WHETHER A TRANSISTOR IS NPN OR PNP

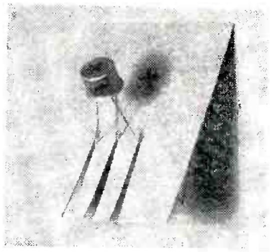
Using an ohmmeter, you can determine whether a transistor is *npn* or *pnp*—if you know transistor theory or can compare the readings obtained with those of a known type of transistor. While this is the common practice, there is an easier way to do it. Determine the polarity of your meter's probes (in most cases, *but not all*, the *COMMON* probe is negative). Mark the negative probe jack on the meter case with a "B" for base and the positive probe with an "E" for emitter. Now, mark the low resistance end of the ohms scale with the legend *"pnp"* and the high resistance end with *"npn."* Touch the negative (or "B") probe to the base of the unknown transistor, and other probe to emitter. Meter will deflect to *pnp* or stay on *npn*.



R. E. Kelland

NO-COST HEAT SINK PREVENTS HEAT DAMAGE

You can use a heat sink made from scrap copper or aluminum (see photo) to protect transistors and diodes from heat damage when soldering them to printed circuit boards. Taper the slots to fit the type of transistor being mounted (the prongs of the heat sink should clamp onto all three transistor leads simultaneously). However, if you design your own printed circuit boards and take care to maintain all transistor and diode lead hole centers reasonably the same, two or three different such heat sinks will generally suffice for most components—other than those in TO-3 and TO-36 cases. Use very thin sheet copper or aluminum for close-to-the-board mounting. And you'll have to mount the solid-state parts on the board first.



—*Roland J. Tauer*

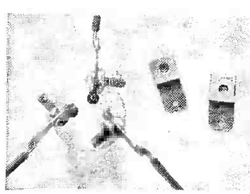
INTERCOM SPEAKER SUBSTITUTE

Since good buys on 45-ohm loudspeakers are rare, it is sometimes more economical to use a 4- or 8-ohm speaker when making replacements in equipment calling for 45-ohm speakers. To make this substitution, you will need an impedance-matching transformer (Lafayette Radio Electronics stock 33H8578 at $1.75, or similar) with a nominal primary impedance of 45 ohms and a secondary impedance to match the new speaker. The fact that many of these transformers are designed for use in transistor circuits does not bar their use in vacuum tube circuits. Power rating of the transformer does not have to be as great as the capability of the speaker as long as volume level is maintained below the power-handling capability of the transformer.

—*Robert L. Brown*

SAFE CONNECTIONS FOR TRANSISTORS

Home-made J-clamps can save the day when you need a means of safely connecting the large pins of a TO-8 transistor or SCR into a circuit. The clamps can be easily fabricated from thin brass or copper-shim stock as shown in the photo. For TO-8 pins, cut the shim stock to $\frac{5}{32}$" x $\frac{3}{4}$", fold over $\frac{1}{4}$" from one end (use the transistor or SCR pin to obtain the correct fold radius), and drill a #42 hole through both tabs $\frac{5}{32}$" from the fold. Then drill another much smaller hole through the tab



opposite the fold. Finally, secure the clamps to the transistor pins with #2-56 hardware, and solder the hookup wires to the tabs, passing the wires through the small holes. Be sure the hardware holds the clamps firmly in place. If desired, you can also slip a length of heat-shrinkable tubing over the clamps to keep them insulated from the surrounding circuit.

—*Frank H. Tooker*

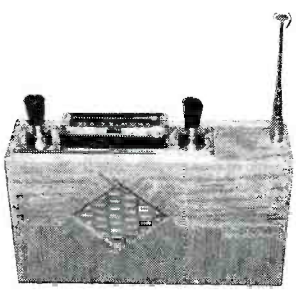
TWO BLOCKS OF WOOD BECOME WIRE LEAD STRAIGHTENER

Resistors, capacitors, diodes, and other small parts that have wire leads are easier to store and use if the leads are straight. After you breadboard a project or cannibalize parts from surplus equipment, there is often a considerable number of leads to be straightened. You can save a lot of time and effort if you place roughly hand-straightened leads between two blocks of hard wood, and stroke the top block back and forth a few times to get rid of bends and kinks.

—*James E. Arconati*

CONVERT AUTO RADIO INTO PERSONAL PORTABLE

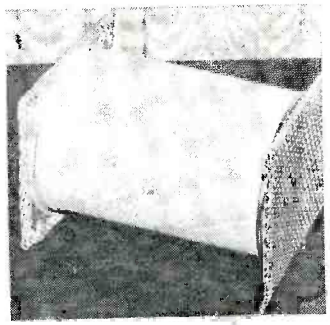
Instead of installing a portable radio in your car, how about converting a car radio into a portable? It isn't as difficult as it may sound. You'll need a telescoping antenna, a 55-pF mica capacitor, and six 1.5-volt penlight cells in addition to an all-transistor auto radio. To minimize current drain and prolong battery life, disconnect the dial light inside the radio. Then install the radio in a suitable cabinet (I used a cigar box covered with a decorative adhesive-backed vinyl). Finally, connect the batteries and antenna to the appropriate terminals on the radio, and solder the capacitor between the antenna and chassis of the radio to permit peaking the antenna trimmer. You'll find that the converted radio has excellent sensitivity and selectivity, good sound (especially if it has a tone control), and more than enough power for comfortable listening.



—*William S. Gohl*

HOW TO CONNECT 3.2-OHM SPEAKERS TO YOUR 8-OHM AMPLIFIER

While most modern audio amplifiers are designed for 8-ohm loads, there is a way to connect 3.2-ohm speakers to the new amplifiers without an impedance-matching transformer. You just connect two such speakers in series across the 8-ohm tap on your amplifier (see photo). The 4″-diameter speakers can be mounted at opposite ends of a one-pound coffee can and the speaker cones covered with expanded aluminum grilles or a grille cloth.



For other size 3.2-ohm speakers, appropriate size containers can be used. For best results, the speakers should be connected so that their phasing is opposite. (To check phasing, momentarily connect a 1.5-volt battery to the two free wires and observe the movement of the speaker cones; one cone should pull inward while the other moves outward. If both cones move in the same direction simultaneously, reverse the connections of one of the speakers.)
—*W. S. Gohl*

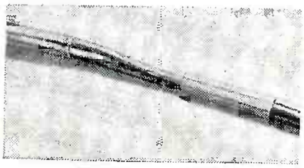
BAD POTENTIOMETER CAN CAUSE TROUBLE

Don't be surprised if an electronic device you stored away for a few years fails to operate properly when you put it back into service. If the set still won't work after you have made all the obvious tests and/or installed new parts, take a look at the potentiometer(s). Connect the probes of an ohmmeter to the center and one of the outer lugs of each potentiometer (if the pot is in parallel with any other component in the set, remove the wires from one of the outer lugs), and rotate the shaft while observing the meter. The meter pointer should deflect smoothly from the minimum to the maximum resistance stamped on the potentiometer. Then check the resistance from each lug to the potentiometer case (see photo); it should be infinite. If incorrect readings are obtained, and a suitable cleaner will not rectify the problem, the potentiometer should be replaced.

—*Lewis A. Harlow*

SOFT DRINK STRAWS MAKE NEAT WIRING HARNESSES

Instead of using multiconductor cables when you wire relays, interconnect discrete components, or fashion wiring harnesses, you can save a lot of money by neatly bundling the required number of single-conductor wires together. Then, to form a neat wiring harness, simply slip pre-cut lengths of plastic soft drink straws over the bundle of wires. Depending on how much flexibility you require from your homemade harness, the lengths of plastic straw should be between 1" and 2". The resulting harness will have a neat appearance.



—*Steven Koons*

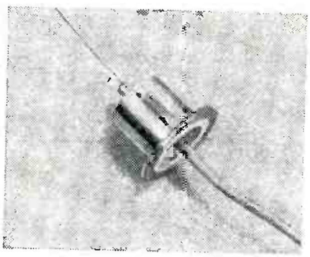
NEOPRENE FAUCET WASHERS MAKE HANDY RUBBER FEET

Neoprene faucet washers are almost as handy in electronics as they are necessary in plumbing. They are fairly hard, will stand a lot of abuse, and do not leave "eraser" marks on polished surfaces when used as feet for the chassis of an electronic project. These washers are available in a variety of sizes, are relatively inexpensive, and can be obtained from all plumbing supply stores and many hardware stores. When you install them, use a good all-purpose household cement.

—*Robert E. Kelland*

MAKE INEXPENSIVE FEEDTHROUGH INSULATORS AND HERMETIC TERMINATIONS

Defunct "top hat" diodes can be converted for use as feedthrough insulators and/or hermetic terminations for your projects. To prepare such a diode, you remove the flange cap by carefully filing it until the welded joint parts (see photo). Then use pliers to round out the pin on the crown of the diode case, and remove the wire lead from the pin. This leaves the glass-to-metal—Kovar—seal intact. Now, drill a hole (the same diameter as that of the crown of the diode case) in your chassis, insert the case in the hole, and solder the flange to the chassis. If you need a feedthrough insulator, just slide the wire through the pin in the crown of the diode case; for a hermetic termination, strip about ⅜" of insulation from the terminal wire, slide the wire into the pin, and crimp the pin for a firm joint.



—*H. St. Laurent*

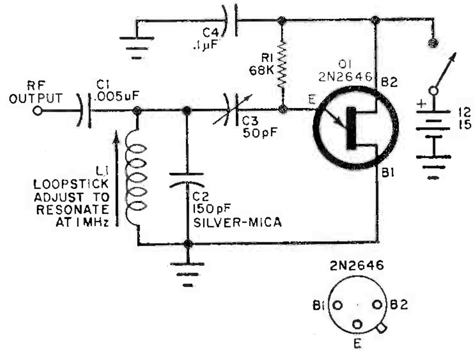
Megahertz UJT Oscillator

THEY SAID IT COULDN'T BE DONE

BY FRANK H. TOOKER

USED in simple relaxation oscillators, unijunction transistors (UJT's)—particularly those of the inexpensive variety—will not operate very far into the low radio-frequency range. However, the circuit shown at right enables sine-wave output from 2N2646 UJT's at 1 MHz. With selected UJT's of this type, the circuit will continue to operate up to about 1.5 MHz, above which frequency performance is poor.

In the circuit, *L1* and *C2* make up a tuned circuit which is resonated at 1 MHz by adjusting the core of *L1*. Components *C3* and *R1*, in series with *L1-C2*, comprise a relaxation oscillator circuit. Capacitor *C3* charges through *R1*, and when the peak-point emitter voltage of UJT *Q1* appears across *C3*, the UJT fires, discharging *C3* across the *L1-C2* tuned circuit. This sets the tuned circuit into oscillation and, thereafter, the positive-going excursions of the voltage across



The UJT operates at submultiple of output frequency and shock-excites tank circuit to generate r.f. output. This oscillator circuit can reach 1.5 MHz.

L1-C2 add to the voltage across *C3* to fire the UJT.

Conventional UJT's will not operate at 1 MHz—and even selected ones operate poorly at 500 kHz—but at lower submultiples of 1 MHz (333 kHz, 250 kHz, and 200 kHz), the UJT fires dependably. The setting of variable capacitor *C3* determines *Q1*'s firing rate. Thus, by adjusting *C3*, the firing of the UJT can be synchronized (accurately locked-in) with every third, fourth, or fifth cycle of oscillation of the *L1-C2* tuned circuit.

Since a comparatively large voltage is developed across *L1-C2*, the lock-in setting of *C3* isn't especially critical. In practice, all that is necessary is to adjust *C3* to the minimum value of capacitance that will produce a maximum signal at the oscillator's r.f. output terminal. To avoid hand-capacitance effects while you're adjusting *C3*, it is essential that its stator (not the rotor) be connected to the emitter of the UJT.

If you have several UJT's, try each one, for some 2N2646's work better in this circuit than others. The output of the oscillator is at a very high impedance; thus, if it is to be loaded at all, it must be worked into a high impedance to maintain oscillation.

—30—

MEASURE A.C. AMPS & WATTS

(*Continued from page* 133)

to amperes, divide the recorded wattage value by the line voltage. For example, if you have 600 watts on a 120-volt line: 600/120 = 5 amperes.

With respect to a.c. loads that are predominantly inductive—such as electric motors—the adapter will indicate volt-amperes, not watts. This phenomenon is common to all types of a.c. ammeters. To convert volt-amperes to true watts, multiply by the power factor of the device under test. If the power factor is unknown, use 0.8 as an average value.

Always start voltage measurements with the VOM set to its highest a.c. range, as the starting currents of some devices, particularly electric motors, can be very high. The resultant high voltage surge may damage the meter. —30—

MILLIVOLTMETER

(*Continued from page* 123)

duces no change in the deflection of the meter. (Use of the magnifying glass at this point is very helpful.)

Making a Measurement. Always check with a VOM or a VTVM to make certain that the voltage to be measured is 1.0 volt or less before connecting the unknown to the D.C. Millivoltmeter.

With the millivoltmeter connected to the unknown, set FUNCTION switch *S1* to CAL. Allow a minute or two for the instrument to stabilize, then adjust the CALIBRATE control as described above.

With the SENSITIVITY control turned back to minimum, set the MULTIPLIER switch to the required range and set the FUNCTION switch to READ. Holding *S3* down, adjust *R3* until *M1* reads midscale. Advance the SENSITIVITY control in steps and adjust *R3* until, with the SENSITIVITY control at maximum, pressing and releasing *S3* repeatedly produces no change in the deflection of the needle of *M1*. Turn off the FUNCTION switch. The unknown voltage can then be determined by multiplying the dial reading by the multiplier setting. For example, if, after making the necessary adjustment, the dial reads 2.75 and *S2* is set at 10, the potential being measured is $2.75 \times 10 = 27.5$ millivolts.

The measurement procedure may seem somewhat elaborate as explained here, but it is actually no more involved than the operation of a resistance bridge. Once you are accustomed to the order of the adjustments, you can make them almost automatically.

There is usually some slow wandering or drifting of the midscale reading of meter *M1* while the instrument is turned on. This is normal in an instrument of this sensitivity. It is due primarily to temperature variations and minute changes in the output of battery *B2*. None of this affects the accuracy of the instrument, but the center-scale position of the meter needle should always be checked and corrected if necessary, just before pressing *S3* and adjusting either the CALIBRATE control or the *R3* dial. —30—

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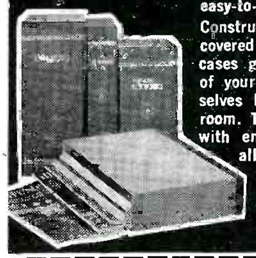

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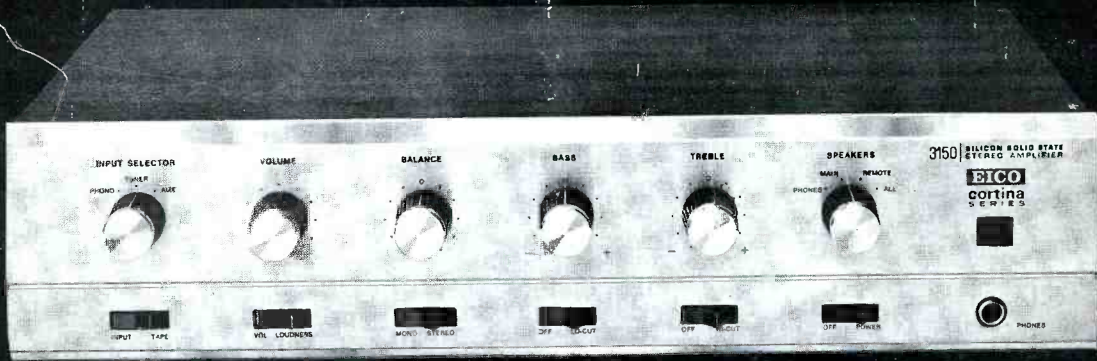

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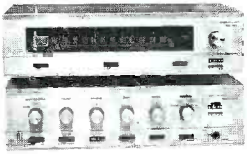

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