TENTH ANNIVERSARY EDITION

1968 POPULAR ELECTRONICS

ELECTRONIC EXPERIMENTER'S HANDBOOK

WINTER EDITION

$1.25

MEMO:

This AMLIGNER is one of the many fascinating projects in this book. Look at the metal locator, handy remote control and VOX systems, 70-watt hi-fi power amplifier, a good auto theft alarm, really sensational stereo speakers, easily built test equipment, plus useful projects for Hams, CB'ers, and SWL's.

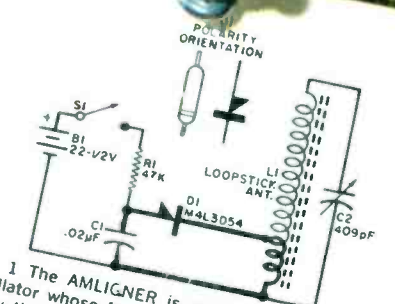
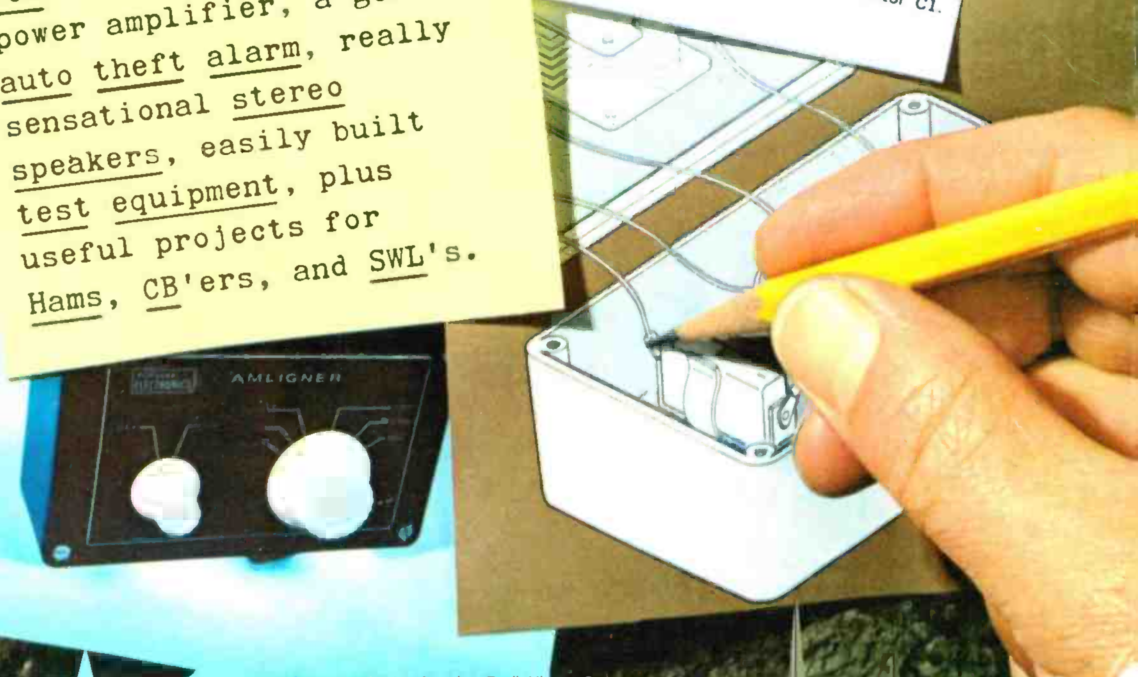


Fig. 1 The AMLIGNER is a free-running relaxation oscillator whose frequency is determined essentially by the value chosen for charging capacitor C1.



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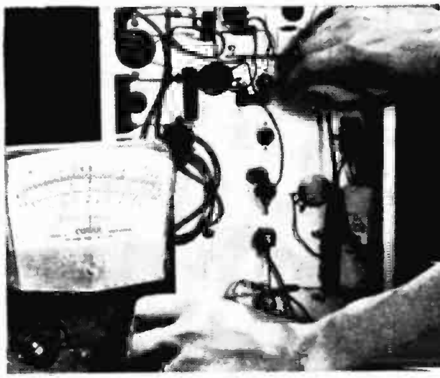

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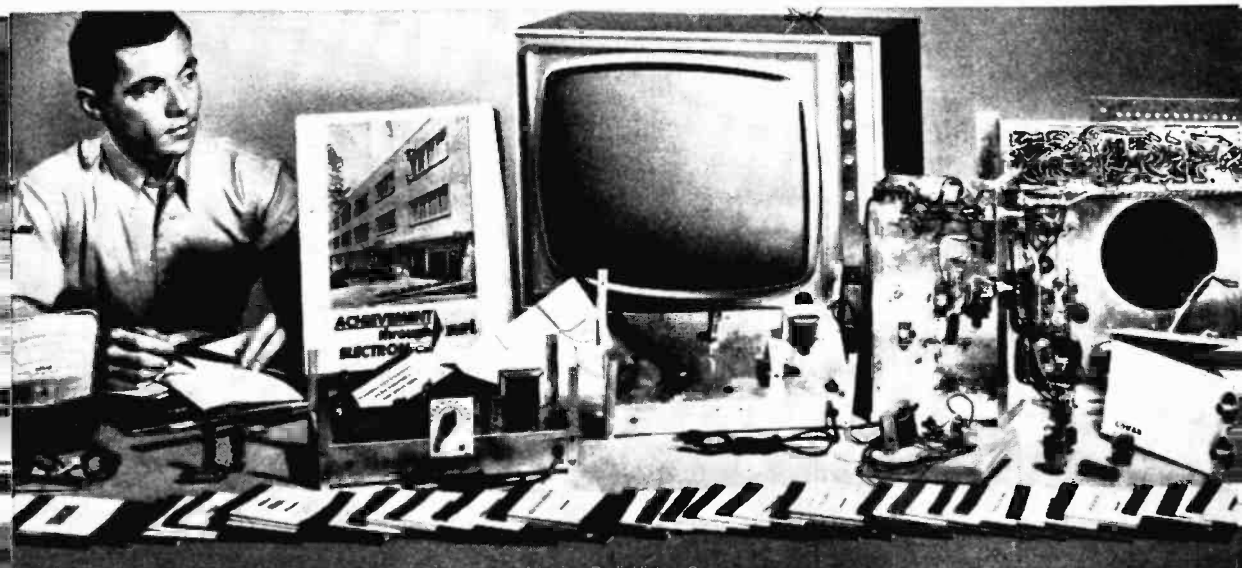

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WINTER EDITION
1968 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

TENTH ANNIVERSARY

Fourteen issues—and ten years ago—the first edition of the ELECTRONIC EXPERIMENTER'S HANDBOOK was published in cooperation with the staff of POPULAR ELECTRONICS. The reader reaction was so favorable that annual editions of this HANDBOOK were published through 1964, and semi-annual editions thereafter.

Hundreds of thousands of copies of the EXPERIMENTER'S HANDBOOKS were sold and the 500-plus construction projects in their pages have covered the gamut from the very simple to the very complex. The history of this HANDBOOK—though it is only ten years old—is a compressed history of experimental/hobbyist electronics itself.

In 1957, transistors and printed circuits were items infrequently used by the electronics hobbyist. Practically every project requiring electronic components was assembled by point-to-point wiring. The projects worked, but they looked awkward, lacked styling, and—in today's terms—were unsophisticated. No one in 1957 would have dreamed, or even suspected, that in only ten years the electronics experimenter would be utilizing integrated circuits (what are they?), unijunctions (eh?), Citizens Radio (you mean they changed the frequencies?), binary counters (ha! what with—pencil and paper?), or capacitive discharge ignition systems (another trick gadget for your car?).

Partially by design and partially by accident, some of the construction projects detailed in this edition are modern-day versions of the same projects that appeared in the first edition of the EXPERIMENTER'S HANDBOOK. If you have an old copy, you'll enjoy comparing the two.

But, who knows? Maybe in another 10 years we'll laugh at projects in this edition!

OLIVER P. FERRELL

CONTENTS

CHAPTER

1

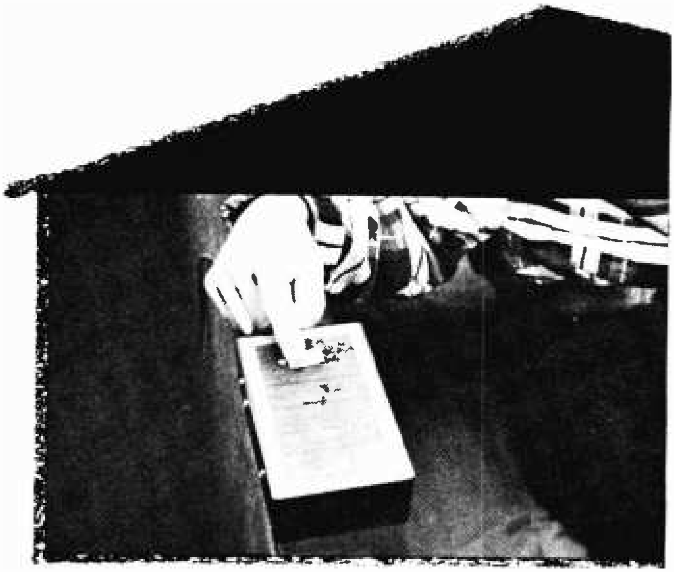
USEFUL PROJECTS

Looking backward, the first edition of ELECTRONIC EXPERIMENTER'S HANDBOOK contained a number of construction projects that in 1968 would have been grouped under this chapter heading, "Useful Projects." There were such things as a rain alarm, baby sitter (really an intercom), automatic light switch, Geiger counter, and even a metal locator. It's pretty difficult not to chuckle when reading that first edition—if only because the current techniques of building projects, the availability of components, and the overall improvements in circuitry are so outstanding.

Take the 1957 vs. the 1968 metal locator as an example. The older project was a cumbersome device and the photos show a poor fellow sweating as he lugs the ungainly search loop and big heavy box with batteries and three vacuum tubes over hill and dale. In 1968, our new metal locator (see page 25) has been developed around integrated circuits; the operating principle permits deeper search penetration, no earphones are required, and the whole unit is carefully balanced so that no straps are necessary and the locator can be carried in one hand.

Quite a difference!

BUILD A
Carrier-Current Remote-Control System



By R. ZARR

PUT A RADIO-FREQUENCY SIGNAL ON YOUR 117-VOLT A.C. LINE TO CONTROL ELECTRICAL DEVICES FROM ANYWHERE IN YOUR HOME

HOW LAZY CAN YOU GET? Now you can turn electrically operated devices on and off without getting out of your favorite chair—or off that couch! Two small easy-to-build units, one a transmitter and the other a receiver, are all that are needed.

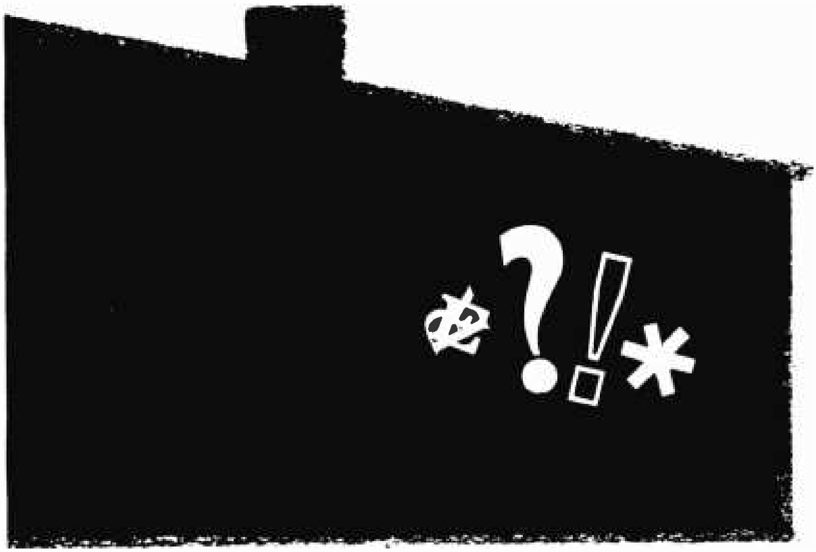
Both units are plugged into any a.c. outlet, in the same room or in different rooms. Signals from the transmitter pass through the house wiring and are picked up by the receiver, which is equipped with a sensitive relay. Press the button on the transmitter and any light or electrical device plugged into the receiver goes on. You need only press the button again to shut things down. The signal frequency is about 120 kHz; actual frequency is not critical, but it is important that the transmitter and the receiver be tuned to the same frequency.

There's nothing to prevent you from building more than one receiver and using a few of them—all controlled by one transmitter—to operate more devices in more than one location.

How It Works. The transmitter is a Colpitts oscillator as shown in Fig. 1. The oscillator frequency is determined by capacitors *C4*, *C5* and the setting of coil *L1*. Resistors *R1*, *R2* and *R3* establish the bias for *Q1*. The signal developed across *R3* is coupled to the a.c. line by *C1* and *C2*. Transformer *T1* steps down the line voltage to about 12 volts; diode *D1* rectifies and *C3* filters this voltage to power the transmitter. Capacitor *C6* serves as a d.c. blocker and a.c. coupler.

Switch *S1* turns on the transmitter and acts as the control switch for the entire system—when the transmitter is on, the receiver is on. Indicator lamp *I1* is optional.

The signal on the power line is picked



up by tuned circuit *C7*, *C8*, *L2* in the receiver (Fig. 2). The signal from the tuned circuit is rectified and used to "turn on" *Q2*. When *Q2* conducts sufficiently, relay *K1* energizes and connects whatever is plugged into *SO1* directly to the 117-volt a.c. power line. However, *S2* must be on for all this to happen.

The stronger the signal, the greater the current flow through *K1*. The voltage across the relay winding is a relative indication of the signal strength on the line. Without a signal, you should get about 0.2 to 0.6 volt d.c., depending upon the amount of transistor leakage current. A strong signal, such as you get when the transmitter and receiver are plugged into the same outlet, will produce more than 5 volts. When the units are separated by about 50 feet, about 3 volts will appear across the relay.

Do not exceed the current rating of the relay contacts. If you want to control a larger load, use a power relay and hook it up as shown in Fig. 3. If you duplicate this power relay, no modification of the receiver is necessary.

Transformer *T2* puts out about 6.3 volts a.c. (almost any inexpensive filament-type transformer will do); *D2* and *C9* rectify and filter, respectively, this voltage to power the circuit. Indicator lamp *I2* is optional. To de-energize the relay, either *S1* in the transmitter or *S2* in the receiver should be shut off.

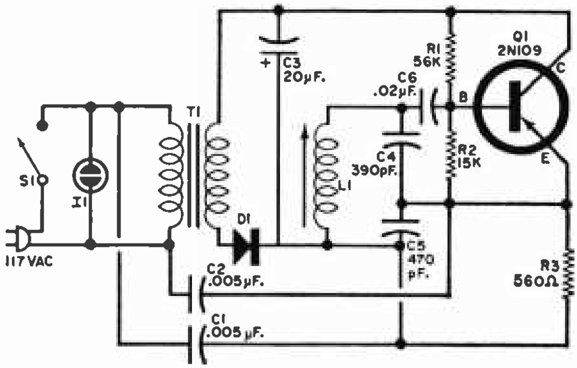
Construction. Parts layout is not critical. You can arrange the components in any convenient manner, but be on the alert to prevent short circuits.

Molded Bakelite boxes are best to use for the remote control units because these boxes are nonconductive and easy to work with. If you decide to use metal boxes, do not ground or otherwise connect the components to the boxes. Should any of the capacitors (*C1*, *C2*, *C7* or *C8*) break down, the entire circuit could be at 117-volt a.c. line potential. A case-grounded circuit could also put the case at line potential.

A see-saw switch with a built-in indicator lamp can be used to eliminate the need for mounting a separate lamp assembly in the transmitter unit, and it gives the unit a clean, attractive appearance.

You can wire in the parts in "breadboard" fashion as shown in Figs. 4 and 5. Cut two pieces of perforated board to size, one for the receiver and the other for the transmitter. Screw four ½"-long metal or plastic spacers onto each of

Fig. 1. The Colpitts oscillator circuit in the transmitter (right) develops a high-frequency control signal which is fed into the a.c. line through C1 and C2. Operating frequency is determined by C4 and C5 and the setting of L1.



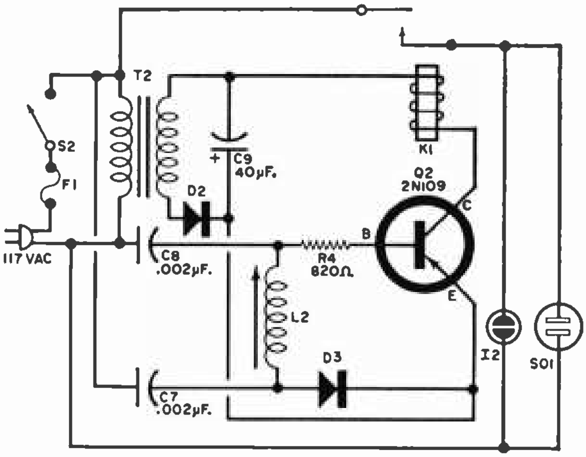


Fig. 2. When tuned circuit C7, C8 and L2 in the receiver unit (left) picks up the control signal on the a.c. line, Q2 conducts to energize K1. When K1 energizes, full line power is applied to any appliance plugged into SO1.

PARTS LIST

C1, C2—0.005-μF, 1000-volt disc capacitor
C3—20-μF, 50-volt electrolytic capacitor
C4—390-pF mica capacitor
C5—470-pF mica capacitor
C6—0.02-μF disc capacitor
C7, C8—0.002-μF, 1000-volt disc capacitor
C9—40-μF, 25-volt electrolytic capacitor
D1, D2—DD-117 diode (International Rectifier)
D3—1N48 diode
F1—Fuse, 1-ampere
I1—See S1
I2—Indicator lamp (Allied Radio 8 U 698 or similar)
K1—Miniature relay (Lafayette 99 C 6091 or similar)
L1, L2—1.3 to 2.1-mH coil (Miller No. 4414)
Q1, Q2—2N109 transistor
R1—56,000-ohm, ½-watt resistor
R2—15,000-ohm, ½-watt resistor
R3—560-ohm, ½-watt resistor
R4—820-ohm, ½-watt resistor
S1—S.p.s.t. switch with built-in indicator lamp (Lafayette 99 C 6259 or similar); or use separate switch and indicator lamp
S2—S.p.s.t. switch
SO1, SO2—Chassis-mounting receptacle
T1—12-volt, 1.0-ampere filament-type transformer
T2—6.3-volt, 1.0-ampere filament-type transformer
Misc.—Bakelite boxes (2), a.c. line cords (4), perforated board, terminals, spacers, etc.

the boards to obtain adequate clearance between the board and the case. And drill a small access hole in each case to line up with the tuning coils, so you can get to the tuning slug.

Tuning. Turn the transmitter and receiver on. If the relay does not pull in (*Continued on page* 152)

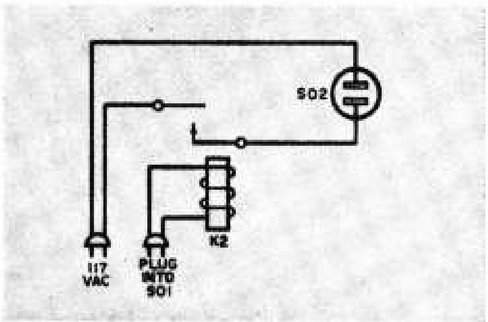
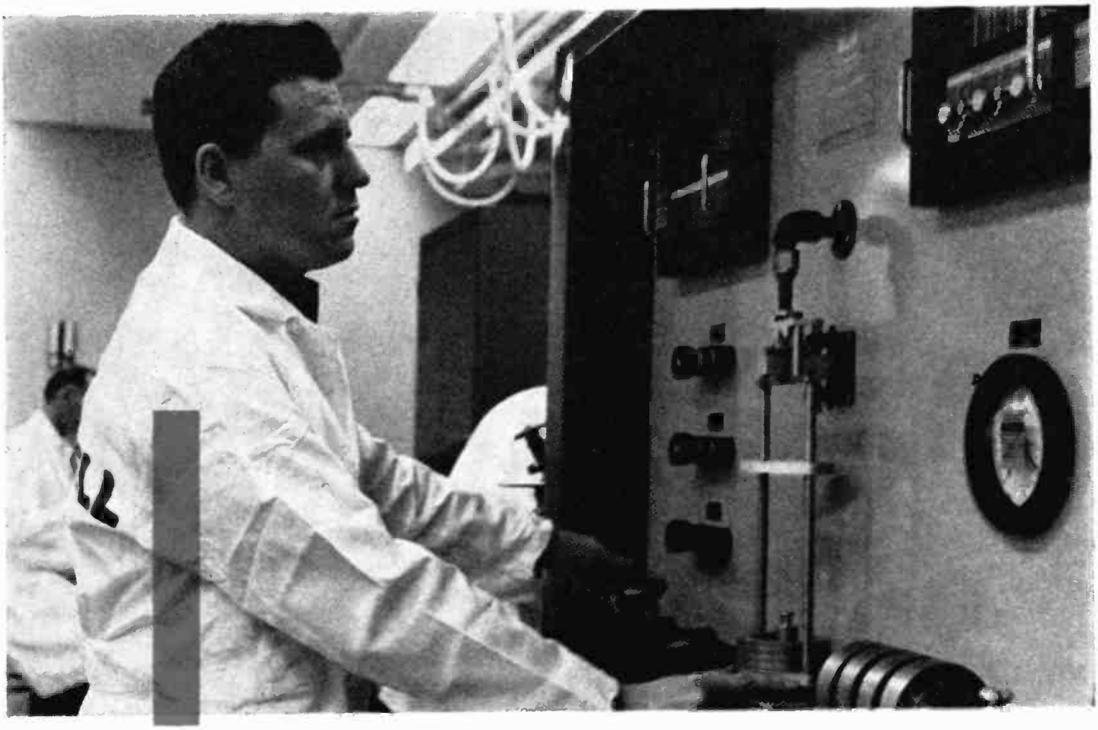


Fig. 3. To control high power equipment, a power relay must be used between the receiver and the equipment to prevent damage to relay in receiver.



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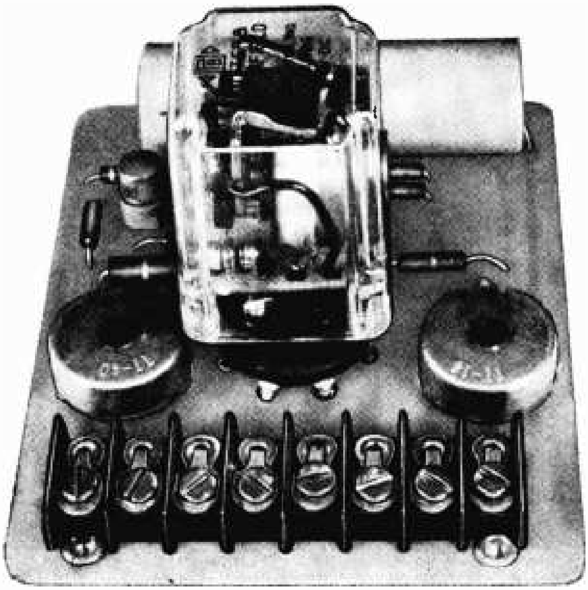


BUILD THE SUPERTROL

For . . .
- Automatic start switching
- Interval timing
- Voltage sensing
- Delayed stop action
- Etc., etc., etc.

By FRANK GROSS

ASK NOT what the Supertrol can do, but rather, what it cannot do. For here is a circuit with an abundance of useful applications. The Supertrol is primarily a free-running master sequence generator, suitable for an exhibit or display, which provides a completely adjustable on/off ratio of from 50 milliseconds to 10 seconds. Husky 10-ampere relay contacts provide dual complementary—off/on, on/off—outputs.

Change around a connection or two and the Supertrol becomes a sensitive voltage level detector which opens or closes a relay with a positive snap action as the input voltage exceeds 2 volts, or drops below 1 volt.

Add a d.p.d.t. switch and once again change some connections around and you have a time-delay relay or an interval timer—depending upon your choice of output contacts. With this arrangement you can turn on a load once for a predetermined time interval, or get a continuous output at the end of an adjustable 0- to 20-second time interval.

How It Works. The Supertrol's actual circuit (Fig. 1) is nothing more than a jazzed-up version of a basic Schmitt trigger as described on page 17. Transistors *Q2* and *Q3* comprise the Schmitt trigger while *Q1* is an emitter follower used to keep the control circuit from loading down capacitor *C1*. The capacitor charges through potentiometer *R11*, so that this control determines the relay's *on* time. Similarly, *R12*, which provides a discharge path for the capacitor, determines the relay's *off* time.

Most of the resistors added to the basic circuit are for stabilizing purposes, and to help eliminate current surges from the power supply and the unit's control circuitry. Capacitor *C2* helps to speed up the turn-off operation, while *D1* protects *Q3* from voltage spikes due to the inductance of the relay coil.

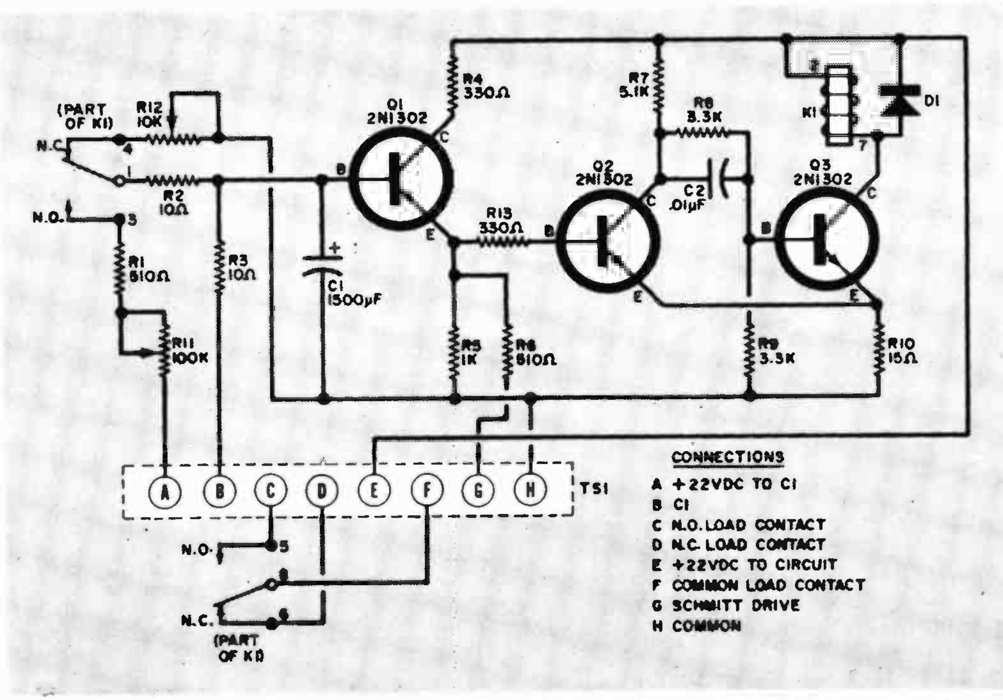


Fig. 1. The Supertrol is a practical application of the well-known Schmitt trigger circuit. A technical explanation of the triggering operation appears on page 17. Relay K1 is the workhorse of the Supertrol and the second set of contacts (octal pins 5,6, and 8) are used to operate other circuits up to a drain of 10 amps. The author brought all control wiring functions out to a terminal strip, but this may be eliminated if the Supertrol is to be used for only one job.

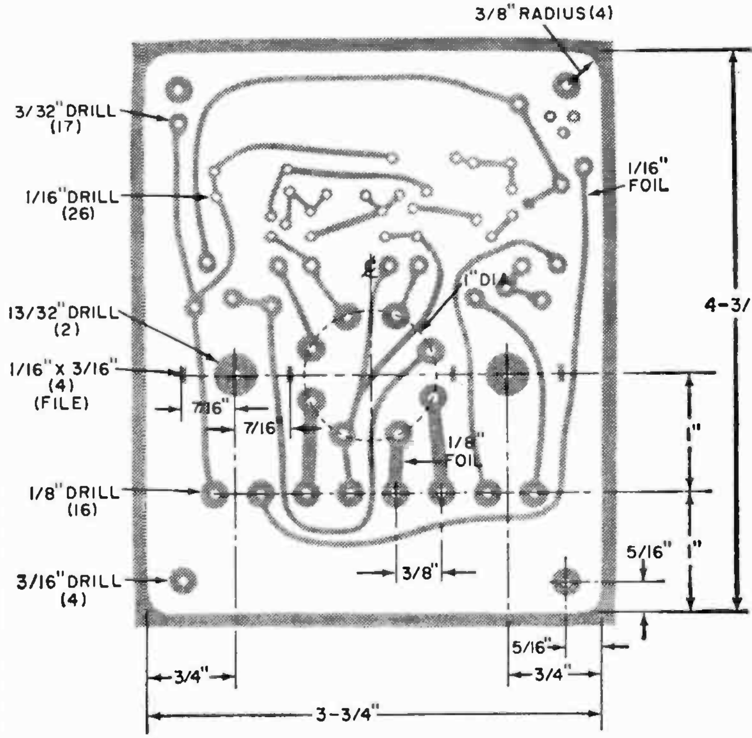


Fig. 2. A printed circuit board can be etched following the outlines shown in this drawing. Use of this outline should be predicated on the physical size of capacitor C1, location of the terminals for the octal socket to hold K1, and whether or not the builder uses twist-tab potentiometers for R11 and R12. Point-to-point wiring can be used in place of a printed circuit without encountering any problems.

PARTS LIST

C1—1500-µF, 6-volt d.c. electrolytic capacitor
C2—0.01-µF disc capacitor
D1—750-mA, 200-PIV silicon diode
K1—24-volt d.p.d.t relay, 400-ohm coil, with 10-ampere contacts (similar to Potter & Brumfield KRP11DG)
Q1, Q2, Q3—2N1302 transistor or similar unit
R1, R6—510-ohm, 1-watt resistor
R2, R3—10-ohm, ½-watt resistor
R4—330-ohm, ½-watt resistor
R5—1000-ohm, ½-watt resistor
R7—5100-ohm, ½-watt resistor
R8, R9—3300-ohm, ½-watt resistor
R10—15-ohm, ½-watt resistor
R11—100,000-ohm twist-tab potentiometer (similar to Centralab TT-40)
R12—10,000-ohm twist-tab potentiometer (similar to Centralab TT-14)
1—3" x 4" x 5" box, or printed circuit board, or both*
1—8-terminal barrier strip (similar to Cinch Jones 140-Y)
Misc.—Octal PC tube socket, knobs (2), threaded rivet-type standoffs (4), solder, 22½ volt battery or a.c.-operated d.c. supply—see below.

*An etched and drilled circuit board, complete with all mounting hardware, is available for $2.50 postpaid in the U.S.A. from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216.

Construction. The Supertrol can be built on a printed circuit board or on a punched phenolic circuit board, and can be housed in a small plastic container or in a metal box. If a printed circuit board is preferred, one can be purchased from the source indicated in the Parts List. If you want to etch your own board, you can do so following the layout given in Fig. 2, and the parts can be mounted as shown in Fig. 3.

For printed circuit construction, be sure to use the specified twist-tab potentiometers since the PC board has been laid out with holes drilled for these units.

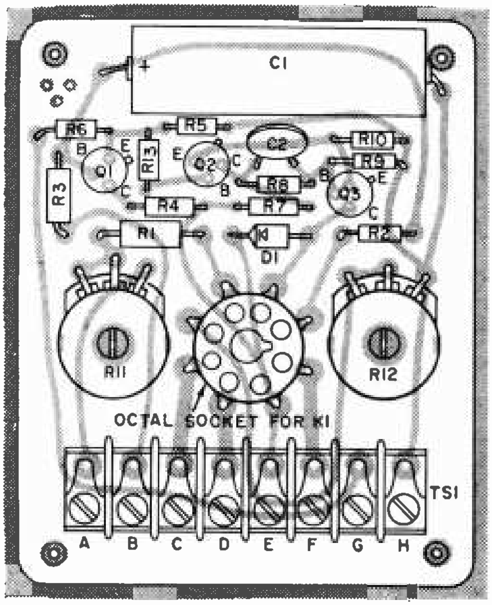


Fig. 3. If you make or buy a printed circuit board tne components should be positioned as shown. The 3 spare holes in the corner mount a socket to hold Q1 when this transistor is not in the circuit.

POWER SUPPLY PARTS LIST

C1—500-µF, 25-volt electrolytic capacitor
D1—750-mA, 100-P.I.V. silicon power diode (similar to Motorola 1N4002)
R1—4700-ohm, ½-watt resistor
T1—Power transformer: primary, 117 volts; secondary, 18 volts, 100mA, or higher (similar to Stancor TP-1 or Knight (Allied Radio) 54 A 3987

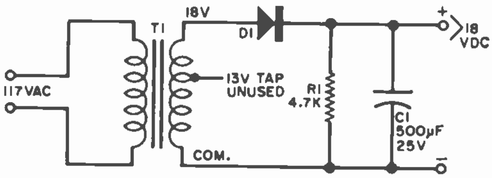


Fig. 4. For continuous duty operation, this power supply can be substituted for the 22½-volt battery. The circuit will work on 17 to 24 volts d.c.

Suitable standoffs can be used to mount the circuit board in its enclosure, if one is used, or else support it on a table or other surface.

While transistors *Q2* and *Q3* can be wired directly to the circuit board, *Q1* should be installed in a socket since it has to be removed from the circuit during certain applications. After completion, the circuit can be tested by hooking it up as shown in Fig. 5. With power applied, it should start oscillating at about 1 hertz. If it does not, adjust *R11* and *R12* as necessary.

If the Supertrol is to be used only on occasion, and if you do not want to go through the expense of building an a.c.-operated power supply, you can operate with a husky 22½-volt battery which can be housed with the circuit board in the same enclosure. If, on the other hand,

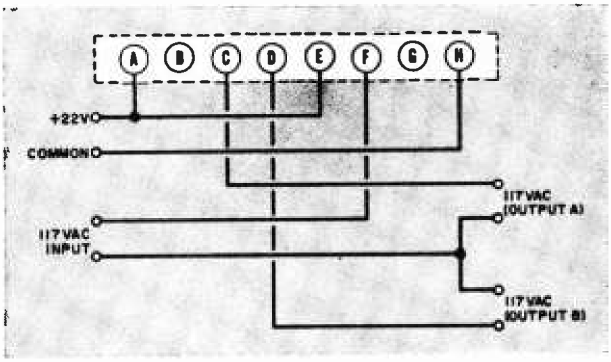


Fig. 5. To test the Supertrol, connect a 22½-volt battery with the plus side going to terminal strip points A and E, and the negative side of the battery to point H. The circuit should start oscillating at about 1 hertz. If the relay does not start clicking, juggle R11 and R12 until the relay has a rhythmic beat. As explained below this circuit is also used to make the Supertrol a display sequence generator.

you plan to use the Supertrol on a fairly continuous basis, you may want to build the power supply shown in Fig. 4 using the parts shown on the accompanying Parts List. The output voltage from this supply will be up 7 to 24 volts depending on the load.

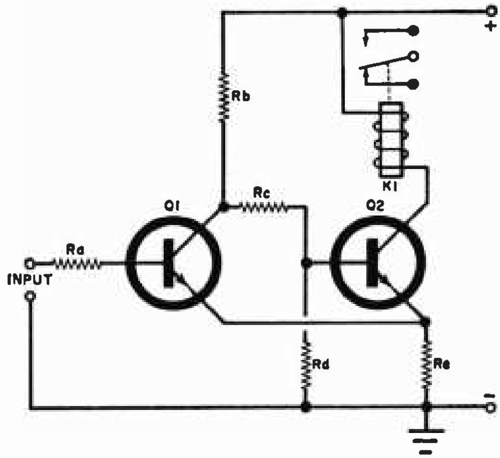
Applications. To have the Supertrol function as a display sequence generator, make the connections shown in Fig. 5, enabling one set of relay contacts to alternately switch the "hot" side of the 117-volt a.c. line between Outputs *A* and *B*. The *common* side of the line goes directly to the load, and there is no connection between this set of contacts and the rest of the Supertrol circuit. The switching time required to go from *A* to *B* is determined by the adjustment of *R11* and *R12*. This circuit is ideally suited for generating running exhibits and displays.

The connections required for a voltage level detector function are shown in Fig. 6. Here, emitter follower *Q1* must be removed from its socket. This enables the circuit to turn on whenever the input signal exceeds 2 volts or turn off when the signal drops below 1 volt. Input impedance is approximately 1000 ohms. Relay contacts *C* and *D* are used as required to provide power for an alarm bell, signal light, etc.

CIRCUIT THEORY

To understand the secret behind the Supertrol's success, consider the Schmitt trigger circuit shown at right. The circuit and biasing arrangement is such that Q1 is normally OFF while Q2, which controls relay K1's current, is normally on.

If a positive voltage—say about 2 volts—is applied to base resistor Ra, Q1 turns on, causing Q2 to turn off due to reverse biasing applied across Rc and the increase in the voltage across emitter resistor Re. This causes the relay, which acts as Q2's collector load, to drop out as the current falls to zero or to any value below its pickup point. The circuit will revert to its original quiescent state whenever the voltage at the input falls below the tripping level, and the relay will pull in again.



By placing a relatively large capacitor in Q1's base circuit (see Fig. 1), and a charging path from a battery through the relay contacts and a couple of current-limiting resistors, the circuit can be made to free-run by the charge and discharge of the capacitor, enabling Q1 and Q2 to change state at a predetermined interval. The rate at which the transistors change state is established by the charge and discharge rate of the capacitor; and this, in turn, is a function of the resistor values chosen. It can be seen that if a potentiometer is substituted for at least one of the resistors, the charging time can be varied at will.

In this application, the connection from the battery to terminal *A* is broken to prevent *C1*, which is rated at 6 volts, from charging up and shorting out. If you want to replace *C1* with a capacitor of higher voltage rating, say 25 volts, then the connection at point *A* need not be broken. It is important that you put *Q1* back in its socket before applying power to the circuit.

The connections for an interval timer or a time delay relay are the same as required for the voltage level detector (Fig. 6), except that the relay contact selection must be as shown in Fig. 7. This circuit also includes a d.p.d.t. switch, used to control the load power while charging capacitor *C1* is being shorted out. In position 2, power is applied to one set of contacts to enable the capacitor to charge sufficiently to trigger the Schmitt trigger circuit. The charging time is, of course, determined by the setting of *R11*. When *C1* charges to its upper trip point, *Q1* conducts and the relay switches power from the interval output to the delay output. When the switch is flipped to position 1, the capacitor is shorted through a resistor, and the circuit is reset.

The hookup shown in Fig. 7 can be used for a darkroom photo timer, as a delay relay to allow the filaments of a transmitter to warm up before plate voltage is applied, or as a starting relay for a generator or a fluorescent lighting system. You can also use it in a driveway or hallway lighting circuit to extinguish the lighting by delay action. By varying *R11*, the circuit can be made to introduce a time delay varying from 50 milliseconds to 10 seconds.

To keep the load from oscillating, an additional relay can be added to the output connections to lock up on its own contacts and thereby provide a continuous stable output. Another approach to this problem is to reset the switch to position 1 approximately 8 seconds or so before the oscillation starts. -30-

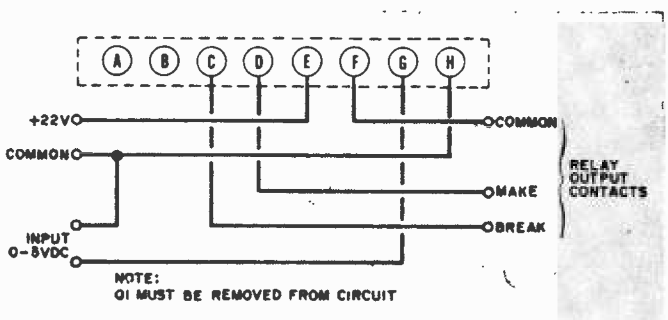


Fig. 6. Remove transistor Q1 and make the external connections in this diagram and your Supertrol becomes a low voltage sensor. An input of 2 volts turns the circuit on and a drop below 1 volt turns the circuit off. This circuit could be used as an alarm.

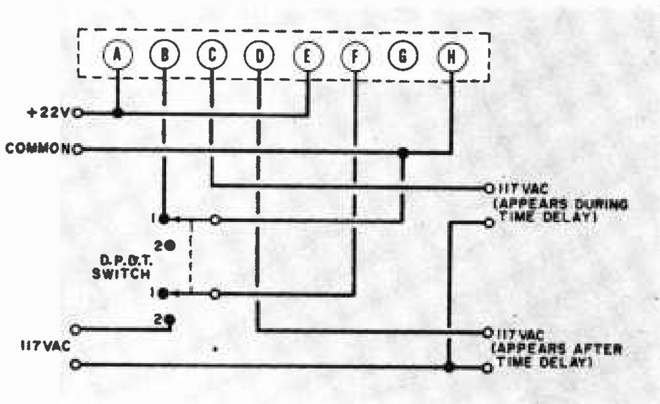
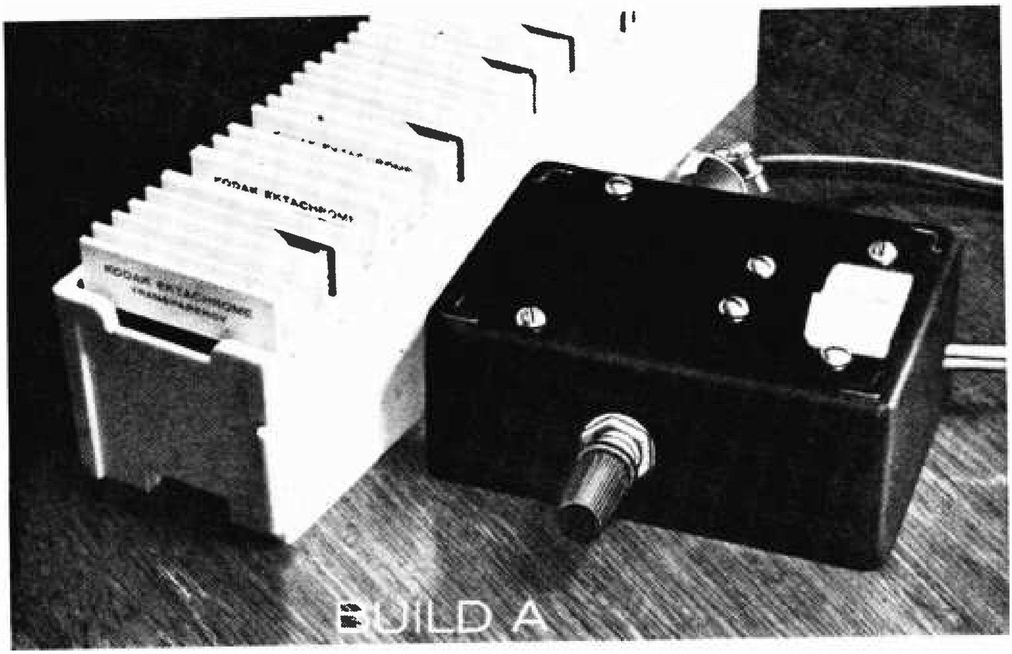


Fig. 7. The most practical application of the Supertrol is as an interval timer. However, this requires an external d.p.d.t. toggle switch wired into the circuit as shown here. Timing begins with the switch in position 2. Circuit reset is position 1.



BUILD A "Relaxatrol" to Automate Your Slide Projector

VARIABLE TIMER CONVERTS PUSH-BUTTON MACHINES TO FULLY AUTOMATIC OPERATION

By GARY W. TOWNER

LOOK, NO HANDS—here's a low-cost way to fully automate a push-button semi-automatic slide projector. Build a "Relaxatrol," set the speed of operation, and join the audience. It is an ideal accessory for continuous repeat-performance applications.

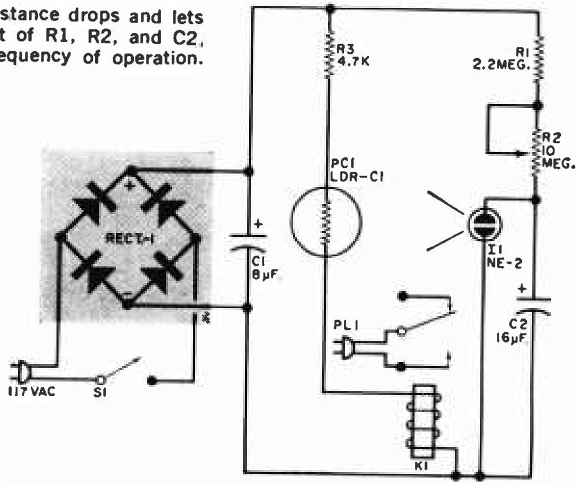
Actually, the Relaxatrol can be used to automatically control at preselected intervals almost any device which is operated manually with switches—without modifying the equipment. The only requirement is that the control be hooked across the switch on the equipment. The control can be overtaken or "dropped out" of the equipment at any time without any additional connections or disconnections.

How It Works. A simple relaxation oscillator consisting of *R1*, *R2*, *C2*, and *I1* (Fig. 1) periodically energizes *K1* to trigger the projector. Capacitor *C2* takes on a charge through *R1* and *R2*, until the voltage across it is sufficient to fire *I1* (usually on the order of 60 to 70 volts).

When the lamp fires, it discharges *C2* until the voltage drops sufficiently to black out the lamp. The frequency of lamp ignition depends upon the values of *C2*, *R1* and *R2*, as well as the voltage across the entire circuit. Variable resistor *R2* makes it possible for you to adjust the frequency according to your needs.

Neon lamp *I1* is close-coupled to a

Fig. 1. When PC1 "sees" the light from I1, its resistance drops and lets enough current flow to energize K1. Time constant of R1, R2, and C2, as well as the applied voltage, determines the frequency of operation.



light-dependent resistor (*PC1*). When the lamp lights, *PC1's* resistance drops and allows enough current to flow through *K1* to energize it. In the absence of light, the combined resistance of *R3* and *PC1* is enough to keep the relay in its *off* position. The relay simply does what the slide-change push button on the projector would normally do, if the relay contacts are wired in parallel with the push button.

A bridge rectifier can be made up of four individual diodes, but you may find it more convenient to use the commercially available module described in the Parts List. Capacitor *C1* serves as a power supply filter.

PARTS LIST

C1—8-μF, 150-volt electrolytic capacitor
C2—16-μF, 150-volt electrolytic capacitor
I1—NE-2 neon lamp
K1—10,000-ohm, 4.5-mA relay (Allied Radio 75 U 774, type LB-5 or similar)
PC1—LDR-C1 light-dependent resistor (Allied Radio 7 U 565, or similar)
PL1—2-terminal plug (small size; use with matching socket)
R1—2.2-megohm, ½-watt resistor, ± 10%
R2—10-megohm linear potentiometer
R3—4700-ohm, ½-watt resistor, ± 10%
RECT-1—Rectifier bridge (International Rectifier 10DB3A, or similar)
S1—S.p.s.t., 6-ampere switch
Misc.—Black alligator clip insulator, 2⅞" x 4" x 1 9/16" plastic case, 2-terminal strips (4), line cord, hookup wire, knob, etc.

Construction. Layout is not critical and it may be possible to assemble all the parts inside your projector. If you do, be sure to keep the parts away from the hot lamp. However, in most instances, it is better to build a separate unit.

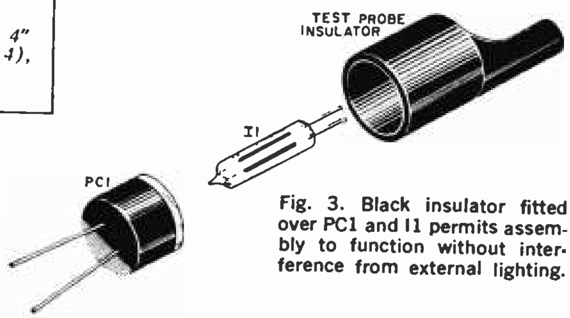


Fig. 3. Black insulator fitted over PC1 and I1 permits assembly to function without interference from external lighting.

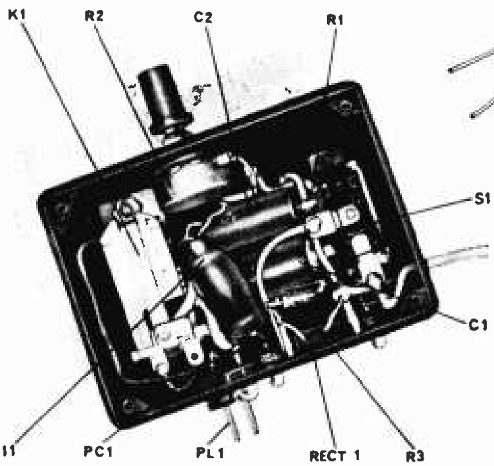
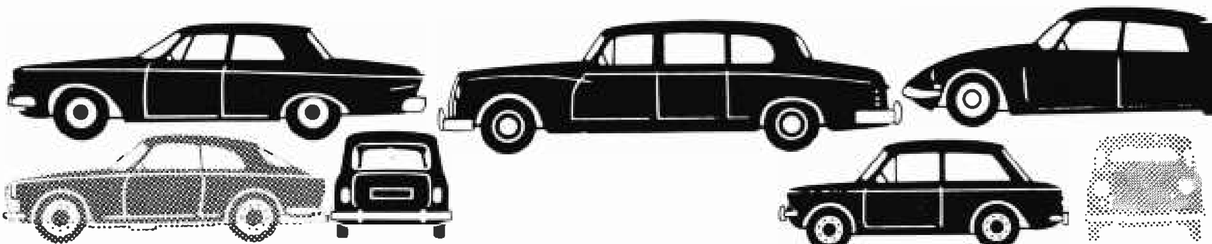


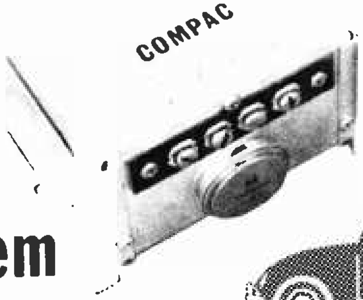
Fig. 2. Parts layout is not critical. Small plastic box helps insulate relay and other components from a.c. line. A line cord can be substituted for PL1.

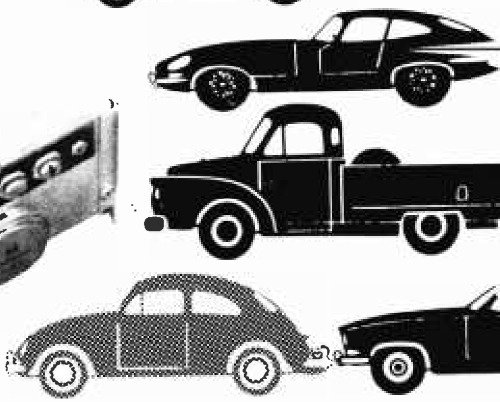
The small plastic meter box shown in Fig. 2 is inexpensive, easy to work with, and looks good. A test probe insulator, the kind usually placed over an alligator clip, couples the light from the neon lamp to *PC1* and shields the assembly from "outside" light. (See Fig. 3.) You may cut away some of the insulator at each end if it is too long. Assemble the unit as shown in the drawing, and do your best to obtain a light-tight assem-

(*Continued on page* 144)



"COMPAC" Solid-State C-D Ignition System





EASIER STARTING, MORE HIGH VOLTAGE, LESS BATTERY CURRENT DRAIN, AND FEWER MISFIRES

By MURRAY GELLMAN

SMALL enough to fit on a motorcycle or scooter, yet powerful enough to drive a Cadillac, this "Compac" solid-state capacitor discharge ignition system can be put together for almost half the price of its big brother (see Spring, 1966, EXPERIMENTER'S HANDBOOK). Improved gas mileage, increased life of breaker points and spark plugs, faster cold-weather starting, low battery current drain, and sustained high voltage at high engine speeds can be achieved with this new ignition system in any make of car, truck, or boat using a negative-ground 12-volt battery and a conventional ignition coil; and you can get more out of a two-cycle engine, too.

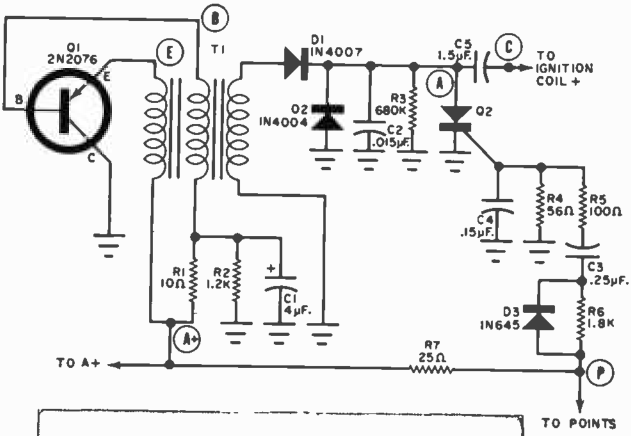
Conventional—and some transistorized—ignition systems draw more than 10 amperes of battery current; this CD system pulls only 0.5 ampere. Because of the low current drain, a small 12-volt motorcycle battery and an ordinary automobile ignition coil can be used to give a Go-Kart more "go." If you remove the coil from the flywheel housing, you will keep the magnets from loading down the engine on account of magnetic flux drag, and be able to get more useful power out of your engine.

Two Compacs were installed on a 110-horsepower, 6-cylinder outboard engine that kept fouling up the spark plugs about every 10 hours. This engine has two ignition coils, one for each three cylinders. Seventy-five hours of engine time have elapsed as this is written, and the spark plugs are still in use.

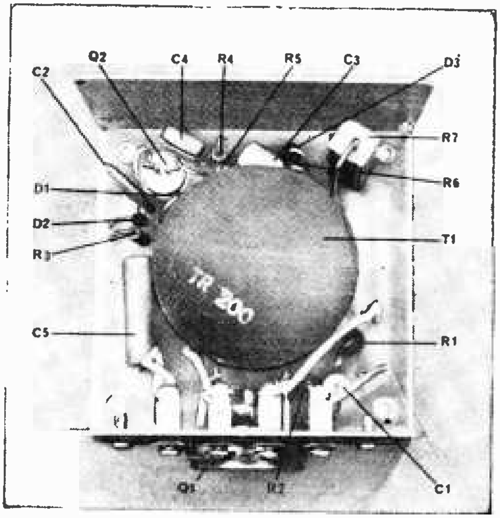
How It Works. Transistor *Q1* and the first and second windings of transformer *T1* work as a blocking oscillator and act like a switch (chopper) to alternately switch the battery current on and off. The "stop and go" current flow permits transformer action, and because of the step-up turns ratio, about 600 volts peak-to-peak is developed across the secondary winding.

This stepped-up voltage is rectified by *D1*, and appears across *C5* in series with the primary winding of the ignition coil. Capacitor *C5* charges up to about 300 volts and holds this charge until silicon-controlled rectifier *Q2* conducts. When *Q2* conducts, the energy stored up in *C5* is "dumped" very rapidly into the primary winding of the ignition coil. The 300 volts is stepped up to more than 30,000 volts by the ignition coil. And herein lies the reason for several features which make the CD system more desirable than the conventional ignition system.

One transistor chopper and transformer steps up voltage and charges C5. Ignition occurs when the points open and Q2 conducts. Trigger circuit is immune to point bounce, prevents false firing.



In the conventional system, the energy is stored in the ignition coil in the form of a large magnetic field which builds up only when the points are closed, the size of the field depending upon—among other things—the length of time the points are closed (dwell time). At high engine speeds, the loss in dwell time prevents the field from building up to its maximum, and the high voltage falls off accordingly. The CD system is essentially independent of dwell time, and also allows the coil to "kick-off" from a 300-volt level rather than from a 12-volt level. The higher initial voltage and the fast-acting switching action of *Q2* puts more energy into the front part of the ignition spark (rise time is on the order of 1.5 µsec.) and will fire fouled spark plugs that cannot be fired by a conventional ignition system.

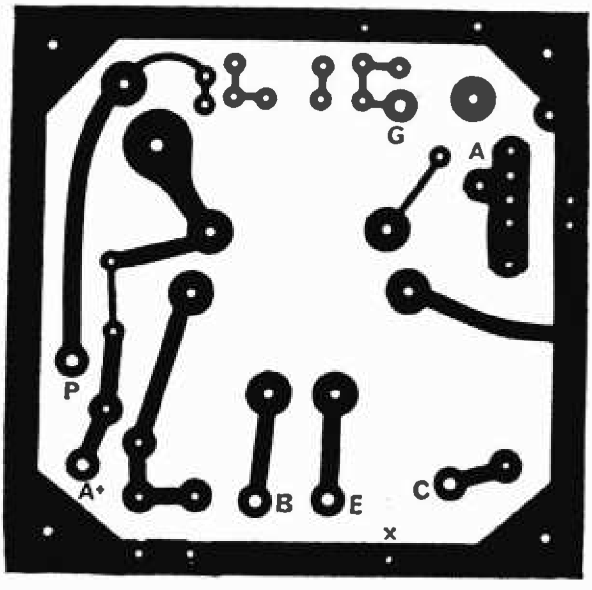


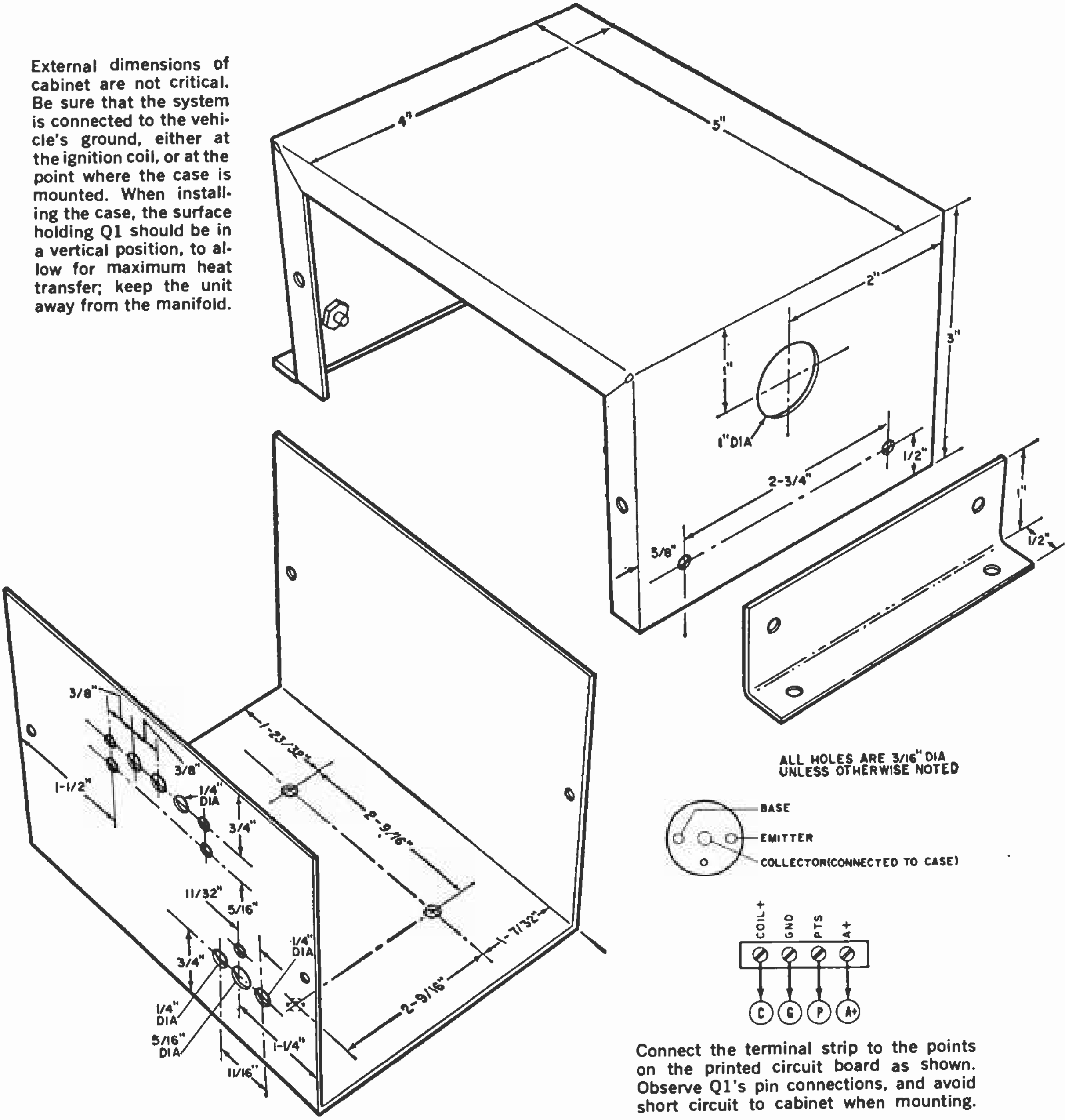
Complete unit is shown mounted in custom-built case to obtain minimum external dimensions. Any standard case can be used. Actual-size wiring layout (below, right) can serve as template to make printed circuit board.

PARTS LIST

C1—4-µF, 50-volt electrolytic capacitor
C2—0.015-µF, 600-volt capacitor
C3—0.25-µF, 25-volt capacitor
C4—0.15-µF, 25-volt capacitor
C5—1.5-µF, 250-volt capacitor
D1—1N4007 diode, or similar
D2—1N4004 diode, or similar
D3—1N645 diode, or similar
Q1—2N2076 pnp transistor, or similar
*Q2—MCR2305-5-R silicon controlled rectifier (Motorola)**
R1—10-ohm, 2-watt resistor
R2—1200-ohm, 1-watt resistor
R3—680,000-ohm, ½-watt resistor
R4—56-ohm, ½-watt resistor
R5—100-ohm, ½-watt resistor
R6—1800-ohm, ½-watt resistor
R7—25-ohm, 5-watt resistor
*T1—TR-200 transformer (SYDMUR)**
1—3" x 4" x 5" cabinet
*1—Printed circuit board**
Misc.—Four-screw terminal strip, threaded 6-32 x 3/16" rivet-on spacers, machine screws, wire, solder, etc.

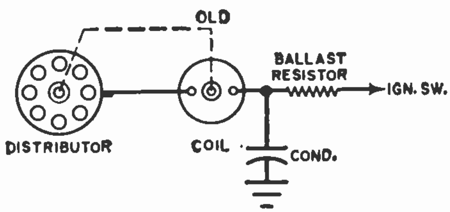
*The following parts are available from SYDMUR, 1268 E. 12 St. (or P.O. Box 25A, Millwood Station) Brooklyn, N.Y.: transformer *T1*, $10.95 plus 50 cents for shipping; silicon-controlled rectifier *Q2*, $5.95; and printed circuit board, $3. A complete kit is available for $24.95, a factory-wired and tested unit for $34.75. Add 75 cents for shipping either kit or wired unit.

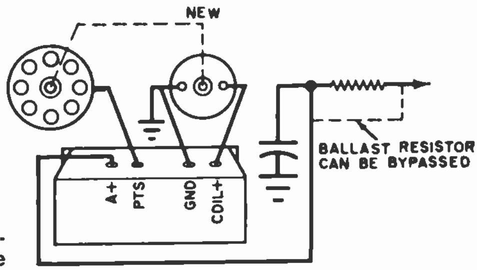




External dimensions of cabinet are not critical. Be sure that the system is connected to the vehicle's ground, either at the ignition coil, or at the point where the case is mounted. When installing the case, the surface holding Q1 should be in a vertical position, to allow for maximum heat transfer; keep the unit away from the manifold.

Connect the terminal strip to the points on the printed circuit board as shown. Observe Q1's pin connections, and avoid short circuit to cabinet when mounting.





New connections between the distributor and ignition coil are easy to make. Ballast resistor can be left in, or bypassed. Use original ignition coil.

When the ignition points open, a positive pulse is applied to *Q2*'s gate, and with the speed of a fast-acting electronic switch, typical of solid-state devices, *Q2* conducts and the spark occurs. The positive pulse is developed simply enough, but the system's immunity to point-bounce is interesting.

When the points are closed, the voltage at point *P* is zero; but when the points open, battery current through *R4*, *R5*, *C3*, *D3*, and *C4* makes the gate end of *R4* positive, and it remains so until the capacitors become fully charged. When the capacitors are fully charged, essentially no current flows through *R4*. But once *Q2* is conducting, it is no longer dependent upon its gate pulse, and it continues to conduct until its anode voltage is removed or reversed. When the points close, *C3* discharges, but it does so more slowly since the discharge path now includes *R6*.

Should the points open relatively too soon, as in the case of point-bounce, not enough current can flow through *R4* to false-fire *Q2*, because of the charge still on *C3*. Capacitor *C4* stabilizes the voltage built up across *R4* and maintains the gate voltage just long enough to insure firing action.

As in any inductive circuit, a substantial reactive kick takes place which could be quite destructive. Instead of fighting this kick, which is of opposite polarity to the initially developed voltage, it is passed to ground through *D2*, but before it goes, it is put to work to turn off *Q2*. The circuit is now just about back to its starting point and is ready to go again the next time the points open.

This kick doesn't always go in one direction; the actual action is more like ringing, and when the polarity of the kick swings back to agree with the original polarity of the power supply, *C5* gets a head start and starts to charge up again.

Perhaps just as unique and interesting as point-bounce immunity is the squelching action of *Q2* and *T1* to stop oscillation of *Q1* while the circuit is firing. When *Q2* conducts, it loads down *T1*, reduces the *Q* of the circuit and damps out the oscillations. Not until *Q2* "opens" does *Q1*'s circuit start to oscillate again. The transformer is designed to prevent the self-oscillation of *Q1* and the large transients that occur in the circuit from destroying *Q1*. When *Q1* is "quiet," there is no current from the transformer and *D1* circuit to compete with the discharge of *C5*, and a greater amount of energy is released to the ignition coil in a shorter period of time.

Resistor *R3* serves as a bleeder to slowly discharge *C5* when the ignition system is shut down. Capacitor *Q2* slows the rate of speed of reapplication of a positive voltage across *Q2* to prevent it from firing without a gate pulse. Resistor *R7* allows a minimum of current (about 0.48 A) to flow through the points to help keep them clean, as well as completing the *C3* charge circuit. Resistors *R1*, *R2* and capacitor *C1* maintain proper bias conditions for *Q1*.

Construction. Assembly time is less than 20 minutes, once you have all the parts in front of you. Use a printed circuit board made of G 10 fiberglass material with 2-oz. copper foil to hold the components. A phenolic board may warp and split the foil after exposure to the normally high temperatures found in an automobile's engine compartment, and should not be used.

All of the parts are stock items and can be purchased locally, except *T1* and the printed circuit board. (See Parts List.) Should you decide to make your own board, follow the actual-size drawing and layout shown. Do not change the position of any of the conductors on the board to prevent false-triggering of *Q2*.

Mount all of the components on the board, observe polarity of the diode and capacitors, and solder. Cut the excess lead lengths from the components after soldering; the leads thus serve as a heat sink. Be careful not to bridge-solder over adjacent conductors on the board—to prevent shorts and other wrong connections.

Solder four 1½"-long leads into holes *A*, *B*, *E* and *G* and four 4-inch leads into holes *A+*, *C*, *P* and *X*. Apply a small amount of silicon grease to the mounting surface of *Q1* and to the surface of the case to improve heat conduction. Apply just enough pressure to the transistor nut to have the grease

(*Continued on page* 142)

BUILD

IC-67 Metal Locator

SOLID-STATE, PRECISION INSTRUMENT OF ADVANCED DESIGN DEEPLY PENETRATES THE EARTH TO LOCATE METAL OBJECTS

By FRANK GROSS

THERE ARE TWO kinds of metal locators available: those that penetrate deep underground to detect large objects; and those that work on very small objects but do not go much more than a few inches below the surface. You can't have both—the math and the physical laws involved just won't let you. Presented here is a high-performance, deep-type metal locator employing the latest in solid-state integrated circuitry and military mine detector techniques.

You'll find the IC-67 one of the newest and hottest receiver-transmitter type locators to hit the beach. It is not an experimenter's toy; it is a precision instrument with circuitry as good or better than anything now on the market. You can use it for any large metal object detection problem. It easily and strongly spots pipes, cables, and irriga-

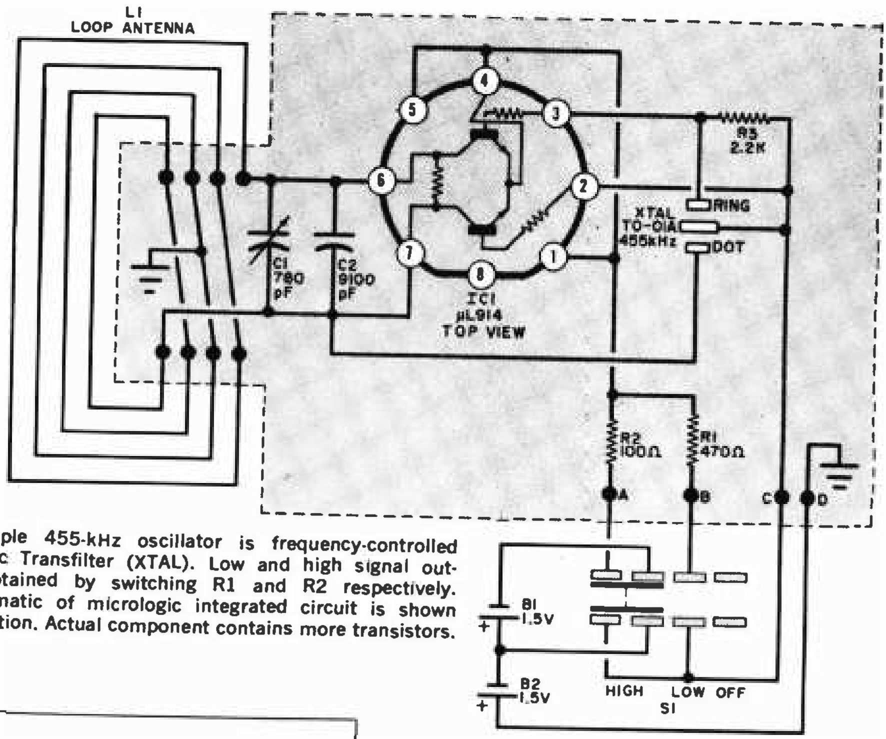


Fig. 1. Simple 455-kHz oscillator is frequency-controlled by a ceramic Transfilter (XTAL). Low and high signal outputs are obtained by switching R1 and R2 respectively. Partial schematic of micrologic integrated circuit is shown for simplification. Actual component contains more transistors.

TRANSMITTER PARTS LIST

B1, B2—AA 1.5-volt penlight cell, (2 required)
C1—170-780 pF trimmer capacitor
C2—9100-pF polystyrene capacitor (Mallory type SX, ± 5%; do not substitute)
IC1—µL914 epoxy dual gate (Fairchild)
L1—9" x 11" loop (1-turn four-conductor flat cable, 16 AWG, (formed from 37" of Belden 8476 or similar)
R1—470-ohm, ¼-watt carbon resistor
R2—100-ohm, ¼-watt carbon resistor
R3—2200-ohm, ¼-watt carbon resistor
S1—D.p.3-t. slide switch (Wirt G-128 or similar)
XTAL—TO-01A Transfilter (Clevite)
*1—1¼" x 2½" printed circuit board***
1—4" x 2⅞" x 1 9/16" plastic case and cover (Harry Davies #220 or similar)
1—Battery holder (Lafayette 99R6331 or similar)
Misc.—Dialplate, hardware, PC terminals (12), staples, wire, solder, etc.*

Note: IC1 and XTAL are available from Semiconductor Specialists, 5700 W. North Ave., Chicago, Ill. 60639.

*,**See Receiver Parts List

tion valves buried as deep as seven feet, making it a top instrument for construction or landscape work. As a treasure finder, a silver dollar *in air* can produce a noticeable output, but when it comes down to the practical matter of reliably finding buried objects, a coffee can is probably the best you'll be able to do.

Integrated circuits and low battery voltages as well as low power drain go hand in hand; only six penlight cells are used. A fully automatic zero-cost battery-tester feature is included. No headphones or dangling cords are required; a small sonic module easily provides a loud audio output from a very high gain receiver. A "crystal" stabilized transmitter in a CW broadcast system is used. An output meter and a choice of two transmitter power levels help locate the "treasure." Four controls run the instrument, and the entire project weighs in at only five pounds.

Most important, you get some features not found on commercial units. A signal expander circuit lets you reject all the background noise and signal variations to permit you to concentrate on what you're looking for. At the same time, the signal from deep targets is sharpened to enable you to precisely pinpoint deeply buried objects.

Total semiconductor cost is $4.50, but the final bill will probably amount to about $40—split $35 for components and $5 for lumber. This is about one-quarter to one-ninth the cost of comparable commercial instruments.

While not intended as a beginner's project, the circuit is not too difficult to build and the parts are easy to get. Pay particular attention to the parts list and construction details; certain changes could cause trouble. A parts kit is available (see Receiver Parts List) or you can assemble your own parts.

How It Works. Essentially this instrument is nothing more than a receiver and a transmitter equipped with loop antennas. Loop antennas are very directional—two of them at right angles to each other provide practically zero signal coupling. But a metal object in the vicinity of the two antennas will upset a null condition and give you an output signal. Energy transmitted from the vertical rear transmitter loop is "reflected" by the object to the horizontal front receiver loop. Both loops must be rigidly connected and at least one of them precisely adjustable to null the no-target coupling.

The *transmitter* (Fig. 1) consists of a loop antenna driven by a 455-kHz oscillator. A dual micrologic integrated circuit (*IC1*) forms a push-pull CW oscillator when feedback is cross-coupled by a ceramic Transfilter (*XTAL*). As output power depends in part upon emitter current, a high or a low output level can be obtained simply by switching *R1* or *R2* into the circuit.

The *receiver* is a three-stage TRF type, followed by a detector, a signal expander, a meter, and sounder device. The receiving loop resonates at 455 kHz, picks up the signal from the transmitter and drives the r.f. amplifier (*IC1*). Transformer *T1* also resonates at 455 kHz, and couples the amplified signal to *IC2* for further amplification; *T2* similiarly provides coupling to *IC3*. (See Fig. 2.)

The amplified output of *IC3* is transformer-coupled by *T3* to a conventional diode detector (*D1*). A d.c. voltage appears across *R4* and *C10* which is a function of the signal strength. To obtain signal expansion, the output voltage across *R4* and *C10* is added to the voltage across *R9* and part of the *Expansion* control *R7*, and applied to the base of a special, high gain transistor (*Q1*) to increase current flow through the meter and the sounder, which serve as visual and audible indicators.

If the expansion voltage is large, *Q1* operates as an ordinary linear amplifier, and all target and clutter signals are equally amplified. On the other hand, if the expansion voltage is very small, *Q1* stays "off" unless a very strong signal is received. In this mode, only the peaks of the strongest signals reach the output, which "sharpens" target positioning and rejects background noise and clutter.

For intermediate settings of the *Expansion* control, the nonlinear operation of *Q1* amplifies the *stronger* signals more than the *weaker* ones, and "expands" the target signals at the expense of the clutter. Simply adjust the *Expansion* control to optimize results for each location.

Total receiver r.f. gain is on the order of 30,000, which is considerably more than the gain of an average AM radio. The gain of *IC1* and *IC2*, and hence overall gain, is controlled by *Gain* control *R6*.

Construction. No metal locator will work properly with a sloppy, loose or out-of-square frame. For topnotch operation, the frame *must* be absolutely rigid; the loop assemblies must be precisely at right angles; and there must be a means for smoothly adjusting the null between the two loops. Otherwise, "straight-through" transmitter energy will come booming through the receiver and completely "swamp" any target signals. Extra time spent on the frame will be more than made up by improved performance.

The main frame should be made from a quality piece of ¾" kiln dried maple, or plywood, as shown in Fig. 3. A 5/16" dado blade, if available, makes child's play out of the rear slot; otherwise, just use repeated cuts and fence settings on a table saw to get the same result. Do not drill the ¾" pivot hole just yet.

Flush-mount three #10 Teenuts (washer-shaped metal fastener about ¾" in diameter, with three large fangs on outside and *10-32* threads on the inside) on the frame as shown. Put a dab of glue under each Teenut. The pilot hole for the Teenut on the rear end of the frame should go all the way through, into the

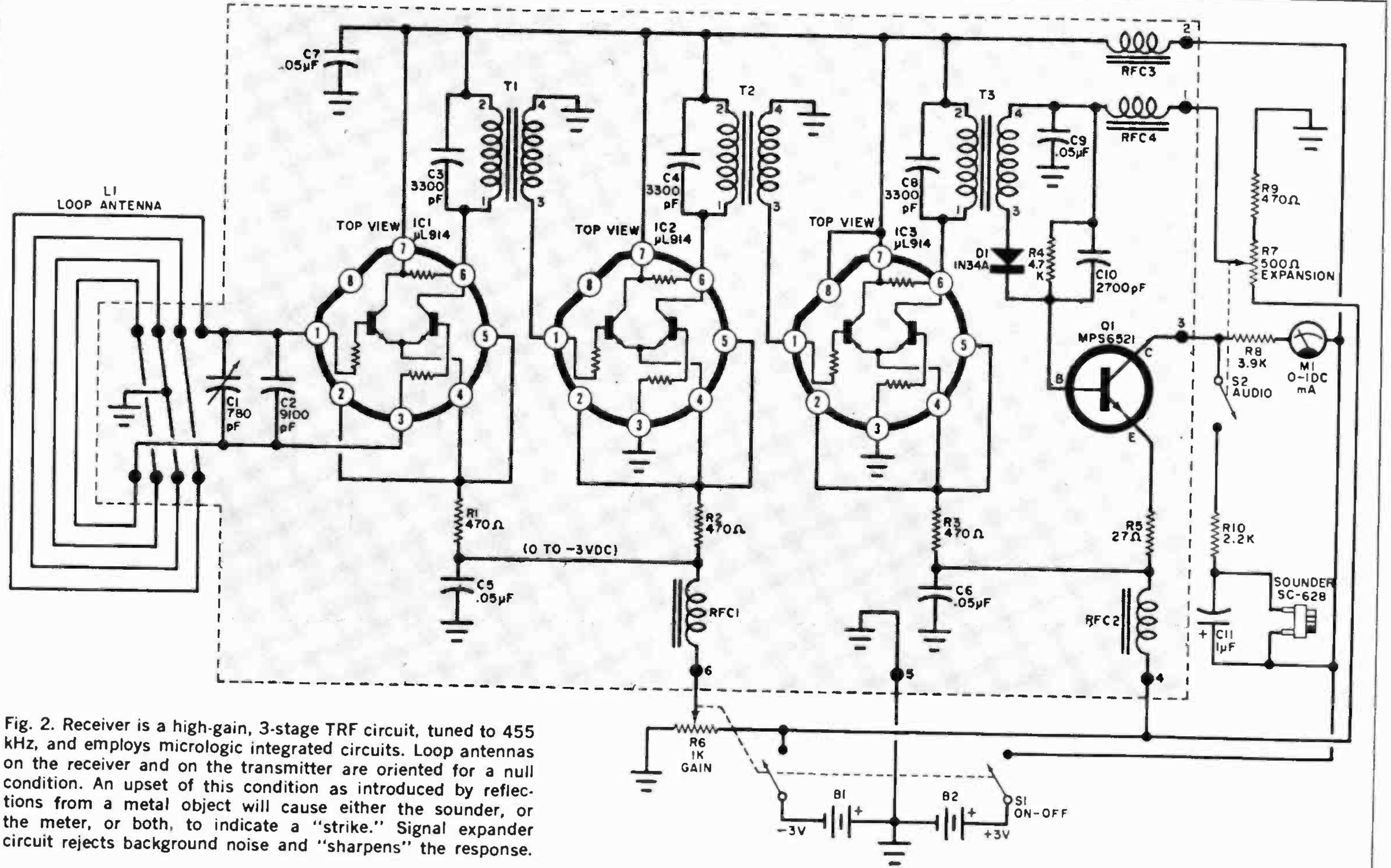


Fig. 2. Receiver is a high-gain, 3-stage TRF circuit, tuned to 455 kHz, and employs micrologic integrated circuits. Loop antennas on the receiver and on the transmitter are oriented for a null condition. An upset of this condition as introduced by reflections from a metal object will cause either the sounder, or the meter, or both, to indicate a "strike." Signal expander circuit rejects background noise and "sharpens" the response.

RECEIVER PARTS LIST

B1, B2—AA 1.5-volt penlight cells (4 required)
C1—170-780 pF trimmer capacitor
C2—9100-pF polystyrene capacitor (Mallory type SX, ± 5%; do not substitute)
C3, C4, C8—3300-pF ceramic capacitor, 10% tolerance (Vitramon VK33; do not substitute)
C5, C6, C7, C9—0.05-µF miniature Mylar capacitor, or paper
C10—2700-pF ceramic capacitor
C11—1-µF, 6-volt electrolytic capacitor
D1—1N34A diode
IC1, IC2, IC3—µL914 epoxy dual gate (Fairchild)
L1—9" x 11" loop (1-turn, four-conductor flat cable, 16 AWG, formed from 37" of Belden 8476 or similar)
M1—0-1 d.c. milliammeter (Emico Model 13, edgewise-type, or similar)
Q1—MPS6521 transistor (Motorola; do not substitute)
R1, R2, R3, R9—470-ohm, ¼-watt carbon resistor
R4—4700-ohm, ¼-watt carbon resistor
R5—27-ohm, ¼-watt carbon resistor
R6—1000-ohm linear carbon potentiometer with d.p.s.t. switch S1
R7—500-ohm linear carbon potentiometer, with push-pull s.p.s.t. switch S2
R8—3900-ohm, ½-watt carbon resistor
R10—2200-ohm, ½-watt carbon resistor
*RFC1, RFC2, RFC3, RFC4—10 turns 34-AWG enameled magnet wire on Ferroxcube K5-001-00/3B shielding bead; do not substitute****
S1—D.p.s.t. switch on R6
S2—S.p.s.t. push-pull switch on R7
Sounder—6-28 volt d.c. audio sonic alarm module (Mallory or Sonalert SC628)
*T1, T2, T3—36 turns 34-AWG enameled magnet wire on Indiana General "Q-1" CF101 core, bifilar-wound; do not substitute****
*1—3⅜" x 2⅝" printed circuit board***
1—6¼" x 3¾" x 1⅞" plastic case and cover (Harry Davies #240 or similar)
1—Battery holder (Lafayette 99R6331 or similar)
Misc.—Knobs (2), PC terminals (14), staples, dialplate, hardware, wire, solder, etc.*

*Metalphoto dialplate set (1 for receiver and 1 for transmitter): both available for $1.50 from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014, postpaid in USA.

The following parts are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Tex. 78216:

**Etched and drilled circuit boards (1 for receiver and 1 for transmitter) both for $3.50

***RCF and transformer kit consisting of 4 beads and 3 toroid cores with necessary lengths of magnet wire, $2.50

Complete kit of parts, including Teenuts, less lumber, dialplates, and batteries, $35.00. All prices postpaid in USA.

slot. The boards to hold the transmitter and receiver, also shown in Fig. 3, can be cut from ¼-inch plywood.

Cut two flanges and the pivot from a small piece of 7⁄16" maple as shown in Fig 4. Flush-mount four Teenuts on each flange. Glue the front flange into the 3" notch in the front of the main frame. The Teenuts on the flange should be on the bottom side. Be certain the flange is centered and square. Use clamps for the glue job. Insert and glue the pivot into the rear flange.

The pivot and flange assembly should be sanded to a smooth fit in the slot on the main frame. There should be no wobble or side play. After careful alignment, drill the ¾" hole through the pivot and frame at the same time. Cut and insert a ¾" length of ¾" dowel. Secure with a dab of glue at one end only. Be sure that no glue gets into the pivot assembly to restrict movement.

Steel-wool all the woodwork and apply a coat or two of clear varnish. Keep the slot clear of varnish. After the final coat is thoroughly dry, assemble the microbalance as shown in Figs. 5 and 6.

Use a 3"-long *10-32* machine screw, a compression spring, and protecting washers. You may have to try several springs to get just the right length and tension. You can redrill and tap a knob equipped with a setscrew for a ⅛" shaft to go over the top end of the long screw, and secure it in place with the setscrew. Rotating the knob rotates the pivot, which in turn rotates the transmitter board with respect to the receiver board. Each full turn of the knob represents 0.8 degree of transmitter tilt.

Fasten the transmitter and receiver boards to the main frame with four *10-32* ⅝"-long machine screws. If you use knurled head or thumbscrews for this purpose, you will be able to remove the boards to facilitate carting and storage. Certain special jobs of tracking pipes, or triangulating for depth measurements, can be more readily accomplished with this disassembly feature.

Metal cases should not be used to house the transmitter or the receiver on this type of metal locator as they would cause field-pattern distortion. Low-cost plastic instrument cases are suitable. Be sure to have all the electronic parts on hand and plan their layout before actual assembly is begun. External component dimensions may vary and you may have to make some allowances.

Drill the cases as shown in Figs. 7 and

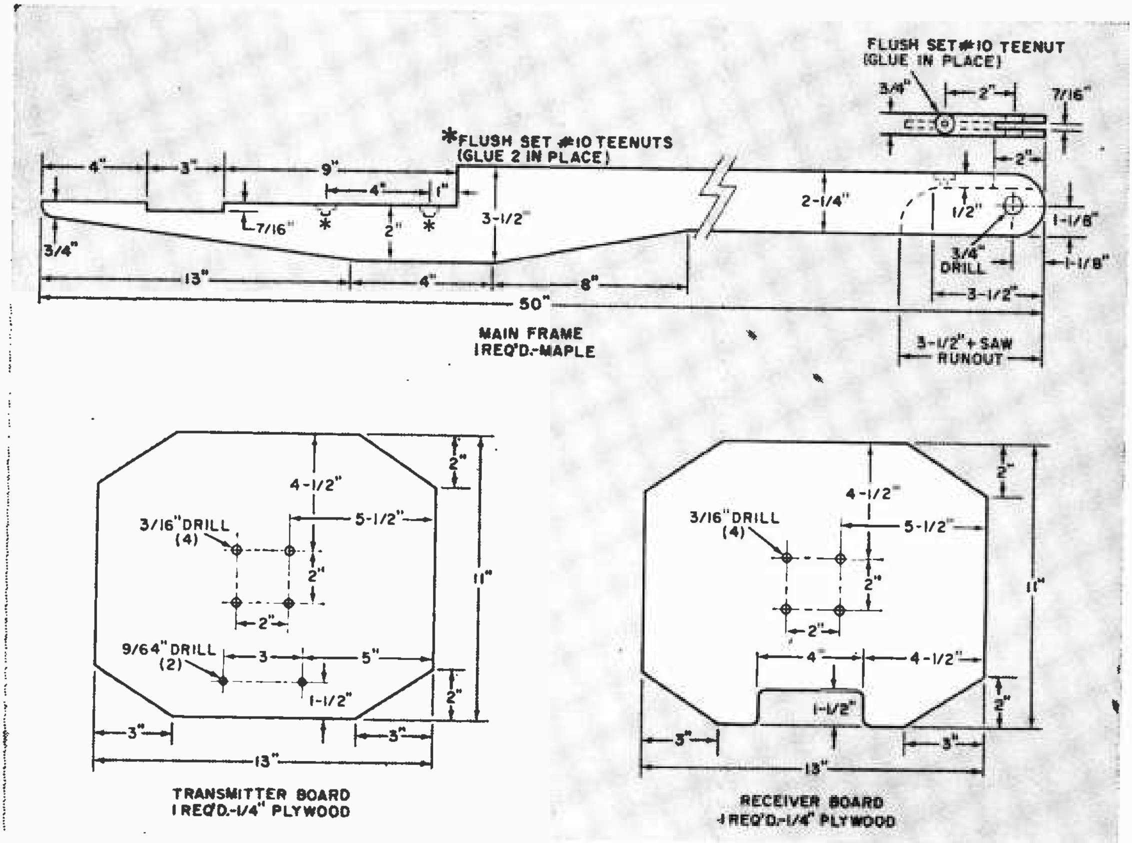
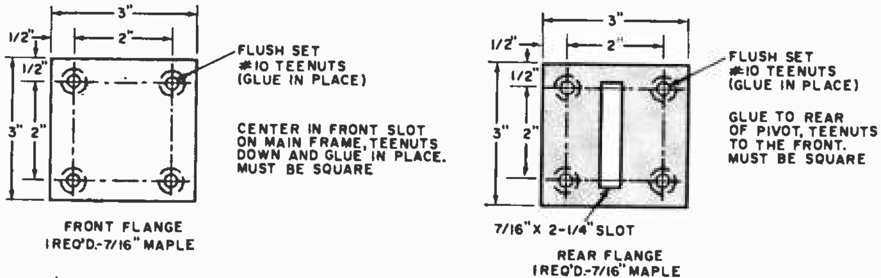


Fig. 3



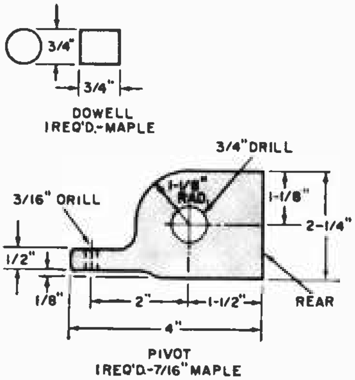
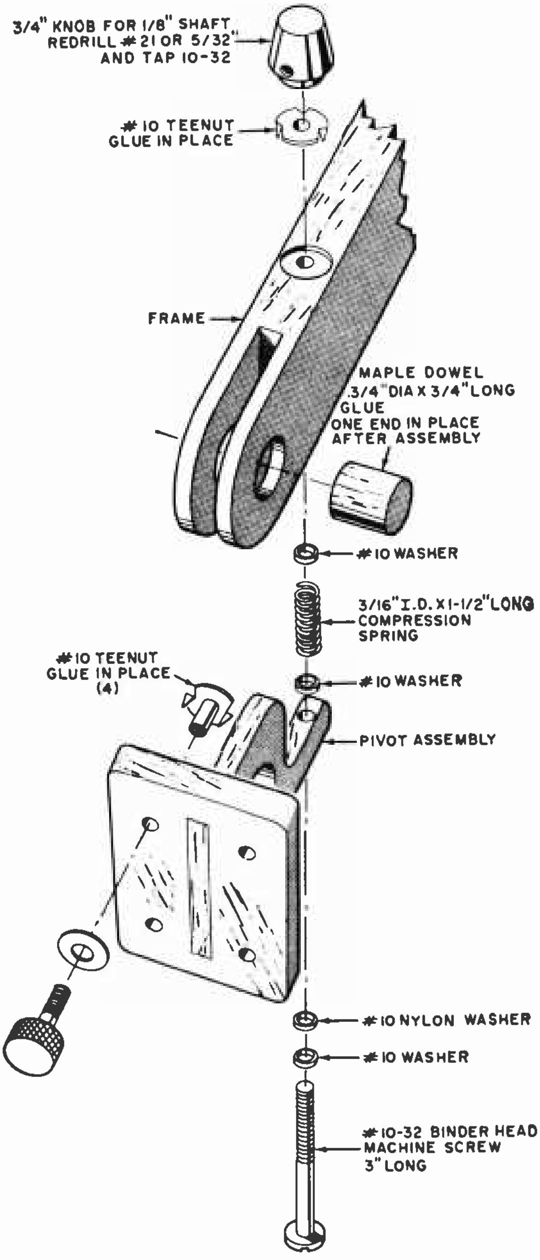


Fig. 3. As in any precision instrument, all parts must be made to fit squarely and securely. Exact contour of frame and boards is not critical, but do maintain relative positions and distance between boards. The less metal hardware, the better. Use maple or other hard, high-quality wood for frame.

Fig. 4. Insert and glue the pivot into slot on the rear flange. Rear of pivot should be flush with back side of flange as shown in Fig. 5. The ¾"-hole should be drilled through the frame and pivot assembly at the same time. Position the pivot assembly as accurately as possible before drilling.

Fig. 4



8, but do this carefully to avoid damage. A rotary file will save you time on the two big holes in the receiver. Glue nylon nuts over the holes in the case, as indicated, and keep the threads and the hole clear. Insert a metal screw while the gluing job is in progress, and then

FRAME PARTS LIST

1—Beam: 50" x 3½" x ¾" maple
2—Antenna boards: 13" x 11" x ¼" plywood
1—Pivot: 4" x 2¼" x 7/16" maple
2—Flanges: 3" x 3" x 7/16" maple
1—Dowel: ¾"-diameter x ¾"-long maple
11—Teenuts: 10-32 x ¾" diameter
1—Machine screw: 10-32 x 3" long, binder head
1—Knob: ¾" diameter for ⅛" shaft, with setscrew
1—Spring, compression: 3/16" i.d. x 1½" long, 6 turns
4—Thumb screws: 10-32 x ¾"
3—Washers: #10 metal
5—Washers: #10 nylon
4—Machine screws: 10-32 x ¾"
Misc.—Glue, varnish, steel wool, etc.

Fig. 5. The microbalance assembly (left) should work freely, but not sloppily. One complete turn of the knob is equal to 0.8 degree of transmitter tilt.

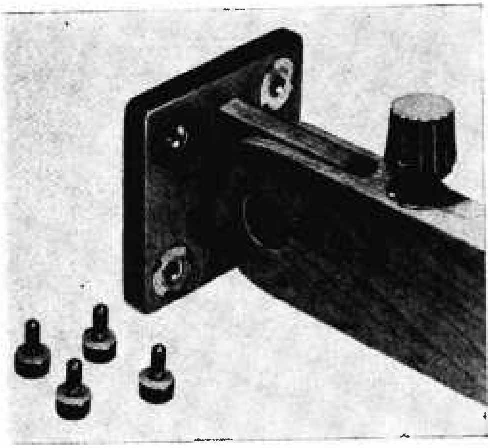


Fig. 6. Use of knurled-head bolts or thumb screws facilitates the removal of the transmitter board for storage, and to solve certain locating problems.

remove the screw before the glue sets. Metal nuts can be used if you have difficulty locating the nylon type.

Two plastic battery holders for four AA cells are also cemented in place—one in the receiver, and one in the transmitter. Solder a lead to an appropriate eyelet or conductor on the receiver's battery holder to provide a "center tap," to give you a center-tapped 6-volt supply. On the transmitter's battery holder, connect the two bottom conductors together and a lead for a center tap, to provide a center-tapped 3-volt supply. Only two cells are used for the transmitter. You could use a 2-cell battery holder for this purpose, but the 4-cell holder permits easier access.

If the cases come through without

covers, use any suitable insulated material. A piece of 1/16" fiberglass is suitable. Add a dialplate to obtain a finished appearance, and to identify the controls.

Electronic Package Construction. *Note: Due to the exceptionally high receiver gain, it is important that an exact duplicate of the prototype PC board be used, and that the exact core materials and winding instructions are followed for the transformers and r.f. chokes. Failure to do so will almost certainly result in receiver instability and bandwidth problems.*

The r.f. chokes are wound on ferrite beads. Start with about 12" of 34-AWG enameled magnet wire, and wind 10 turns equally spaced toroidal-fashion around the bead. Keep the wire tight and the turns neat. Do not nick the wire on the bead edge. After winding, cut each end to 1/4" length and strip the enamel back 3/16". Sand your way down to shiny bare copper, and tin the leads.

The transformers are only slightly more difficult. Start with 10 feet of 34 AWG enameled magnet wire. (Do not substitute.) Fold the wire in half and twist it until you get about 12 turns

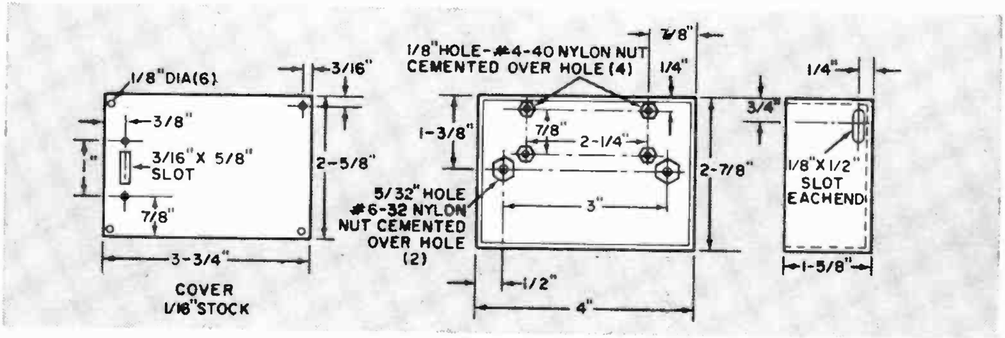


Fig. 7. Use a small plastic box to house the transmitter. Do not employ any more metal hardware than is absolutely necessary. A metal case will distort field pattern uniformity.

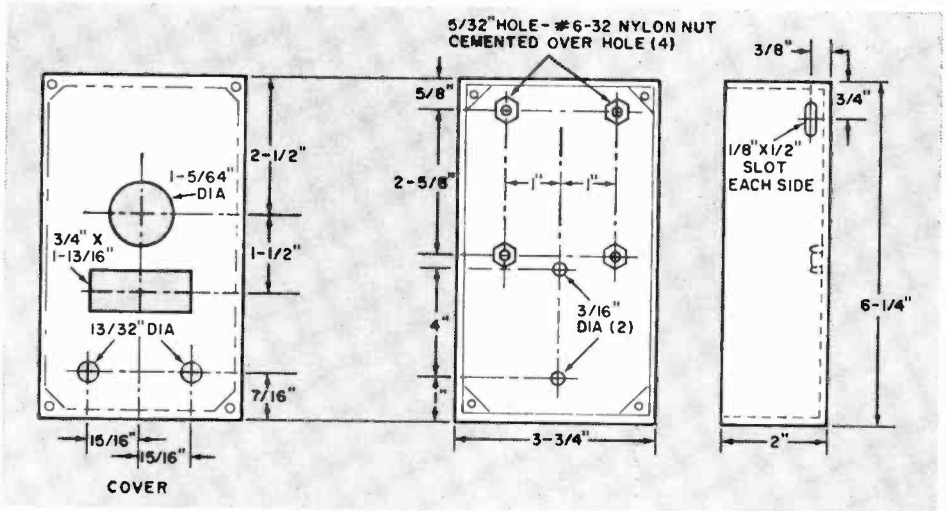


Fig. 8. Receiver housing is also made of plastic; work slowly and carefully when drilling or cutting. Slots in side of box should be large enough to accept antenna without bending or bunching conductors.

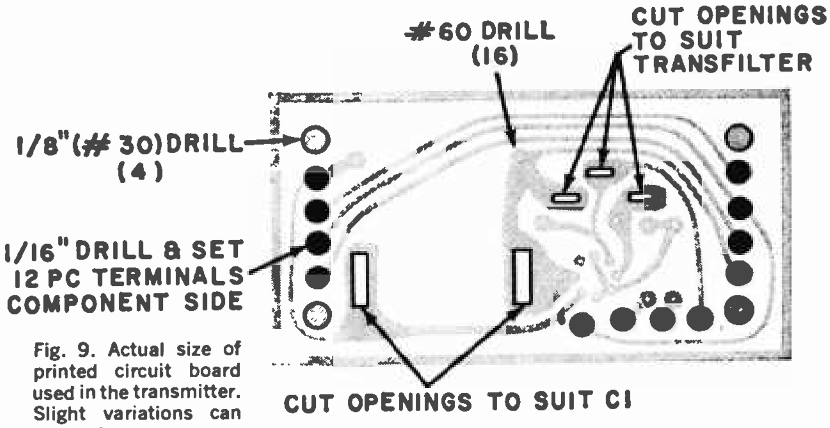


Fig. 9. Actual size of printed circuit board used in the transmitter. Slight variations can be made to accommodate parts which are of different size, but avoid any excessive variation in either size or layout of the components.

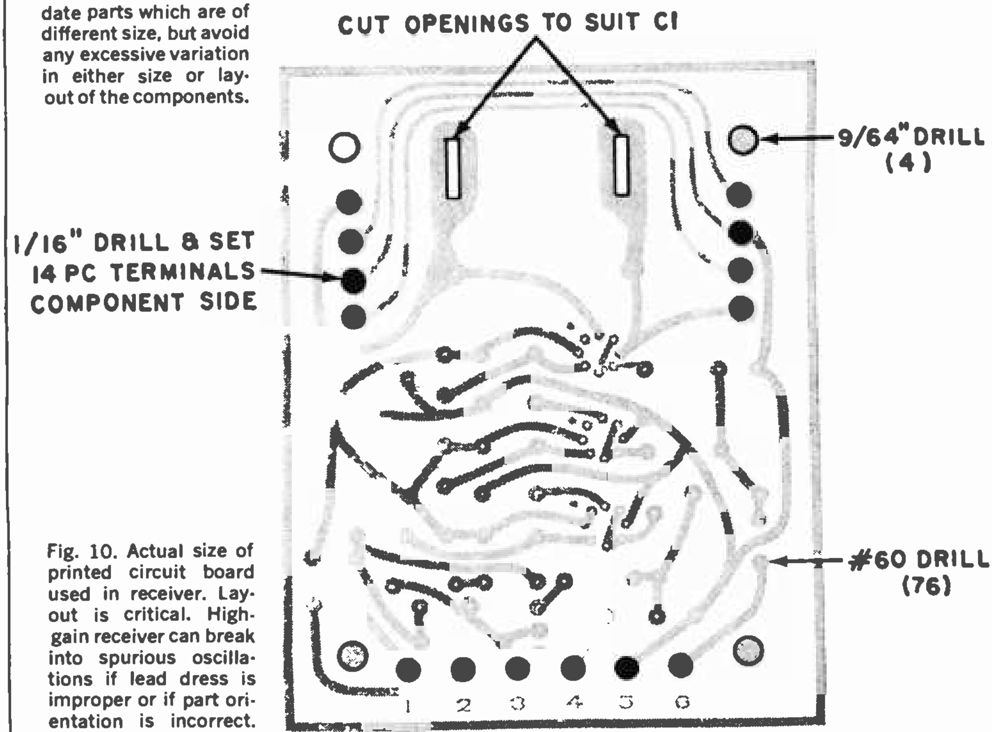


Fig. 10. Actual size of printed circuit board used in receiver. Layout is critical. High-gain receiver can break into spurious oscillations if lead dress is improper or if part orientation is incorrect.

per inch. Guard against kinks, nicks, and abraided insulation. Now, using this bifilar wire, wind *exactly* 36 turns on a CF101 core. Work your way evenly around the core until you near the end of the first layer. Leave a small gap on the core, with no wire in it. Then begin a second layer, working your way back to the beginning, and so forth. Keep your turns neat, tight, and sequential.

After counting out the 36 turns, cut the leads to ¼" and strip and tin to $3/16$", just as you did on the r.f. chokes. There should be four leads. Use an ohmmeter to identify each pair of wires. Also check for shorts between windings and the core.

Circuit boards are available, but if you want to make your own, follow the actual size layouts shown in Figs. 9 and

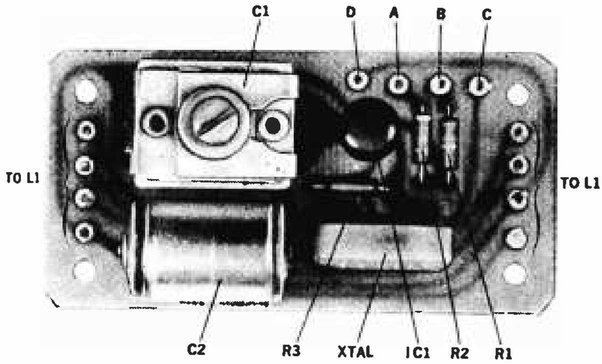
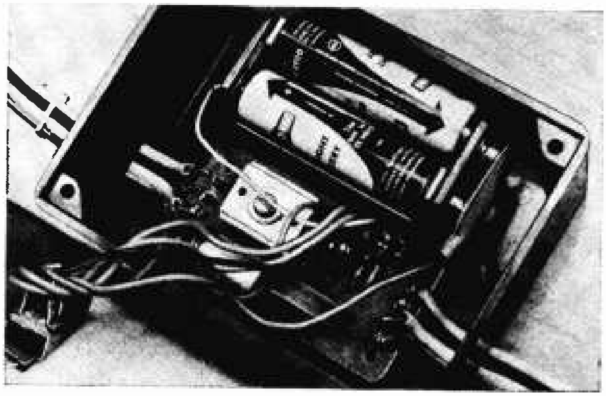


Fig. 11. Components are mounted on transmitter board. Note that pin numbers on IC1 run counterclockwise when you're looking at the top of the component.



10. Mount the components as shown in Figs. 11 and 13. Do not substitute capacitors; those called for have the proper "Q" and tolerance. The transformers and chokes are held in place by their leads. After the initial checkout, you can further secure them with a dab of coil dope.

Controls with switches mounted on them are used to simplify operation of the receiver. The *Gain* control carries on/off switch *S1*, and the *Expansion* control has a push-pull s.p.s.t. switch (*S2*) mounted on its back, as shown in Fig. 14.

Wiring should present no serious problems. Use several colors of wire and double-check all connections. Route all six receiver leads through a single piece of 3/8" sleeving to keep the receiver orderly and also to prevent spurious oscillation.

The two loop antennas are identical and are made out of a 37-inch length of four-conductor 16-AWG flat cable, and shaped into a 9" x 11" rectangle. It is important that both loops be exactly the same and resonate at 455 kHz.

It is not possible to simply bend the cable—you'll have to gradually work or mold it into shape with your hands. The cable must lie flat on the board, so work the cable by alternately bending and flattening as you go. You can best do this on a flat table. Temporarily add a bit of tape in the center of the cable, to mark the center, and work your way towards each end from the middle.

Staple the loops to their respective boards. Remove just enough excess cable (the same amount from each loop) to accommodate the receiver and transmitter terminal spacing. The loop ends are stripped and soldered into place. The loop leads must go to the antenna terminals in sequential order. They will do this naturally if your cable lies flat.

Initial Checkout. Insert the receiver batteries and turn both the *Gain* and *Expansion* controls all the way down. Pull out the *Pull Audio* switch. Bring up the *Expansion* control until the meter reads 0.4 mA. The audio should cut in initially around 0.3 mA. Now bring the gain up. The meter reading should increase only slightly. If it jumps up, you have

(*Continued on page* 38)

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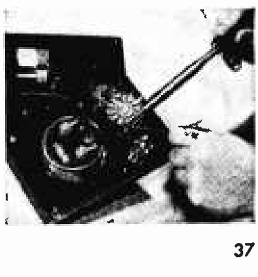


Construction of Multimeter.

oscillation problems, which can usually be cured by more careful lead dress. If necessary, try rotating the transformers slightly.

Set the transmitter a few feet away from the receiver, and switch it to *Low*. The receiver should immediately swing off scale and the audio volume should increase. Decrease the *Gain* control on the receiver to obtain a meter reading of 0.7 mA, and adjust the trimmer capacitor in the receiver and in the transmitter to peak the response.

To be sure that your metal locator is at optimum sensitivity, perform these three tests. First, have someone hold the receiver while you hold the transmitter (antenna loops) *parallel* to the receiver, and walk away slowly. Key the transmitter on and off with the switch, as you walk. In the *High* position, there should still be a discernable receiver output beyond 50 feet; in the *Low* position, you should get a range of about 25 feet.

Second, assemble the locator, hold the beam sideways (receiver loop facing the horizon), turn the *Gain* up, and adjust the microbalance for a null reading (minimum). Approach a chain-link fence, a truck, or other large metallic body; the meter should show an output when you get within nine feet of the object, and should swing off-scale at seven feet.

(*Continued on page* 146)

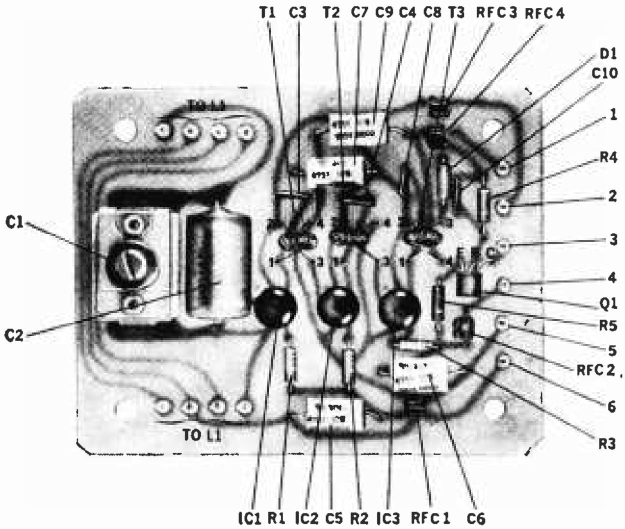


Fig. 12. Component layout in the receiver is critical. You may have to slightly rotate or bend the transformers towards or away from the board to prevent unwanted oscillations. Reverse leads on T3's secondary when connecting it to the board as shown.

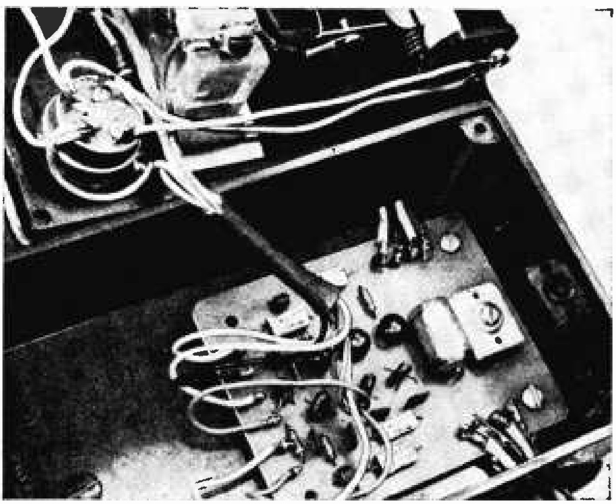
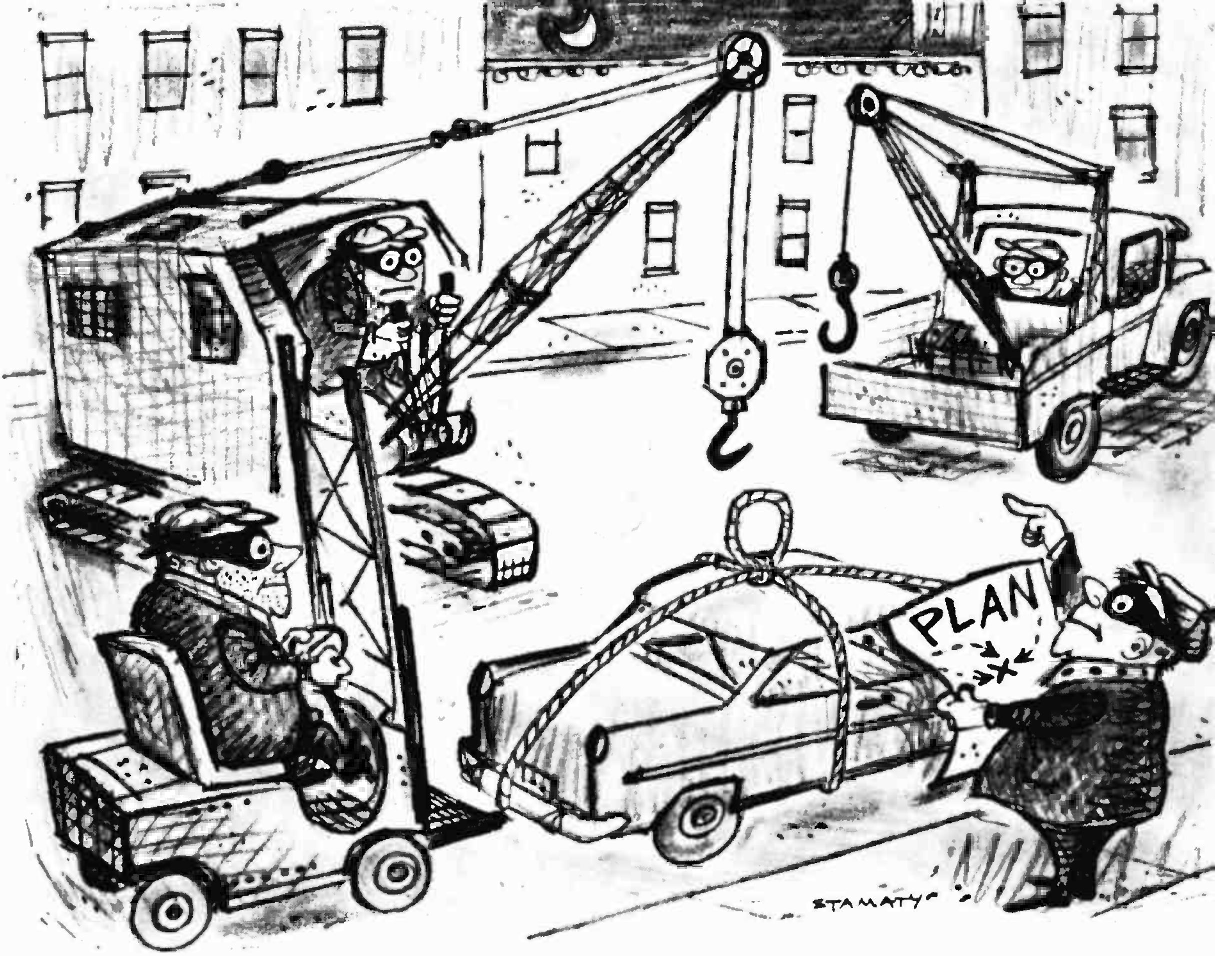


Fig. 13. All r.f. stages in receiver resonate at 455 kHz. Trimmer capacitor tunes the antenna. This is one project where you must stick as close as possible to instructions and not make parts substitutions or compromises.



STAMP OUT AUTO THEFT

THE ONLY WAY YOUR CAR CAN BE STOLEN WHEN IT IS PROTECTED WITH THE "AUTO SENTINEL" ALARM IS FOR THE THIEF TO PICK IT UP BODILY AND CARRY IT AWAY

By R. L. WINKLEPLECK

AUTO THEFT is a big business for organized crime and an actively pursued hobby for thousands of teen-agers looking for "kicks." In an effort to stave off these thefts, many laws have been put into effect through which stiff fines and summonses can be handed out to owners who leave keys in ignitions when they get out of their cars, who fail to lock their car doors when their cars are left unattended for a long time, and who conspicuously display valuable goods in their cars—and who commit other such offenses that are open invitations to a thief to ply his trade. Although these

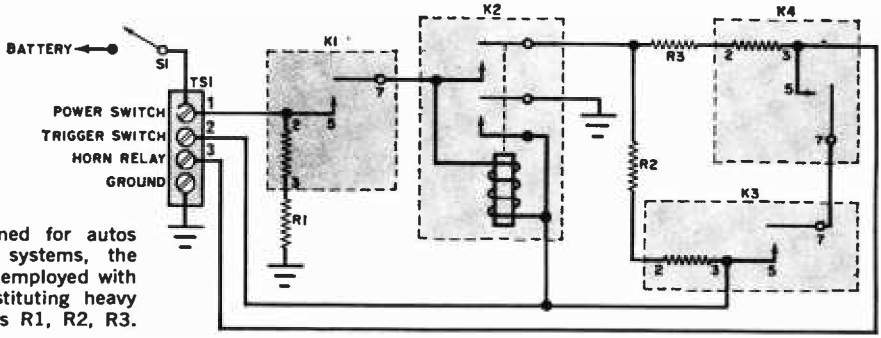


Fig. 1. Although designed for autos with 12-volt electrical systems, the "Auto Sentinel" can be employed with 6-volt systems by substituting heavy jumper wire for resistors R1, R2, R3.

laws are fine as far as they go, they will not effectively thwart a determined car thief. It is for this reason that auto alarms are constantly being designed to help stamp out auto theft.

The "Auto Sentinel" alarm system has a unique quality which places it at the top of the list so far as alarms are concerned; it can be put on the alert without anyone knowing about it, even if the driver is being "cased." There are no external locks or switches mounted on the car to set or deactivate the system. Cost is less than $15.00.

How It Works. The circuit of the Auto Sentinel, shown in Fig. 1, is simple and virtually foolproof. Once it is connected to your car's electrical system and power switch *S1* is thrown on, the battery voltage is applied to thermal relay *K1*. After about 15 seconds, *K1*'s contacts close, and place the alarm system on standby.

If a door is opened while the system is on standby, magnetic relay *K2* energizes and latches in this mode through its lower contacts. Even if the door is opened momentarily and then immediately closed, the alarm circuit is activated.

Once the circuit is activated by a thief, his time begins running out. At the end of about 15 seconds *K3* energizes, grounding the car's horn relay through *K4*, *K3* and *K2*. As the horn relay closes, *K4*'s heater circuit is completed, and after one piercing blast from the horn (at which the surprised thief will, hopefully, drop everything and run for the hills), the horn will continue to sound at a rate of 30 times a minute until *S1* is shut off.

You have 15 seconds (the time needed for *K1* to energize) to get out of your car after the switch is thrown and to close the door. This time margin is more than adequate for you to activate the alarm without alerting anyone to what you are doing, but not adequate enough for a thief to achieve his purpose. Upon re-entering the car, you have another 15 seconds—before *K3* energizes—to switch the alarm system off.

Construction. First, decide where you want *S1* mounted. You can mount it on the same box in which the rest of the circuit is assembled, or you can hide the switch behind the dashboard in any convenient place.

Almost any type of chassis construction is suitable, but since the unit is likely to be subjected to a lot of mechanical stresses, all connections should be mechanically sound—use enough solder

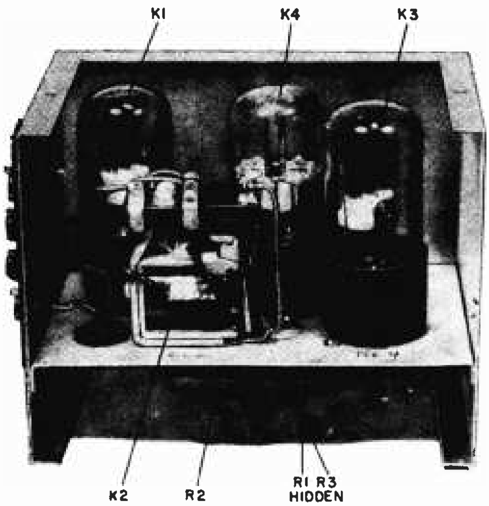


Fig. 2. Typical layout shows all relays mounted on chassis surface while the resistors are underneath it. Note that K1, K3, and K4 are socket-mounted.

to keep them that way. Also, use lock-washers with all screws.

Parts layout is not critical, and can be as shown in Fig. 2. The completed unit is shown in Fig. 3. Construction is the same for both 6- and 12-volt electrical systems except that *R1, R2* and *R3* are not used for a 6-volt system.

If you decide to mount the box in the engine compartment, keep it away from heat, oil, water, and other debris.

Hookup. Connecting the Auto Sentinel to your car's electrical system is a snap. The door switches that operate the dome light, or other courtesy lights, plus a switch on the car's trunk lid, and another on the engine hood all serve as "triggers" for the alarm system. If all your doors, hood, and trunk are not already equipped with switches, you will have the additional task of installing suitable switches in order to protect all entry areas. Mercury switches are the easiest types to install on the hood and trunk lid.

PARTS LIST

K1, K3—S.p.s.t., normally open thermal relay with 15-second delay (Amperite 6NO15 or similar)
*K2—D.p.s.t., 12-volt relay**
K4—S.p.s.t., normally closed thermal flasher with 30 flashes per minute (Amperite 6F30 or similar)
*R1—20-ohm, 5-watt resistor***
*R2, R3—15-ohm, 5-watt resistor***
S1—S.p.s.t. switch
TS1—4-post terminal strip
Misc.—Small utility box, hookup wire, octal sockets (3), solder, etc.

**Change to 6-volt relay for 6-volt alarm*
***Omit these parts with 6-volt systems*

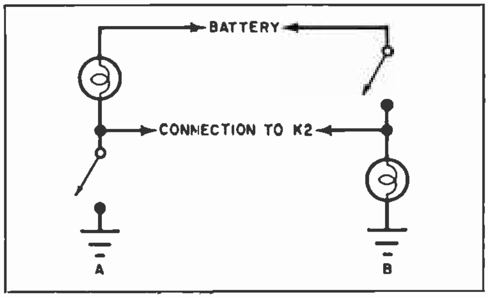


Fig. 4. If a mercury switch is used for the trunk light and it is wired as shown in B, rewire it to conform to the configuration shown in A at left.

Generally, door switches are wired like the circuit shown in Fig. 4(a). Connect a wire from terminal *2* on *TS1* to any door switch on the dome light side as shown. If a mercury switch is used for the trunk light and it is wired as shown in Fig. 4(b), rewire it to conform with 4(a).

Connect the horn relay to terminal *3* on *TS1.* (There's nothing to prevent you from installing a siren and let it do the screeching for you, instead of your horn, if you are so inclined.) Finally, connect *S1* between the ungrounded side of the car's battery and terminal *1.* If the alarm box is well grounded, there is no need to make a connection between terminal *G* on *TS1* and the car's ground.

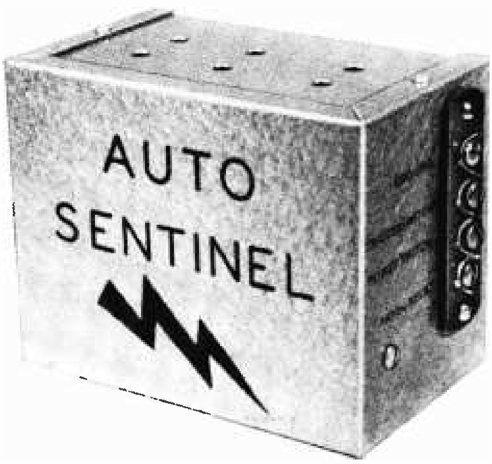


Fig. 3. If desired, the "Auto Sentinel" can be mounted in the glove compartment, or behind the dash where connecting wires can be run out of sight.

Finishing Touches. All that's left now is for you to test the alarm system. If it works as described here, and it should, you're in business, and a thief will just have to look somewhere else to make his illegal livelihood.

After you've stopped the car, shut off the engine, set the parking brake, flip *S1* to its operating position, close the windows, get out of the car, close and lock all doors, and relax.

One final word if you have a tendency to leave your keys in the ignition lock when you get out of your car, forget this whole idea—you'll never remember to turn the Auto Sentinel on—or off! -30-

Now-it's easy to make recordings of children

WITH POPULAR PHOTOGRAPHY'S UNIQUE NEW RECORD ALBUM

"TONY SCHWARTZ ON HOW TO RECORD—THE SOUND OF CHILDREN"

To instruct you in the techniques of recording children's voices, the editors of Popular Photography asked famed sound authority Tony Schwartz to prepare this special record, available exclusively and by mail only through Popular Photography magazine and other Ziff-Davis publications. By listening to it you can quickly acquire the skills needed to make top-quality recordings of youngsters—thus preserving permanently the sound of their voices.

YOUR TEACHER: AN EXPERT'S EXPERT

You couldn't have a better instructor than Tony Schwartz. A pioneer in the use of portable tape recorders, he has been capturing the sounds of actuality for 23 years. You've read his monthly column in Popular Photography. Now hear him explain and illustrate in provocative recorded demonstrations the working methods that have helped him to become the world's No. 1 sound collector.

SIMPLE, COMPLETE INSTRUCTIONS

HEAR ACTUAL DEMONSTRATIONS OF

- A tape recording before and after editing.
- The sound of a battery-operated recorder at three tape speeds: 1⅞, 3¾, and 7½ inches per second.
- The improvement in fidelity when a quality microphone replaces the mike supplied as a recorder's standard equipment.
- How to reduce unwanted noise while recording.
- Acoustics: the sound of sound in the living room, kitchen, hallway, and street.
- Improving sound quality by re-recording a tape.

In addition to the tips on selecting and using equipment, you learn how to create complete sound stories with children—even recreate a situation that has already taken place! Actual sound demonstrations enable you to hear the effects of various tape speeds, microphones, and acoustical conditions. You also learn how to eliminate unwanted noise and to improve your tapes by re-recording them. In less than one hour, you get the benefit of years of experience and recording know-how!

EXTRA!

You'll be intrigued and thoroughly entertained by Side II of this superb new album. It's devoted entirely to three of Tony Schwartz's most famous sound essays, all acclaimed as "works of great artistry that will surely be enjoyed by anyone who enjoys and appreciates the sounds of children."

"CHILDREN AND GOD"—a fascinating composite of thoughts expressed by youngsters of various religious faiths. Their naively reverent concepts of God, heaven, good and bad, and prayer will be a revelation to you. This unique presentation is unlike anything you have ever heard before!

"NANCY GROWS UP"—a remarkable sound portrait of a girl's developing personality. In just two minutes, you hear her voice from 20 minutes after her birth, through the years until she's 13—when she reveals: "I've discovered boys!"

"SOUND SNAPSHOTS"—a potpourri of chuckles . . . once-in-a-lifetime sayings that could come only from the mouths of babes. These uproarious remarks, all said in the innocence of childhood, include delightfully ingenuous observations like these:

"I'm so hot I'd like to take my skin off!"

"I had growing pains yesterday."

"You go up in heaven when you die. You don't have to pay taxes, or anything—I'm positive."

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. . . plus many more that will make you howl with laughter! You and your friends will enjoy listening to all of these entertaining essays in sound again and again.

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Get the most out of your recording equipment by discovering the easy way to make tapes that you'll always treasure. This instructive and entertaining album should be owned by everyone within the sound of a child's voice and laughter. The special low price is:

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CHAPTER

2

AUDIO STEREO HI-FI PROJECTS

No other area of consumer electronics—or as a matter of fact, hobby electronics—has undergone a more sweeping change in ten years than high fidelity. In 1957, stereo hi-fi was via tape only and the stereo disc was still around the corner. The possibility of shrinking the size of 50-70 watt hi-fi amplifiers was a dream, and not too many audio engineers foresaw the day when transistors would eventually replace the faithful vacuum tube.

Of course, in the absence of stereo, you needed only one speaker system for good sound reproduction, and corner enclosures were the current fashion. The sealed box enclosure was in the midst of its development and ceramic speaker magnets were still in the laboratory.

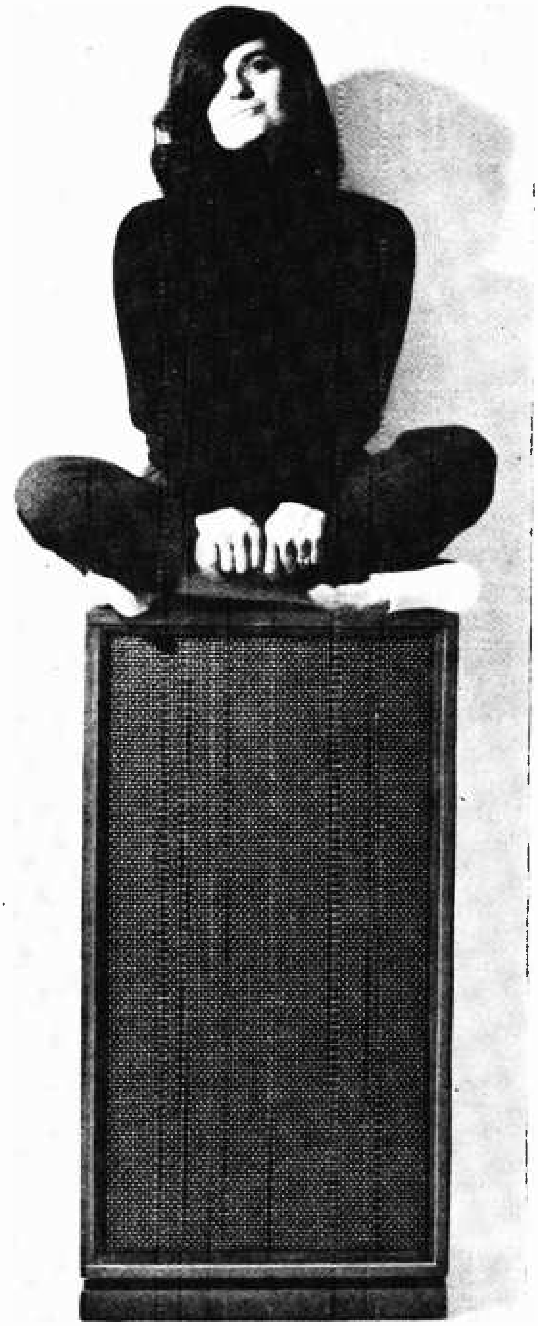
Ten years ago, the experimenter built a lot of hi-fi gadgets—tone compensators, faders, AM tuners, preamps, etc. He also built speaker enclosures, and the first issue of this HANDBOOK contained the very first enclosure design by Dave Weems—this edition contains two. And, from the small 2-watt hi-fi amplifier of 1957, we have leaped to the super-powerful 70-watts-per-channel solid-state amplifier shown on page 57.

It makes you wonder—was 2 watts ever hi-fi?

FOUR ON THE FLOOR

IMPROVED SPEAKERS
PUT "CINDERELLA"
IN A BIGGER CARRIAGE

By DAVID B. WEEMS



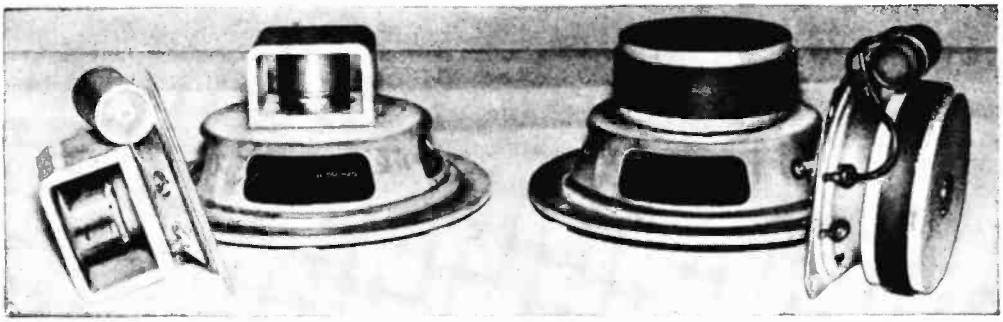
A QUICK GLANCE at a hi-fi catalog would probably reveal that you would have to plunk down $100 to $150 for a quality speaker system containing four woofers and two tweeters in handsome furniture cabinetry. But, for a few well spent hours and about $40, you can get your own system rolling. Four woofers, each rated at 12 watts, do for the "Four On The Floor" what the four-gear "stick-shift" on the floor of a sports car does for a hot-rodder: the woofers add that extra sense of presence when it's needed.

Improved versions of the 6"-diameter acoustic suspension woofer used in the "Cinderella" enclosure (see Fall, 1966, EXPERIMENTER'S HANDBOOK) are now available. While the original woofer and tweeter each had a 4.6-ounce alnico V magnet, the new model woofer has a 20-ounce ceramic magnet, and the tweeter has a 10-ounce ceramic magnet. The new speakers sport better damping and improved transient response.

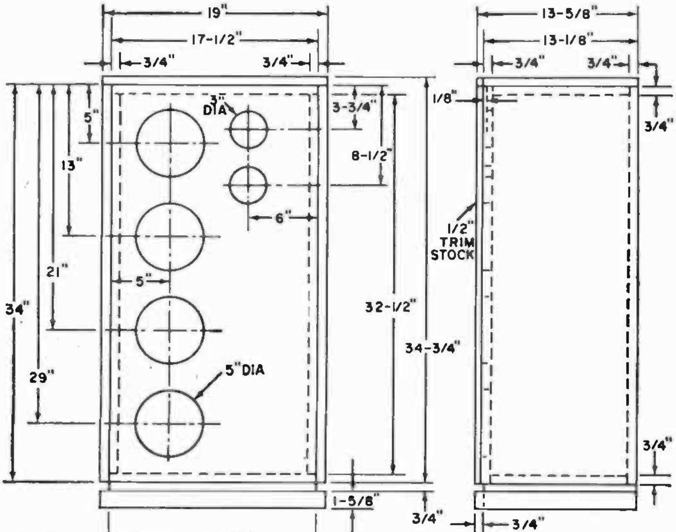
In the same way that multiple woofers beef up the low end of the audio spectrum, two tweeters bring the highs along. The net result is a more sensitive speaker system that will work off as little as a 10-watt amplifier, and yet handle a lot more power; overall response is smooth, and pleasing even to the most discriminating ear.

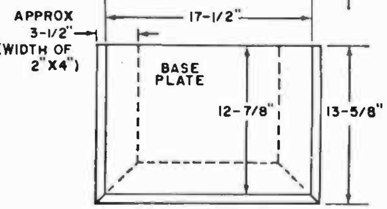
The Enclosure. A "box-within-a-box" design or double-thick walled construction provides a rigid enclosure to let the speaker's energy drive the air rather than the wood. Glue and screw the outer walls to the inner walls. Secure the front of the cabinet in the same way. Be sure to seal all the joints with glue. However, do not glue the back in place.

First assemble the interior frame and cabinet frame as shown, then finish off

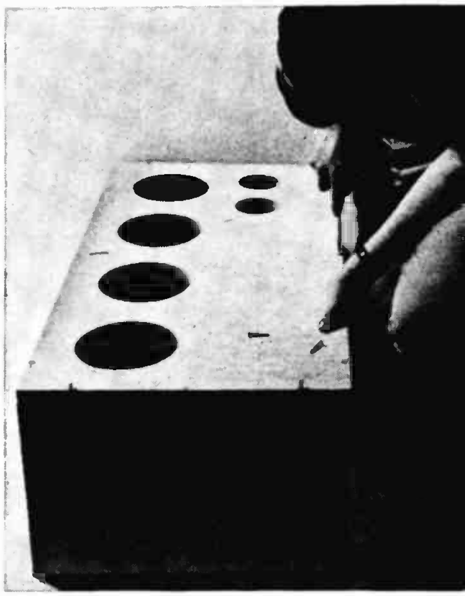


Earlier models (at left) had 4.6-ounce Alnico V magnets; newer versions (at right) sport a 10-ounce ceramic magnet in the tweeter, and a 20-ounce unit in the woofer to provide better damping and transient response.





Inner top, bottom, and side walls can be cut from 9' length of 14" piece of pine shelving. Outer surfaces, including front, back, and base, can be cut from a 4' x 6' x ¾" sheet of fine-quality fir plywood.



Enclosure should be airtight. Except for the back, glue all joints and sides. Carefully mount plywood sides and top after inner box is assembled.

BILL OF MATERIALS

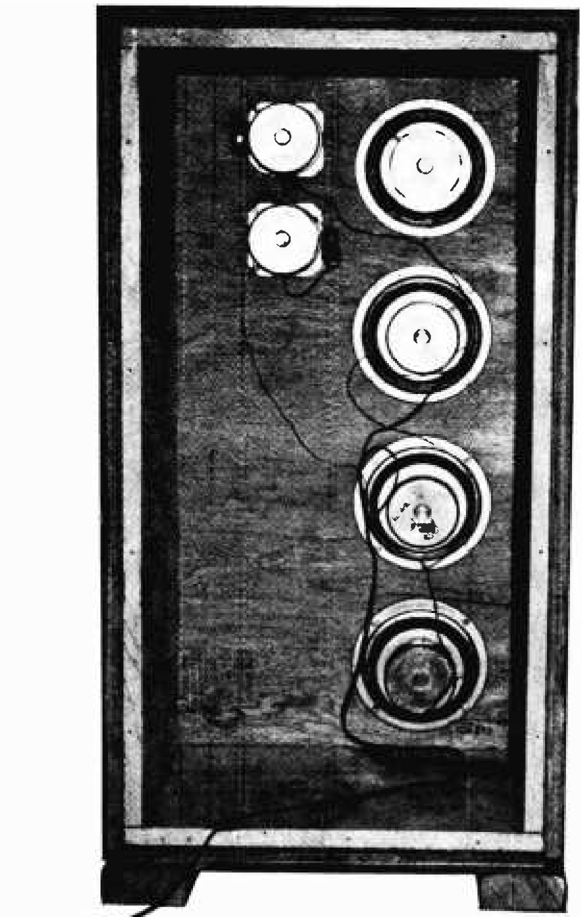
*4—XS-6071 woofers (4 for $25)**
*2—TS-6070 tweeters (2 for $7.50)**
2—17½" x 34" pieces of ¾" fir plywood for exterior front and back
2—13¼" x 34" pieces of ¾" fir plywood for exterior sides
1—13¾" x 19" piece of ¾" fir plywood for exterior top
1—13" x 17½" piece of ¾" fir plywood for exterior bottom
*2—11½" x 32½" pieces of ¾" pine shelving for interior frame sides***
*2—11½" x 17½" pieces of ¾" pine board for interior top and bottom***
1—2" x 4" x 48" piece of pine for footing
1—10' length of ½" quarter-round molding
1—10' length of ½" x ¾" fine grain pine
Misc.—#8 x ¾" sheet metal screws, #8 x 1¼" flat-head wood screws, #8 x 2" finishing nails, two-terminal screw-type terminal strip, 2"-thick x 12"- to 18"-wide fiberglass or quilted cotton batting, grille cloth, glue, small finishing nails

**Available from McGee Radio Co., 1901 McGee St., Kansas City, Mo.*

***Sold as 1" x 12" pine board*

with the exterior top and sides. Use 1¼"-long flat-head wood screws from the inside to hold the exterior walls in place. Pilot-drill the screw holes before securing the sides to the frame, to position the sides precisely. The sides should overlap the rear and bottom by ¾" and the front by ⅛". The top fits squarely over the sides. Be careful to finish and dress the side edges of the top so that they are flush with the sides and back.

The base consists of a ¾"-thick piece of plywood mounted on a 2" x 4" frame which serves as a footing. Carefully miter (45°) the ends of the footing to obtain a smooth, professional appearance. (If desired, a square cut will suffice, but the exposed ends will have to be sanded smooth.) Join these pieces

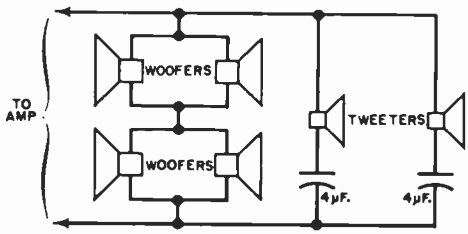


Double-walled construction and multiple speaker system reinforce sound output and provide authoritative smooth response. Pad speakers and walls to dampen and break up standing waves within the enclosure.

with #8 x 1¼" finishing nails, and nail or screw the frame to the bottom of the cabinet. A little glue won't do any harm, but be sure to keep things squared off.

Trim the front of the cabinet with ¾" x ½" fine grained wood and quarter-round molding. Do not nail the molding in place until the entire cabinet has been sanded and stained and the grille cloth has been tacked in place. Apply a coat of flat black paint to the front of the cabinet before installing the grille cloth. Use fine finishing nails on the molding.

Mounting and Wiring. Mount the speakers over their respective holes on the front of the cabinet with #8 x ¾" sheet metal screws. Pad the inside top, bottom, back, and side walls of the cabinet



Hookup shown is for an amplifier's 8-ohm impedance tap. To maintain the proper phase, the top leads are connected to the terminal marked with a red dot.

with 2"-thick fiberglass or quilted cotton batting. To provide the correct amount of damping for optimum performance, fold a three-pound roll of 18"-wide cotton batting in half and tack this to the top of the cabinet so that it forms a thick "blanket" over the speakers.

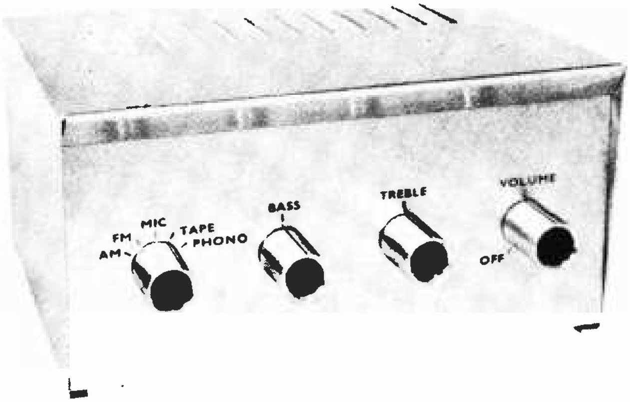
Drill a hole in the back of the cabinet, just large enough to pass the wires through, and seal the hole with any suitable caulking material. Wire the speakers as shown. Observe the red dots to obtain proper phase and solder all connections.

In some rooms the highs may sound too bright, in which case an 8-ohm L-pad can be inserted in series with the woofers to lower their output slightly.

Mount a terminal strip on the back and color-code the red dot terminal just in case you decide to build two units for stereo. Finally, screw the back panel tightly in place. -30-

BUILD THE

"TWO-BY-TWO" STEREO PREAMPLIFIER



SOLID-STATE HI-FI CONTROL CENTER CAN BE USED WITH ANY STEREO POWER AMPLIFIER. CONSTRUCTION IS SIMPLIFIED THROUGH USE OF PRINTED CIRCUIT BOARDS

By DANIEL MEYER

MODERN DESIGN TECHNIQUES make it possible for you to build this modular "Two-By-Two" stereo preamplifier all at once or one circuit at a time. The completed unit can "tailor" phono, tape, microphone, and AM and FM tuner signals to fit almost any hi-fi amplifier, including the "Brute-70" which is described on pages 57 through 63 in this issue.

Generally speaking, a preamplifier—be it a mono or a stereo affair—is the control center of a component hi-fi system. It serves as a "matchmaker" between the program source and the basic amplifier. Regardless of the number and type of program sources, they are all fed into the front end of the preamp, and at the flip of a switch are individually and effortlessly patched into a power amplifier. The preamp also has the ability to raise or lower volume, to boost or cut

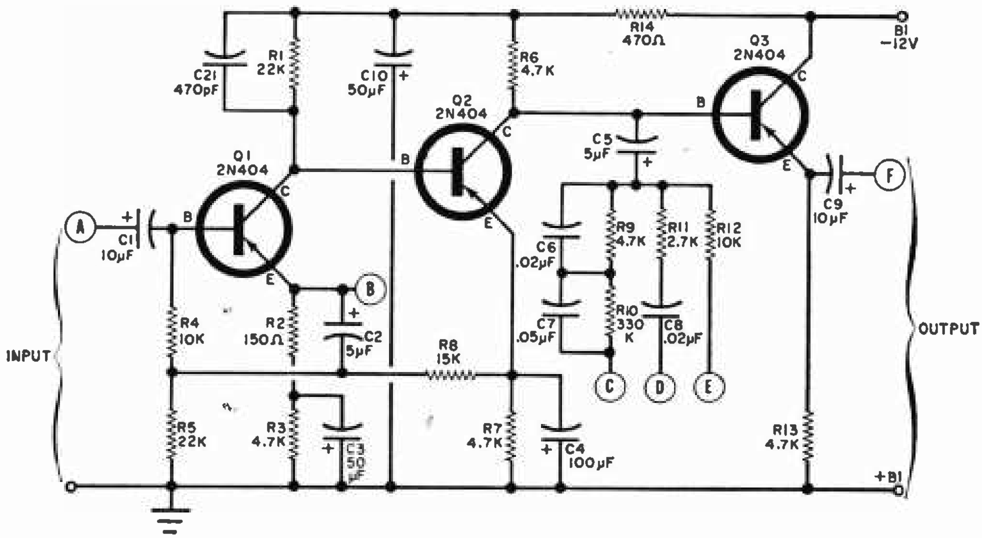


Fig. 1. This is the circuit diagram of one of the fixed gain preamplifiers. The two preamplifiers are identical. Points labeled A,B,C,D,E, and F are printed circuit connection points to input jacks, switches, and other printed circuit boards.

bass and treble, and to compensate for dips and peaks in programs, in room acoustics, and in hi-fi equipment.

In the "Two-By-Two" preamp, there are two sections in each of two identical channels employing 2¼"-square printed circuit boards. One of the sections is a 3-transistor preamplifier equipped with three compensating networks to accommodate the different input devices. The other section is a 2-transistor base and treble tone control circuit capable of a 15-dB boost or cut on both ends of the audio spectrum.

A minuscule amount of power is required by the "Two-By-Two," and almost any 12- or 24-volt d.c. supply will do. In many instances you can steal

PARTS LIST

C1, C9, C13—10-μF, 15-volt electrolytic capacitor
C2, C5—5-μF, 15-volt electrolytic capacitor
C3—50-μF, 6-volt electrolytic capacitor
C4—100-μF, 6-volt electrolytic capacitor
C6, C8—0.02-μF ceramic disc capacitor
C7—0.05-μF ceramic disc capacitor
C10, C18—50-μF, 25-volt electrolytic capacitor
C11—0.005-μF ceramic disc capacitor
C12—0.047-μF ceramic disc capacitor
C14—200-μF, 6-volt electrolytic capacitor
C15, C21—470-pF ceramic disc capacitor
C16, C17—30-μF, 15-volt electrolytic capacitor
C19—500-μF, 50-volt electrolytic capacitor
C20—100-μF, 25-volt electrolytic capacitor
D1, D2—500-mA, 100-PIV silicon diode or better
D3—24-volt zener diode
Q1-Q5—2N404 pnp transistor or similar

R1, R5, R19—22,000 ohms
R2—150 ohms
R3, R6, R7, R9, R13, R15, R16, R17, R21, R28, R30—4700-ohms
R4, R12, R18—10,000 ohms
R8—15,000 ohms
R10—330,000 ohms
R11—2700 ohms
(All resistors ½-watt unless otherwise specified)

R14, R22, R23—470 ohms
R20—2200 ohms
R24, R25—Dual 50,000-ohm, ½-watt, linear-taper potentiometer
R26—Dual 5000-ohm audio taper potentiometer (with switch S2)
R27, R29—220,000 ohms
R31—1000 ohms, 1 watt
S1—Two section, two-pole, five-position ceramic or other low-loss rotary switch
S2—S.p.s.t. switch (mounted on R26)
T1—Transformer: primary, 117 volts a.c.; secondary, 40 volts center-tapped (similar to Knight 54 A 4731)
1—6" x 8" x 4½" cabinet (similar to LMB CB-2)
Misc.—Printed circuit boards, knobs, wire, solder, spacers, 6-32 machine screws and nuts, input and output jacks, etc.

Etched and drilled printed circuit boards at $1.50 each; all parts (less board and potentiometers) for the 3-transistor amplifier section at $4.50 each; and all parts (less board and potentiometers) for the 2-transistor tone control at $3.25 each are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216.

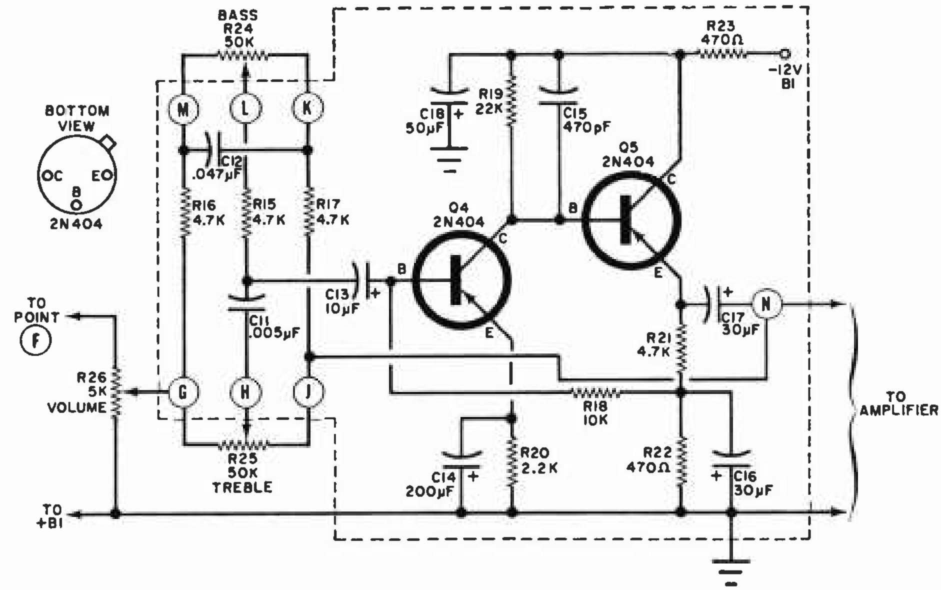


Fig. 2. Circuitry important to the tone controls of the stereo preamp is etched in two printed circuit boards. As in the diagram on the facing page, points G,H,J,K,L,M, and N are connections to jacks, switches, and front panel controls.

this power from your amplifier. Just in case you can't, details for building a simple power supply are presented on page 50.

How It Works. The preamp consists of two high-gain amplifier stages (*Q1* and *Q2*), and an emitter follower stage (*Q3*), as shown in Fig. 1. The three feedback networks (*C, D,* and *E*) from the collector of *Q2* are connected one at a time to the emitter of *Q1* (point *B*) to provide a flat output signal for a magnetic phono cartridge (*C*), a tape head (*D*), and an AM/FM tuner or microphone (*E*). The latter network provides an essentially flat amplifier response characteristic, whereas the first two networks compensate for the disc and tape recording industry's standards and practices.

Input impedance of *Q1* is made high by the bootstrap action of *C2*. This action is achieved in a very interesting manner. An increase in value of any of the bias resistors effectively increases the input impedance. However, there are practical limits which restrict the size of these resistors, and prevent an appreciable increase in impedance. The desired effect of increased input impedance is the reduction of input signal current flow. In this case, it can be achieved by making *R4* "look" like a much larger resistor than it actually is. Fortunately, you can do this with a feedback signal to the bottom of *R4*, which is in phase with the input signal voltage. If the voltage applied to both ends of *R4* is equal and of the same polarity, no current will flow. (The stronger the applied signal, the greater the feedback.) The resulting input impedance is high enough to handle ceramic and other high-impedance microphones without loading problems.

Capacitor *C9* couples the signal to the top of the volume control (*R26*) shown in Fig. 2. The tone controls are low-distortion feedback types with a variable turnover characteristic, which simply means that the point at which boost or cut begins changes as the control is rotated. This is much more desirable than the simpler constant-turnover type tone control, which affects all frequencies up to the designed turnover point even when a small amount of boost or cut is used.

The tone control network, Fig. 2, has a one-stage amplifier (*Q4*), and an emitter follower (*Q5*). Output impedance of this circuit is low, which permits proper operation with almost any type of hi-fi power amplifier made. For a dynamic microphone or other low-impedance pickups not requiring a compensating amplifier response curve, you can omit the compensating networks and wind up with higher gain, but with a lower input impedance—on the order of 10,000 ohms.

A two-pole, five-position rotary switch, as shown in Fig. 3, is used to select any one of the five inputs on one channel of the "Two-By-Two." A double-ganged affair is needed to handle both channels. Use a ceramic or other low-loss switch to minimize crosstalk.

The inherent stability of the circuit permits proper operation over a wide supply voltage range, without modification of bias, and without materially affecting gain. However, the lower the supply voltage used, the lower the clipping point for input signals and the lower the peaks of the output signals, as shown in the specs on p. 141. For best results, use 24 volts. Figure 4 shows a circuit for a zener-regulated, full-wave power supply that you can easily put together, if you need one. It's a good idea to keep a.c. and power supply components on a separate chassis, away from the preamp.

Construction. The "Two-By-Two" can be built and used as a "One-By-One," as a "Two," or just a "One." If you are not interested in stereo and only want a mono preamp, you can assemble a "One-By-One," which is one amplifier section, and one tone-control section. If you just need an amplifier and are not interested in the tone controls, you can build a "One," a "Two," or for that matter a "Three," or even a "Four," leaving off the tone-control section each time.

If you are building the amplifier section only, just connect a jumper wire from point *B* (see Fig. 1) to the proper compensation network, if one is to be used. However, you will find a rotary switching arrangement to be most convenient, if more than one type of input device is to be used.

The simplest way to put this project together is to use printed circuit boards, as shown in Fig. 5. Other construction techniques can be used, but be alert to the need for proper lead dress and for proper component layout to minimize

(*Continued on page* 140)

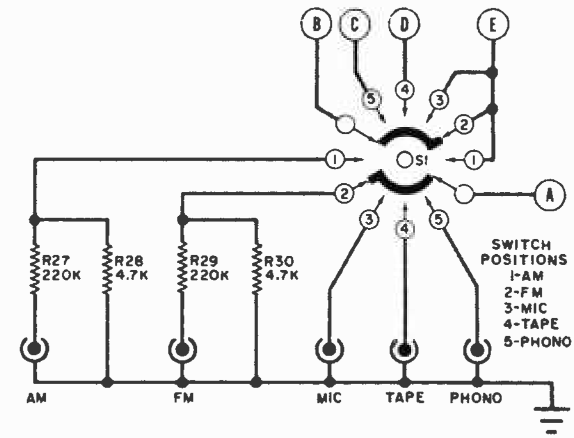


Fig. 3. Input selecting switch feeds compensating network output (C, D, and E) to emitter of transistor Q1 to alter frequency response of preamplifier.

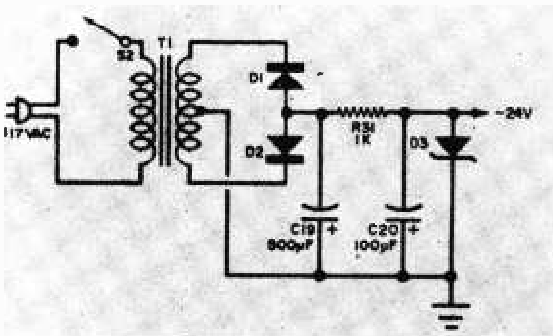


Fig. 4. If you find it difficult to "steal" 12 or 24 volts of pure d.c. from your power amplifier, a zener-regulated, full-wave supply may be substituted.

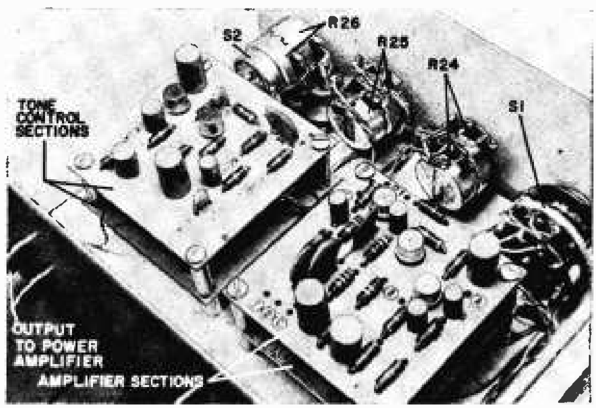


Fig. 7. The amplifier and tone control sections of the "Two-By-Two" can be neatly stacked. Note dual section controls used for a stereo installation.

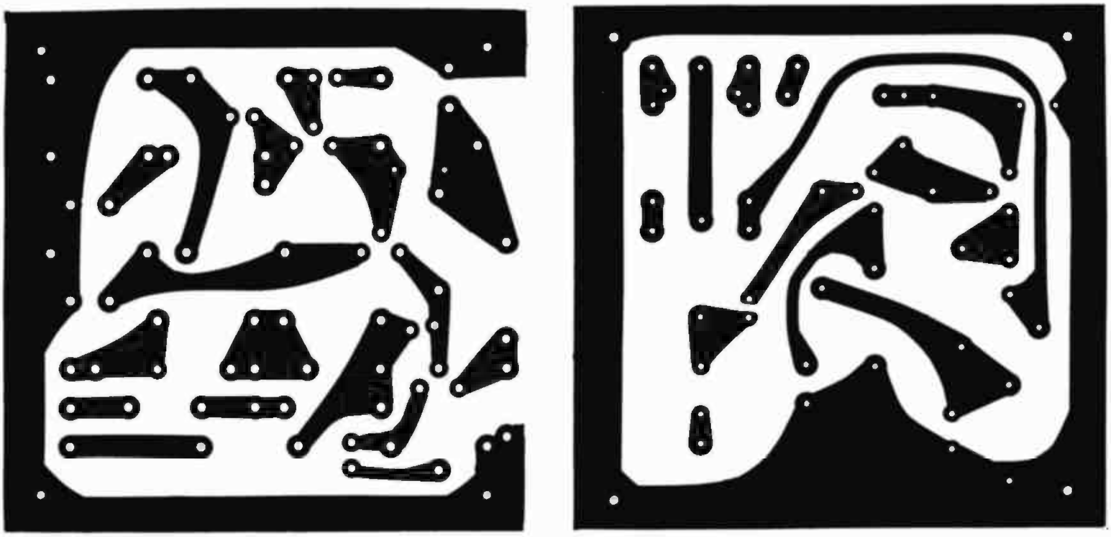


Fig. 5. Same-size layouts of the foil side of the two printed circuit boards are shown above. The fixed-gain preamplifier is to the left and the tone control board to the right. For stereo operation the builder requires 4 boards, two of each circuit.

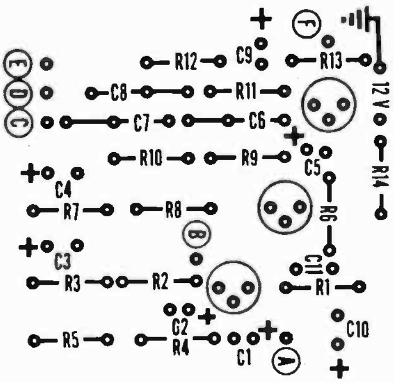
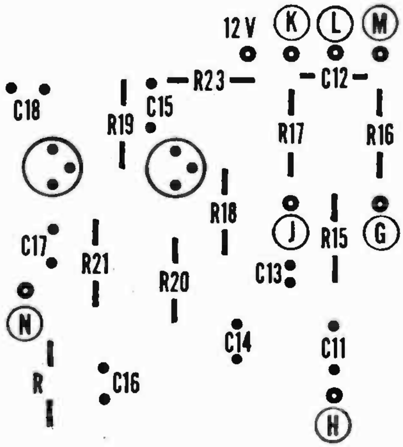


Fig. 6. Position components on plain side of the circuit boards as shown—amplifier to the left and tone control to the right.



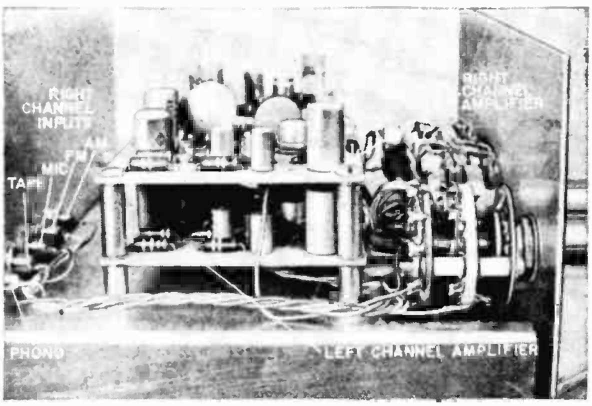


Fig. 8. Side view shows use of metal spacers. Unshielded leads run between switch and input jacks. In case of hum pickup substitute shielded leads.

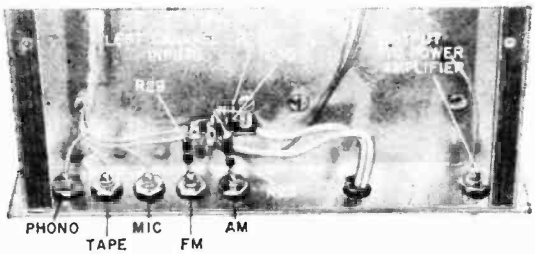


Fig. 9. Underside of chassis is bare except for input loading resistors for the main AM and FM left channel inputs. All input jacks for the right channel are isolated above the chassis. This improves channel-to-channel separation. If hum pickup is a problem use shielded leads here also.

BUILD THE "MIXED TWELVE" SPEAKER SYSTEM

STAGGERED RESONANCE ARRANGEMENT OFFERS EXCELLENT RESPONSE AT LOW COST

IN SPITE OF the obvious limitations of small speakers, the popularity of small speaker systems continues to grow. The reasons why can be attributed to improvements in suspension systems, cone materials, voice coils, magnets, and overall construction. As a result of these improvements, a system made up of many small speakers can be designed to reproduce the bass frequencies (from 200 Hz down) without significantly affecting their normal response to the midrange and the high frequencies.

In the "Mixed Twelve" system, speakers of different sizes are arranged in a

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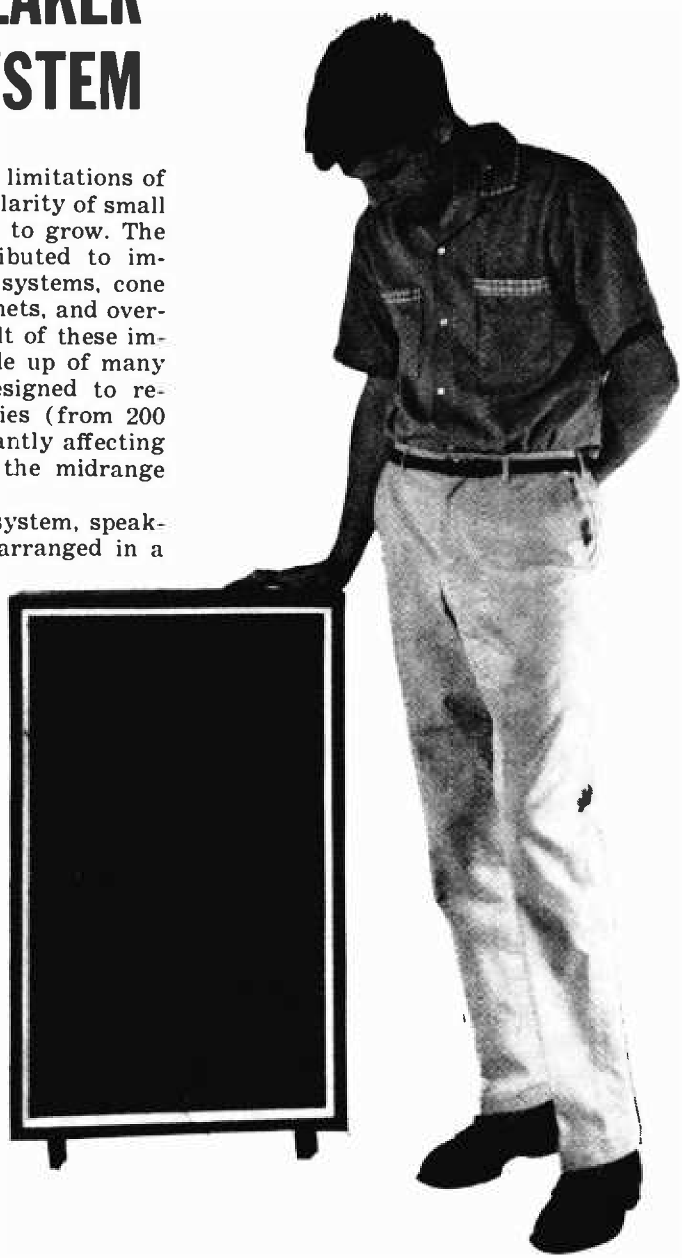


somewhat irregular and unusual manner in order to set up a "staggered resonance" condition. For the money (about $35), performance is excellent, and the ability of the system to reproduce "big" source sounds and handle orchestral transients without "going to pieces" is remarkable.

Some multiple-speaker systems reproduce sounds that bounce from one speaker to another, resulting in what can best be classified as a "ping-pong" effect. (Yes, it is possible to create this effect in a mono system.) In the "Mixed Twelve," the audio spectrum is not split up—every speaker in the system works simultaneously. The sounds are more smoothly reproduced and appear to have a more natural character.

Besides the system's low cost, a big advantage of the "Mixed Twelve" is the fact that it can be driven by a low power amplifier.

The Speakers. While a major reason for using small speakers instead of large ones is economy, keep in mind when selecting speakers that there are some which are too poor in quality to be considered. The three most important things to look for in a speaker, besides the way it actually sounds, are magnet strength,

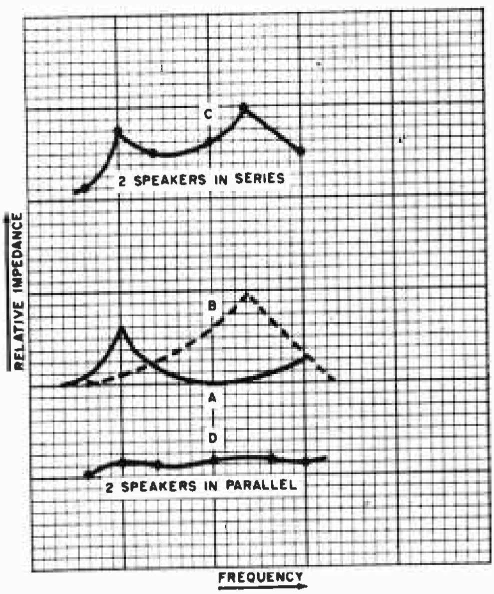


Fig. 1. By connecting two speakers with different resonances in a parallel arrangement, sharp peaks found in a series arrangement can be flattened.

cone material, and overall construction. If any of these appear to be below standard, chances are that the speaker will compromise the quality of the sound.

If the magnet strength is insufficient, damping will be inadequate to prevent the speaker cone from continuing to vibrate after the signal is removed. If the speaker cone material is too light in weight, it will "break up" when loud passages are reproduced and add its own voice. The speaker's own voice and continued vibrations are nothing more—or less—than distortion.

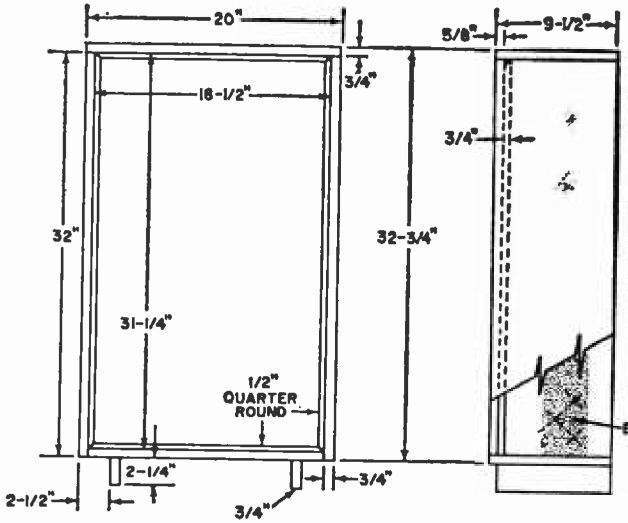
You should also give some thought to the size and shape of the speakers you intend to use. As a rule, a speaker with a large-cone area usually has a better low-frequency response than a speaker with a small-cone area. Conversely, a smaller speaker usually has better high-frequency characteristics. In most speaker systems, the overall audio spectrum is covered by the use of several different-size speakers in one enclosure.

Speaker shape has a direct bearing on the performance of a staggered-resonance system. Round speakers can be used, but oval types offer certain advantages. The oval speaker usually has a better high-frequency response than a round speaker that has the same cone area. And better horizontal sound dispersion is obtained from an oval speaker that has its long axis vertically oriented.

In addition, do not mix speakers having different impedance ratings. If the speakers in a system do not have the same impedance, they will "see" different amounts of power, and the system will not operate as predicted here.

Four of each of the following size speakers are used in the "Mixed Twelve": 3" x 5" (RCA), 4" x 6" (Zenith), and 5" x 7" (imported); the two smaller sizes of speakers have 1.47-oz. magnets, and the largest has a 2.14-oz. magnet. All of them are rated at 3.2 ohms impedance. But you can choose a different assortment of speaker sizes, if you wish, and still come up with a good system.

Speaker Arrangement. Low frequency response (mainly attributed to the stiffness of the cone) in small speakers is limited. When several of them are connected together, however, they help each other boost the low frequency response.



BILL OF MATERIALS

1—31¼" x 18½" sheet of ¾" fir plywood for front panel
*2—32" x 9½" x ¾" sides**
*1—20" x 9½" x ¾" top**
*1—18½" x 9½" x ¾" bottom**
2—8¾" x 2¼" x 1" bottom rails
3—18½" x 2" x 1" braces
(Soft pine lumber)
1—96"-long piece of ½"-quarter-round molding
12—Speakers of your choice—see text
Misc.—Grille cloth, speaker wire, sheet metal screws, finishing nails, etc.

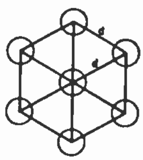
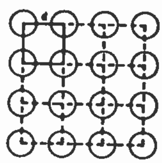
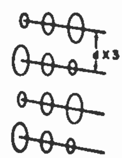
*When ordering, specify 1" x 10" pine shelving.

Fig. 2. Top, bottom and side walls can be cut shallower than shown, but do not change the dimensions of the front board.

If all the speakers had the same resonance characteristic, there would be some unwanted side effects in the midrange. Fortunately, speakers of different sizes and shapes do have different resonant frequencies, and they do bypass many of these side effects when properly hooked up.

Consider two speakers, each having different resonant frequencies with relative curves (*A*) and (*B*) respectively, as shown in Fig. 1. When they are connected in series, a sharply spiked curve (*C*) will be obtained. Total impedance for the two speakers will be approximately double that of either speaker. The curve for the same two speakers connected in parallel (*D*) is more uni-

SPEAKER ARRANGEMENT CHARACTERISTICS

PATTERN	CIRCULAR	SQUARE	LINEAR	STAGGERED
				
NUMBER OF SPEAKER SIZES	1	1	1	3
D/n RATIO*	1.7/1 (D=12, n=7)	1/1 (D=4, n=4) 1.33/1 (D=12, n=9) 1.5/1 (D=24, n=16)	n−1/n	0.5/1 (D=3, n=6) 0.75/1 (D=9, n=12) 0.8/1 (D=12, n=15)
EFFECT OF PATTERN ON MUTUAL COUPLING	Excellent	Good	Fair	Good when speakers are of various sizes
FREEDOM FROM PEAKS IN THE MID-RANGE	Poor	Progressively poorer as n increases	Good	Good
HORIZONTAL DISPERSION CHARACTERISTICS	Poor	Poor	Excellent	Fairly Good

**D=the number of identical distances between adjacent speakers in the speaker pattern, and n=the number of speakers; this is the ratio of the number of identical distances between speakers adjacent to each other and the total number of speakers that gives a good estimate of the tendency of the system to peak. A low ratio is desired because the higher the ratio, the greater the tendency to peak. Terms like good, fair and poor are only relative.*

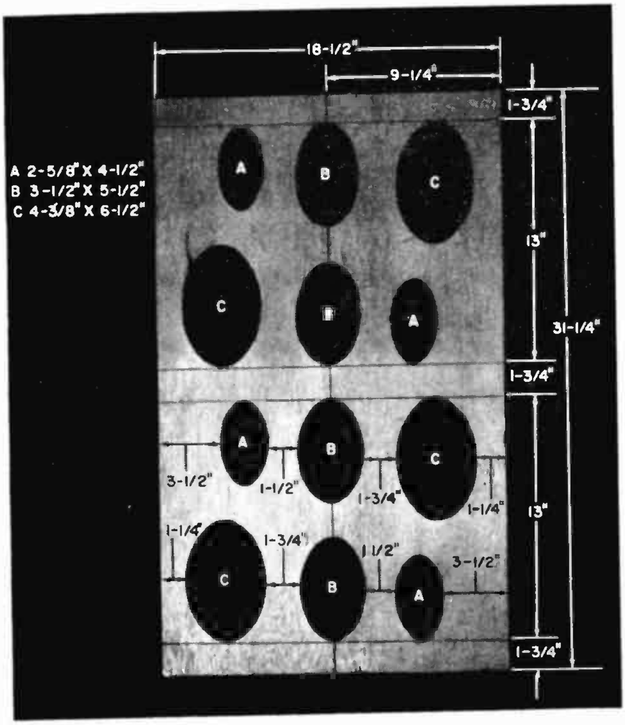


Fig. 3. Using the lines drawn on the front board to obtain proper placement, start drawing speaker cutout lines along the vertical line with medium-size template. Then draw in the other cutout lines.

form and virtually flat over a wide range of frequencies. Also, their combined impedance is reduced drastically.

When several small speakers are used in a single cabinet, a certain amount of desirable mutual coupling at low frequencies is obtained, and a certain amount of undesirable interactions at other frequencies is also present. These interactions can cause dips and peaks in the system's overall response curve. Peaks and dips occur when the distances between speakers are certain fractions of a wavelength of the sound.

To design a multiple speaker system completely free of peaks and dips is almost impossible, but fortunately it is possible to minimize these effects by following a simple rule-of-thumb—stagger the positions of the speakers in the cabinet so that center-to-center distances are not the same for immediately adjacent speakers. The characteristics obtained with different speaker arrangements (at left) can be used for comparison.

Construction. The back of the "Mixed Twelve" cabinet has been deliberately left off to minimize the effects of cabinet resonance. As a result of the backless feature, overall dimensions are not critical. The width of the top, bottom, and sides can be slightly larger or smaller than shown in Fig. 2, but do not change the size of the front panel. (Finished width of 10" shelving is 9⅝" and there's no need to strip the lumber down to 9½".)

To lay out the openings on the front panel, draw a line across the top and bottom, spaced 1¾" in from the top and bottom edges, as shown in Fig. 3. Draw two more lines 13" from the top and bottom lines. Then draw a vertical line down the center.

Cut up a piece of heavy cardboard to serve as a template for the cutouts. You will need a separate template for each different size speaker. The dimensions of *A*, *B*, and *C* in Fig. 3 are typical. If your speakers require a different set of contours, modify the cutouts accordingly. (Avoid using speakers larger than 5" x 7", if you don't want to redesign the entire cabinet.)

Draw the cutout shapes on the front

Fig. 4. Templates that are cut from heavy paper or cardboard greatly facilitate the laying out of speaker cutout lines on the front board. A different template is needed for each size of speaker used.

panel as shown in Fig. 4. Carefully cut out the openings and then paint the front of the panel and the sides of the openings. Use flat black paint to obtain a uniform front panel appearance and to keep the openings from being noticeable through the grille cloth.

Glue and nail all joints. Be sure to sand and stain the cabinet before tacking the grille cloth in place. Frame the front panel with ½" quarter-round molding.

Now center and mount the speakers over their respective holes, using 8 x ¾" pan-head sheet-metal screws to secure them. Glue 1" x 2" pieces of wood between the rows of speakers as shown in Fig. 5.

Wire the speakers all in phase as shown in Fig. 6. You can check speaker

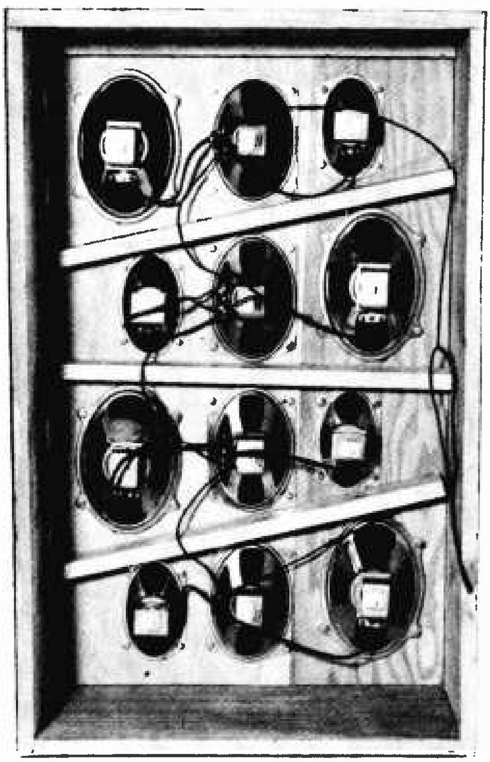


Fig. 5. Glue cleats between rows of speakers. Sturdier cabinet construction can be obtained if cleats are also used for mounting front board in place.

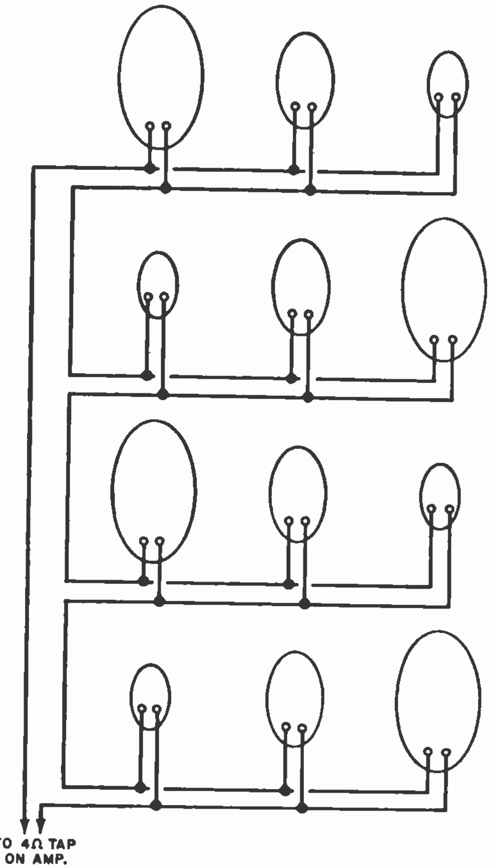
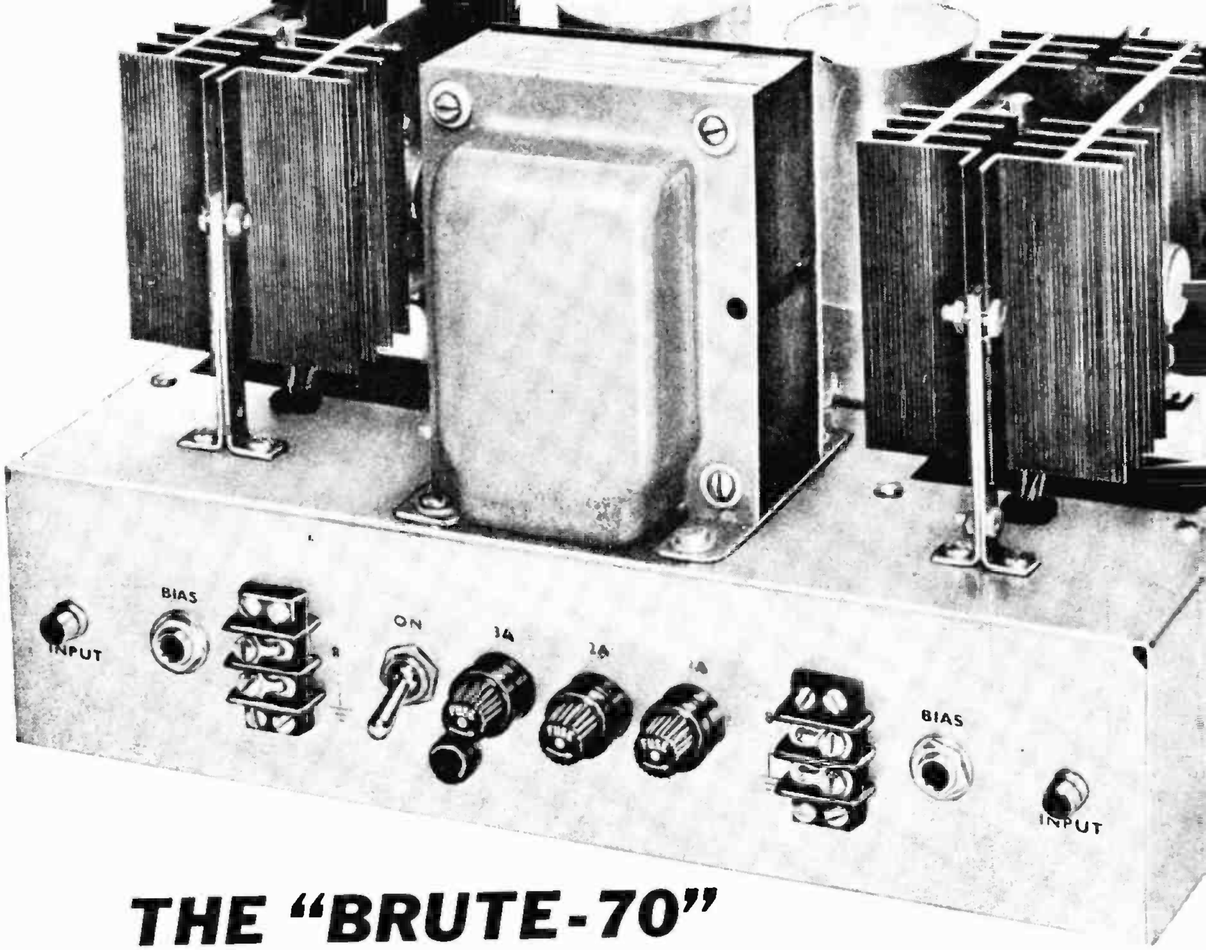


Fig. 6. Double-check wiring to make sure that all speakers are connected in phase. Simple battery test described in text can be used for this purpose.

phase by observing the direction of cone movement as you momentarily connect a 1½"-volt flashlight battery across the speaker terminals. When the speakers are all wired in place, double-check the phase by once again momentarily connecting the battery across the entire system; all cones should move in the same direction at the same time. If any of the cones do not move in the same direction as the majority, reverse the connections on the nonconformers.

To dampen the system, tack a 2"-thick sheet of cotton batting, or other suitable material, to the top of the cabinet and let it drape down to the bottom of the cabinet to form a thick "curtain" over the backs of the speakers.

Connect the "Mixed Twelve" to the 4-ohm output terminals on your hi-fi amplifier . . . and relax. —30—



THE "BRUTE-70"

SOLID-STATE POWER AMPLIFIER FOR MONO OR STEREO HI-FI

By E. G. LOUIS

IN THE NEVER-ENDING search for hi'er fi, audio fans and other experimenters are constantly upgrading their equipment. If the time has come for you to improve the amplifier portion of your system, or if you want to start a new system, you are in a position to benefit from the "Brute-70" solid-state 70-watt hi-fi amplifier, especially if you like to build your own equipment and want to keep your costs down. You can build two Brute-70's and a common power supply, all on one chassis, to obtain an unusually good stereo amplifier—the specifications are most impressive.

The amplifier gets its name from the fact that it puts out a "brute" 70 watts of power—that is, 70 root-mean-square (r.m.s.) watts. If you build a stereo version, as shown here, and if you rate the amplifier by adding both channels together, and use the peak watts figure (r.m.s. watts x 2 = peak watts), like some manufacturers do, you will wind up with a whopping 280 watts. But don't be fooled, the power is still only a brute 70 watts (r.m.s.) per channel.

Unlike many power amplifiers, the Brute-70 is able to deliver most of its full-quality sound at all volume levels, not just at its full rated output. You can listen to the authority of the bass drum and the command of a bugle or to the quiet mood setting background music of Roger Williams or Mantovani without a worry about distortion. Total harmonic distortion is less than 1% at any power level, and less than 0.25% within generally used levels. Frequency response is flat within 1 dB from a low of 5 Hz all the way up to 25 kHz . . . and it drops off only 3 dB at 50 kHz. It has been demonstrated that amplifiers with essentially flat frequency response well beyond the upper limit of hearing (15,000 to 20,000 Hz) have a minimum amount of phase distortion within the audible range. To the purist, distortion of any kind is undesirable. Another type of distortion is avoided here by using a class AB mode of operation instead of class B. Class AB amplifiers do not have the inherent crossover distortion of class B amplifiers.

Based on an RCA-developed design, the outstanding performance of the Brute-70 can be attributed to the use of sophisticated circuitry made possible by the availability of high-quality silicon semiconductors. The circuit is a direct-coupled, transformerless, quasi-complementary configuration with a built-in 35-dB negative feedback system. There is also a built-in short-circuit proof feature which protects both the driver and the output stages from high currents and excessive power dissipation. Use of silicon devices makes the amplifier more tolerant of heat; stability is maintained at ambient temperatures up to 71°C (160°F). And, as if this weren't enough, the mechanical construction, in conjunction with a couple of diodes, provides a thermal feedback loop to enhance stability.

Sound expensive? It should be, but it isn't. Although a veritable Rolls Royce among power amplifiers, the Brute-70 can be assembled for a little over 50 cents per watt.

BRUTE-70 SPECIFICATIONS

Power Output	70 watts r.m.s. per channel
Class	AB
Power Gain	68 dB
Hum and Noise	down more than 60 dB from 1 W
Total Harmonic Distortion	less than 0.25% @ 1 kHz and 70-W output; less than 0.8% @ 20 Hz to 25 kHz from 0 to 70 watts
Frequency Response	5 Hz to 25 kHz ± 1 dB; down 3 dB at 50 kHz
Input Impedance	100,000 ohms
Output Impedance	8 ohms
Sensitivity	0.8-V input for 70-W output
Other Features	short- and open-circuit-proof; direct-coupled series-connected output stage; no output or driver transformers; all-silicon solid-state circuit

This circuit is based on an RCA design described in Data Bulletin ATC-408. A preamplifier of comparable quality to match the Brute-70 is described in this issue beginning on page 47.

How It Works. Only 0.8 of a volt input signal is needed to drive the amplifier to its full 70-watt output. The signal from a tuner, preamp, or other suitable source is fed into the amplifier at *J1* (Fig. 1) and capacitively coupled to *Q1*. Resistor *R1* increases the amplifier's effective input impedance to 100,000 ohms. Capacitor *C1* serves as a d.c. blocker and signal coupler. Transistor *Q1*'s bias is a function of the setting of *Zero Adjust* control *R13*, and the values of *R2*, *R3*, and *R4*, as well as the applied voltages.

Control *R13* is adjusted to obtain zero volts at point *F* under no signal conditions. A close examination of this circuit reveals that a d.c. feedback loop from *R13* to *Q1* exists. Current through *R13* affects the voltage applied to the emitter of *Q1*, which in turn affects the amount of current in all of the other transistors and *R13*. (All stages are direct-coupled.) Quiescent voltage at point *F* is maintained to within ± 0.1 volt.

Capacitor *C3* and resistor *R5* provide an a.c. negative feedback path to *Q1*, on the order of 35 dB, and give the amplifier its flat frequency response. Capacitor *C4* bypasses some of the higher frequencies across *C3* and *R5* and prevents over-dissipation of the predrivers. Not shown (usually not needed), is a 0.01 μf capacitor across *R6* to prevent overdrive if *Q2* has an unusually high beta.

The signal from *Q1* is direct-coupled to the modified Darlington pair predriver stage (*Q2* and *Q3*). The Darlington circuit is noted for its high gain and high impedance. It has a minimum loading effect on the input stage, and, with *Q1*, provides all of the voltage amplification for the entire amplifier. Later stages do not provide any voltage gain, but they function as current amplifiers, and bring the impedance down to accommodate an individual 8-ohm speaker or speaker system. From *Q3*, the signal is direct-coupled to a complementary pair

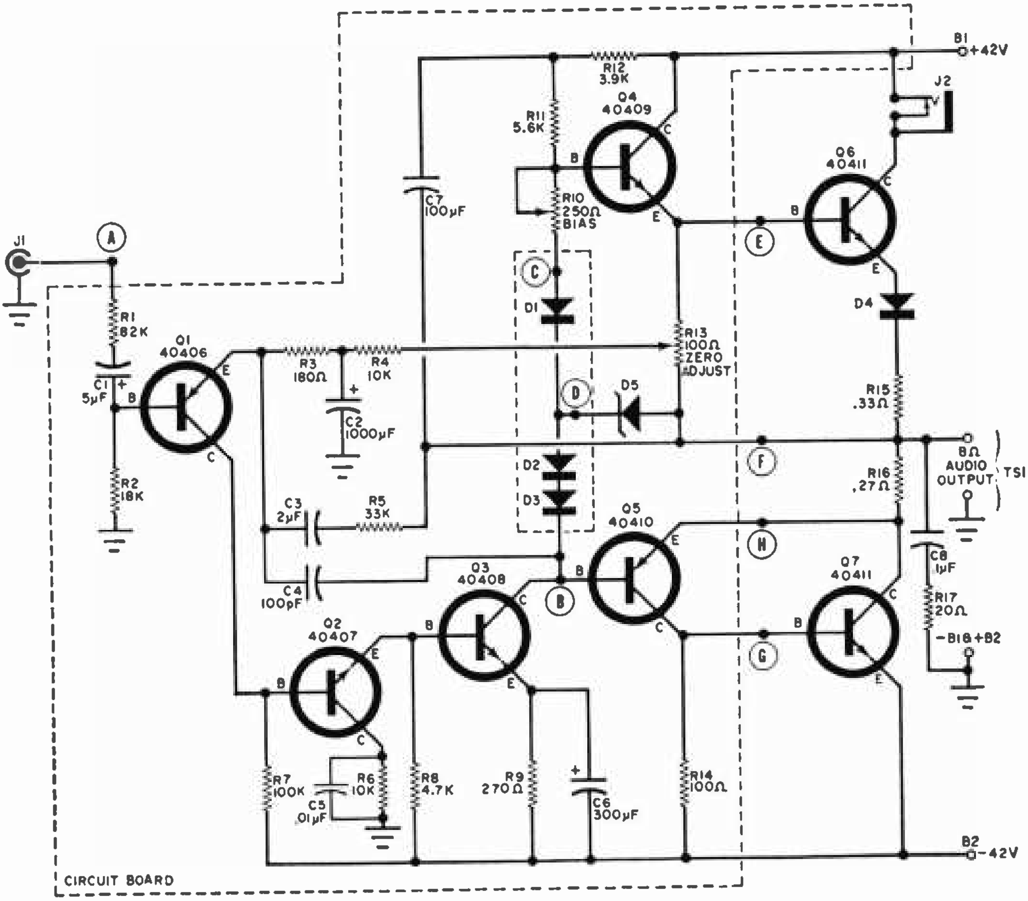


Fig. 1. All components within the tinted area are mounted on a printed circuit board. Diodes D1, D2, and D3, and transistors Q6 and Q7 are mounted on heat sinks. Stability and low distortion can be attributed to a.c., d.c., and thermal feedback loops. Zener diode D5 helps make the amplifier short-circuit-proof.

AMPLIFIER PARTS LIST
(per channel)

C1—5-μF, 15-volt electrolytic capacitor
C2—1000-μF, 3-volt electrolytic capacitor
C3—2-μF, 6-volt electrolytic capacitor
C4—100-pF, 50-volt capacitor, 5% tolerance
C5—0.01-μF capacitor
C6—300-μF, 6-volt electrolytic capacitor
C7—100-μF, 50-volt electrolytic capacitor
C8—0.1-μF, 100-volt capacitor
D1, D2, D3—1N3754 diode
D4—1N1612 diode
D5—4.7-volt, 1-watt zener diode (1N1519, or similar)
J1—Phono jack
J2—Closed-circuit phone jack
Q1—40406 silicon pnp transistor
Q2—40407 silison npn transistor
Q3—40408 silicon npn transistor
Q4—40409 silicon npn transistor, with heat sink
Q5—40410 silicon pnp transistor, with heat sink
Q6, Q7—40411 silicon npn power transistor
R1—82,000 ohms
R2—18,000 ohms
R3—180 ohms
R4, R6—10,000 ohms

All resistors ½ watt, unless otherwise stated

R5—33,000 ohms
R7—100,000 ohms
R8—4700 ohms
R9—270 ohms
R10—250-ohm, ¼-watt trimmer potentiometer
R11—5600 ohms
R12—3900 ohms
R13—100-ohm, ½-watt trimmer potentiometer
R14—100 ohms
R15—0.33 ohm, 10 watts—see text
R16—0.27 ohm, 10 watts—see text
R17—20 ohms
TS1—Two-terminal barrier-type terminal strip
*1—Etched circuit board**
1—7" x 12" x 3" aluminum chassis (Bud AC-408, or similar)
2—Heat sinks (Delbert Blinn X-123-D-3)
Misc.—1" standoff spacers (4), hookup wire, shielded wire, diode clips, brackets, etc.

*A pre-etched and screened printed circuit board is available for $2.75 ($5.50 for two) from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216. A complete kit of parts, including heat sinks, less chassis, power supply, and printed circuit board, is available for $25 per channel.

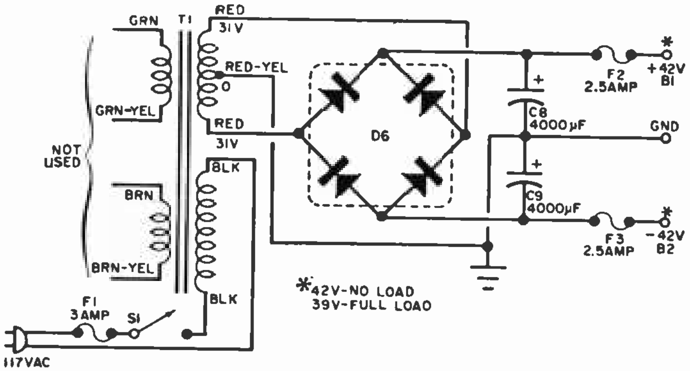
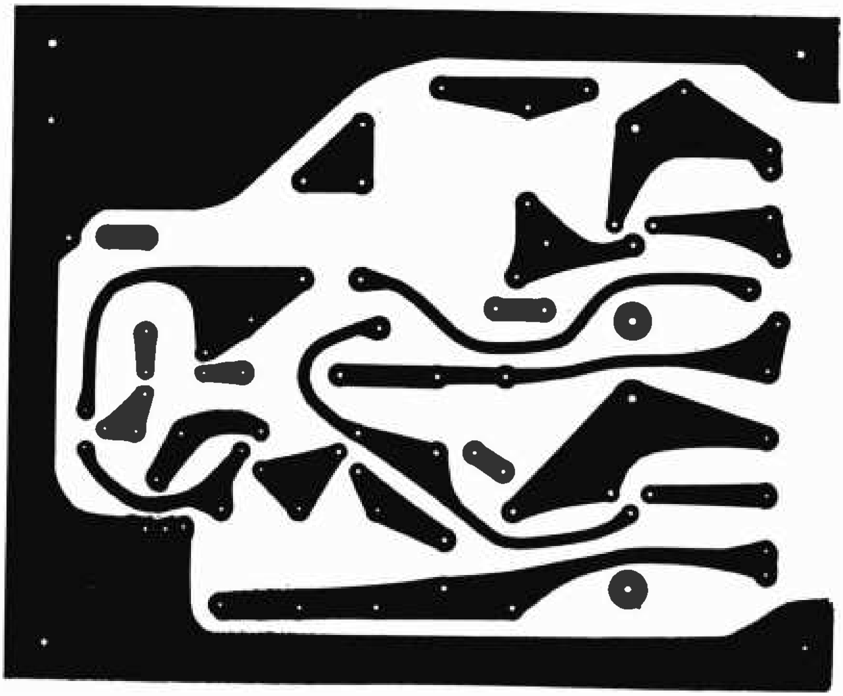


Fig. 2. Positive and negative supply voltages are balanced with respect to ground through a 60-volt center-tapped winding. Try using 2-ampere, fast-blow fuses for F2 and F3. If they don't stand up, use the 2½-ampere size shown here.

Fig. 3. Actual-size photo of printed circuit board. High power and high gain characteristics make lead dress critical. Point-to-point wiring on a perforated board may be used if proper lead dress and parts layout is maintained.



of transistors (*Q4* and *Q5*) which are used to direct-drive the two series-connected power transistors.

Capacitor *C7* performs two functions: first, it decouples the power supply to remove ripple voltage from the predriver and driver stages; and second, it provides a bootstrap voltage to increase the drive voltage to *Q4*.

Bias voltage adjustment for the complementary driver stages is provided by diodes *D1*, *D2* and *D3* and by *Bias Control R10*. The diodes are connected thermally to the output transistor heat sinks to establish a thermal feedback circuit. This thermal feedback arrangement stabilizes the quiescent current of the output stages at its preset value for all case temperatures up to 100°C, thus protecting the driver and output transistors.

The *Bias Control* is adjusted to obtain 20 mA quiescent current in the collector circuit of *Q6*. An ammeter can be plugged into *J2* to measure this current. The forward voltage drop across three diodes (*D1, D2, D3*) and the voltage across *R13* provide the bias voltage necessary to maintain the output stages in class AB operation. The *Bias Control* permits adjustment for component variations.

Another benefit of the high-temperature compensation provided by the thermal feedback loop is the ability to maintain stability even with small-value resistors in the output stages—the less the resistance, the less the loss. In this case, it results in greater output.

Short-circuit protection is provided by a unique current-limiting circuit using zener diode *D5* in conjunction with resistors *R15* and *R16*. Both the driver (*Q4* and *Q5*) and the output (*Q6* and *Q7*) transistors are protected from high current and excessive power dissipation such as would be caused by a reduced load resistance or, in the worst case, a short circuit.

If a condition develops which causes a current to exceed 5 amperes through either resistor, (*R15* or *R16*), the following action takes place: during the negative-going output half-cycle, the small forward voltage across *D5* causes it to conduct in the forward direction; during the positive-going output half-cycle, the zener breakdown voltage is reached and the diode conducts once again, preventing further increase in voltage and further increase in output current.

This amplifier does not require a regulated power supply. A conventional full-wave center-tapped circuit as shown in Fig. 2 can be used to power either a stereo or mono rig. Transformer *T1* steps down the 117-volt line voltage to 60 volts. The center-tapped secondary hooked up to the bridge rectifier provides both a positive and a negative d.c. output voltage (*B1* and *B2*) which is balanced to ground.

Capacitors *C8* and *C9* serve as ripple filters, and help reduce distortion at low frequencies. Fuses are provided for both *T1*'s primary (*F1*) and the d.c. supply lines (*F2* and *F3*). Additional protection

POWER SUPPLY PARTS LIST

C8, C9—4000-µF, 50-volt electrolytic capacitor (Mallory CG452U50D1, or similar)
D6—6-ampere, 100-volt full-wave diode rectifier module (Motorola MDA952-2, or 4 1N1614R diodes, or similar)
F1—3-ampere slo-blow fuse
F2, F3—2½-ampere fast-acting fuse
S1—S.p.s.t. toggle switch
T1—Power transformer; 117-volt primary, 62-volt center-tapped 3.0 ampere secondary (Thordarson Meissner 24R105, or similar)
Misc.—Line cord and plug, extractor-type fuse posts (3), wire, solder, rubber grommet, etc.

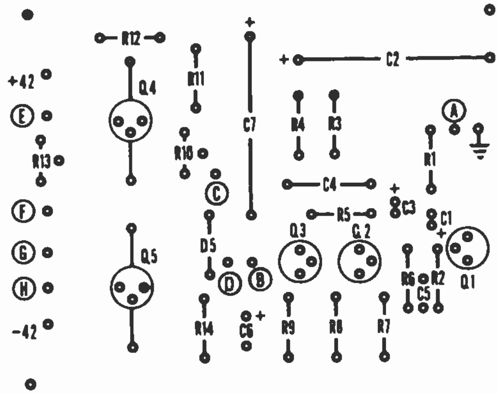


Fig. 4. Component layout on printed circuit board. To orient this view with the printed circuit board on the opposite page, just imagine the copper foil side of the board flipped over from right to left.

of the output transistors can be had by mounting a 100°C thermal cutout on one of the heat sinks of the output transistors and wiring the cutout in series with *S1*.

Construction. For a dual-channel stereo version of the Brute-70, you just double the number of components called for in the Parts List for the amplifier. The components for the power supply are the same for either a mono or stereo setup. A single chassis can be used to hold the mono or stereo amplifier, and the power supply.

Layout is reasonably critical, mostly because of the high gain and high power levels involved and the heat dissipation requirements. An actual-size photo of the foil side of the printed circuit board is shown in Fig. 3. You can purchase a ready-made circuit board (see Parts List) or etch your own.

If you are an advanced experimenter and are familiar with the requirements of proper lead dress for the audio circuits involved, you can assemble the components on a plain perforated board, but in any event you should not compromise on the heat sinks. Only those components included within the tinted area in Fig. 1 are mounted on the circuit board; see Fig. 4 for component layout.

Power transistors *Q6* and *Q7* and bias diodes *D1, D2,* and *D3* are mounted on the heat sinks as shown in Fig. 5. No, you are not seeing things—that's a mirror sitting on top of the amplifier to give

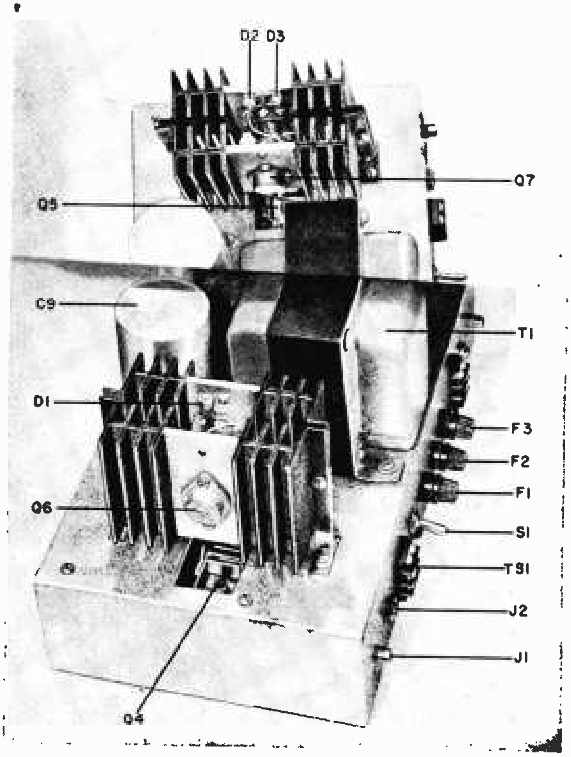


Fig. 5. Mirror standing on top of T1 shows D2 and D3 mounted on the back of the heat sink holding Q6. Other heat sink holds D1 and Q7. Note the cutouts in chassis to allow heat from Q4 and Q5 to escape.

you a view of what's behind the heat sinks in front of transformer *T1*. Note that diodes *D2* and *D3* and transistor *Q6* are mounted on one heat sink, and that *D1* and *Q7* are mounted on the other heat sink. Also note the cutout in the chassis to allow the heat from *Q4* and *Q5* to escape.

Mount power transistors *Q6* and *Q7* on their respective heat sinks using insulating washers, silicone grease, and appropriate fiber shoulder washers for the mounting screws. Bias diodes *D1, D2,* and *D3* are also mounted on the output heat sinks using RCA SA-2100 or other suitable metal clips: this is an important construction step which establishes the thermal feedback loop. Attach leads for later use below the chassis and circuit board connections. Assemble the heat sinks "back-to-back" on heavy-duty "L" brackets, or other suitable vertical supports. The thicker the brackets, the wider the spacing, and the better the heat dissipation.

Driver transistors *Q4* and *Q5* are equipped with integral heat sinks, as shown in Fig. 6. *Bias Adjustment* control *R10* and *Zero Adjustment* control *R13* are mounted on the foil side of the printed circuit board. Lead connections to the circuit board are identified by circled letters.

The power transformer (*T1*) specified in the Power Supply Parts List, and illustrated schematically in Fig. 2, is equipped with a pair of 6.3-volt filament windings which are not required by the amplifier. These filament leads should be taped to prevent accidental shorts, and tied to one side.

Follow the general chassis layout as shown in Figs. 5 and 7. Simply arrange the chassis-mounted components on the blank chassis and mark the places where the holes and cutouts should be.

The input and bias jacks, output terminals, power switch, and extractor fuse posts are all mounted on the front apron of the chassis. The assembled heat sinks, power transformer, and filter capacitors are mounted on top of the chassis. Finally, resistors *R15* and *R16,* full-wave rectifier module *D6,* and emitter diode *D4* are mounted on the underside of the chassis. The assembled circuit boards (only one board for mono) are also mounted inside the chassis on one-inch standoffs.

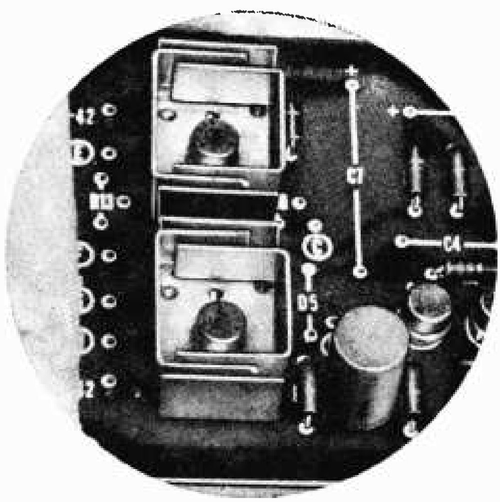


Fig. 6. Transistors Q4 and Q5 come equipped with heat sinks. These silicon transistors have good thermal stability, but proper venting is important.

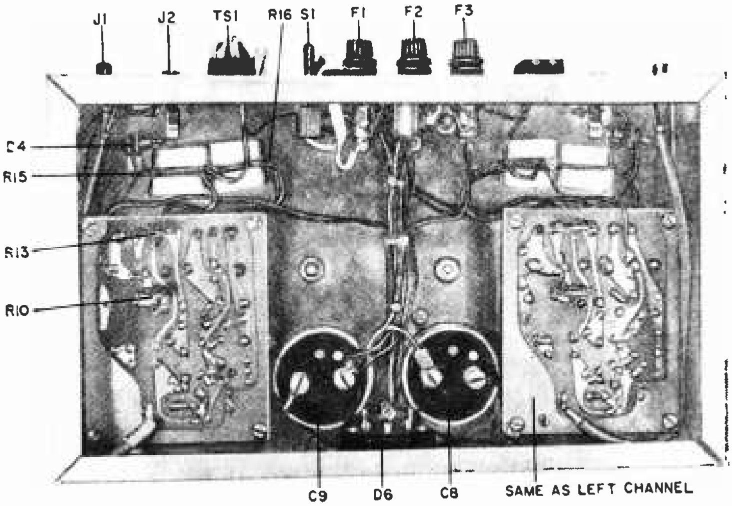


Fig. 7. If you cannot get the values specified for R15 and R16, you can wire two resistors in parallel to obtain the desired wattage and resistance, as shown here. Note the almost mirror image of one channel to the other . . . they are identical.

The chassis improves shielding of the input stages and minimizes extraneous hum and noise pickup. Don't forget the rectangular cutouts on top of the chassis to permit air circulation around driver transistors *Q4* and *Q5*.

If you can't get 0.33- and 0.27-ohm, 10-watt resistors (*R15* and *R16*), you can use two pairs of 0.68-ohm, 5-watt resistors wired in parallel, as shown in Fig. 7.

Recheck the circuit boards and the heat sink assemblies. Then install and wire the power supply components. Install the standoff spacers for the circuit boards and mount the heat sink assemblies, as well as the balance of the parts that go on the front of the chassis. Mount the remaining below-chassis components, and wire them in.

Finally, install and wire the circuit boards. Do not connect the base and emitter leads of power transistors *Q6* and *Q7* just yet. Use shielded cable between input jack *J1* and the input connection point *A* and ground on each of the two circuit boards.

Be sure that polarities have been observed, that there are no accidental shorts, that bias jack *J2* is insulated from the chassis, and that proper size fuses are installed in the holders. Adjustable pots *R10* and *R13* must be accessible.

Adjustment. Only two adjustments per channel must be made after the wiring is completed. A general-purpose VOM will be needed for this step. If you have built the two-channel stereo version, adjust each channel separately.

(*Continued on page* 149)

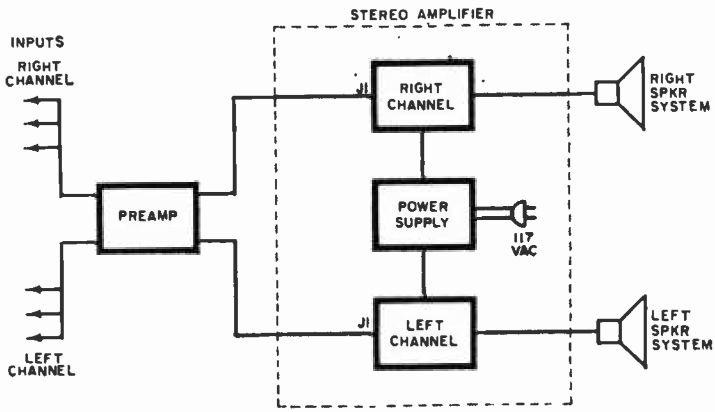


Fig. 8. Typical stereo installation using hi-fi components. While a speaker or speaker system can be connected directly to the amplifier, a preamp is needed to control and select the signals from a tuner, record player, or any other source.

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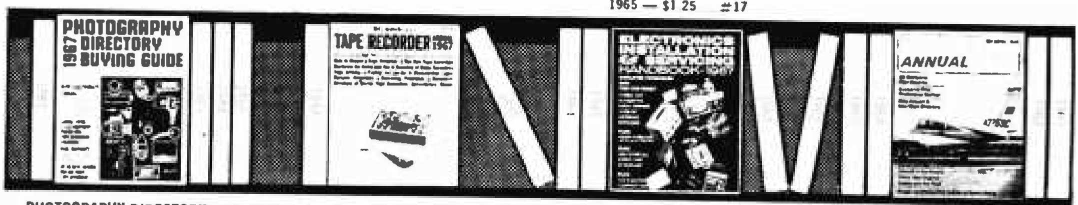

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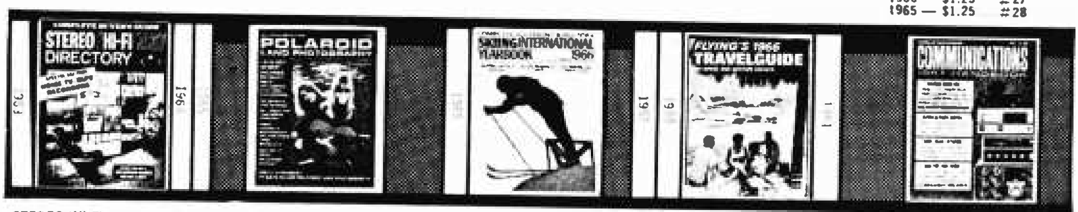

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CHAPTER

3

COMMUNICATIONS SWL CB HAM

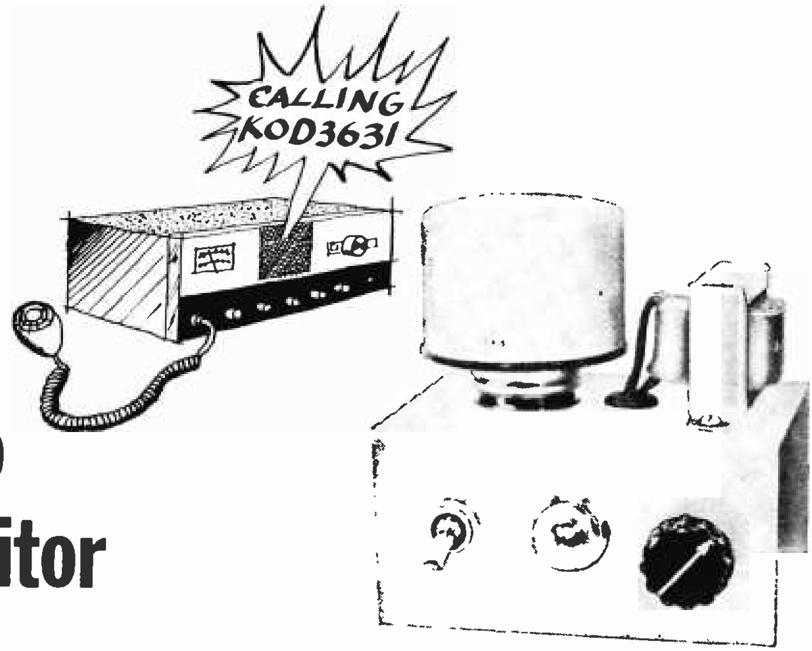
Things happen so fast that it somehow doesn't seem possible that in 1957 the creation of the 11-meter CB band was still a year away. Hams were still fighting the battle of TVI, and although DX conditions were the best of the century, ham radio was just about at its lowest ebb.

Long-time writer on ham projects, Hartland B. Smith, W8VVD, (who also had an article in the 1957 edition), has contributed two projects to this issue. Both of them are solid-state and one of them (GC-2 Deluxe Converter, page 89) is useful only with a commercially available product that was just coming off the drawing boards in 1957—the popularly-priced ham-band-only receiver. Hart Smith's second project matches the "Camper's Special" that appeared in our Spring 1967 edition; the "Cuzzin" (page 85) is a converter to tune the 75-meter phone and 80-meter CW bands.

The Citizens Band is now the most crowded part of the radio spectrum and the call monitor (page 66) should be an attractive project to serious CB'ers. Also for the CB'er—if you feel your modulation is not up to snuff—is the compressor designed by Dan Meyer, KMT2967.

BUILD:

CB Radio Call Monitor



By RICHARD C. PETERSON

NOW YOU CAN ENJOY the convenience of selective calling and remote receiver monitoring from a simple radio call monitor you can build and install in an evening or two. Employing a frequency-selective circuit, the call monitor continuously listens in on the channel you select for the designated call signal, ignoring voice communication and noise peaks outside the selected frequency range.

When the call monitor is in operation, a tone signal from the calling station activates a control relay which turns on a visual or audible indicator at any desired monitoring area to alert the operator that he is being called. It works in conjunction with a transmitting station equipped with a tone-generating device—such as an ordinary code practice oscillator or audio signal generator.

How It Works. The call monitor is shown schematically in Fig. 1. Its *LC* tuned circuit consists of the secondary of transformer *T1* and resonating capacitor *Cx*. With coil inductance varying somewhat from transformer to transformer, the resonant frequency of the circuit is determined essentially by the value chosen for capacitor *Cx*, as shown by the graph of Fig. 2. In general, for this application, a capacitor value of 0.0001 μF to 1.0 μF provides a tuning range of 50 Hz to 2 kHz.

The circuit also includes current limiting resistor *R2*, tuning sensitivity potentiometer *R1*, neon glow lamp *I1*, relay *K1* shunted by filter capacitor *C1*, and battery *B1* controlled by *S1*. Capacitor *C1* eliminates relay chatter by filtering out the a.c. components from the relay coil circuit.

With no input signal applied, and with the correct battery voltage, *I1* is biased just below its firing point. With a signal present, the bias threshold is exceeded and lamp *I1* conducts, pulling in the relay to activate the alarm.

Construction. Start construction by laying out the chassis and drilling the mounting holes along the lines of Fig. 3. Then mount the relay socket and transformer in place on the chassis, running the transformer leads through the 3/8" rubber grommet. The transformer black leads are the signal input terminals.

The battery cutoff switch, neon glow lamp, and sensitivity control are mounted on the front panel. The resistors and capacitors are mounted under the chas-

THIS SIMPLE DEVICE
STAYS "GLUED"
TO YOUR RECEIVER
AND ALERTS YOU
WHEN THERE'S A CALL

sis, and a barrier strip on the rear of the unit facilitates input and output circuit connections.

While a couple of 90-volt dry cell batteries can be hooked up to provide the correct bias voltage for *B1* (exact battery voltage to be determined by test), it is usually more feasible to obtain this voltage from a tap on the transceiver's B+ circuit through an appropriate dropping resistor, except when working with transistorized equipment. If you must use batteries, they can be mounted externally, or under the call monitor's chassis, if there is space.

Checkout and Installation. With the battery switch *off*, set the potentiometer for maximum resistance and connect an audio signal generator, tuned to the frequency you're interested in, across input terminals 1 and 2 (see Fig. 1). Connect the leads of an a.c. VTVM between points 2 and 3. Then adjust the signal generator output for a reading of approximately 10 volts on the VTVM. If this reading cannot be attained, reduce the setting on *R1* as necessary.

From Fig. 2, select an appropriate capacitor for the desired frequency, and temporarily connect it between points 2 and 3 (across the VTVM). The VTVM

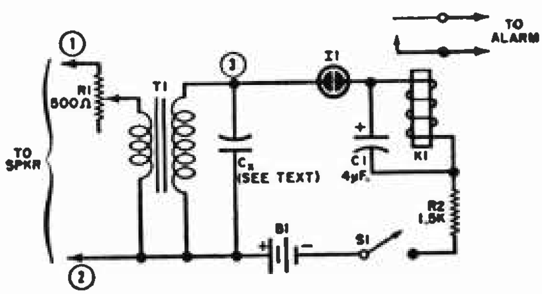


Fig. 1. With S1 closed, the voltage across I1 is maintained below its firing point. An input signal causes the lamp to fire and relay K1 pulls in.

PARTS LIST

B1—90-volt dry cell battery (2 required—see text)
C1—4-μF, 25-volt electrolytic capacitor
Cx—Resonating capacitor—see text
I1—NE-51 neon glow lamp
K1—Sigma 4F-2500S-SIL relay, or similar
R1—500-ohm potentiometer
R2—1500-ohm, 1-watt resistor
S1—S.p.s.t. toggle or slide switch
T1—Stancor A-3327 audio output transformer, or similar
1—3"-deep x 4"-wide x 2"-high open-end chassis
Misc.—Neon lamp holder, 3/8"-i.d. rubber grommet, control knob, 5-terminal barrier strip, 5-pin relay socket (similar to Amphenol 78-RS5), wire, solder, mounting hardware

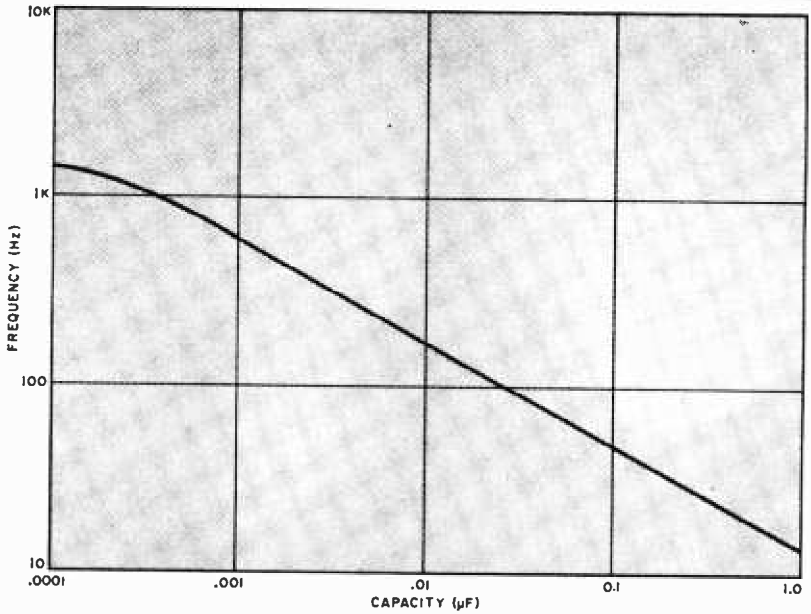


Fig. 2. With the transformer specified, the value of resonating capacitor Cx can be quickly determined from the coordinates of this FREQUENCY vs. CAPACITY chart.

reading should increase appreciably, making it necessary to turn down the generator output to maintain the 10-volt reading. Alternately interchange capacitor *Cx* for one of a higher and lower capacity rating—the capacitor producing the highest voltage reading should be installed permanently in the circuit.

Disconnect the signal generator and connect points 1 and 2 of the call monitor across the receiver's voice coil. Then call up the other station and ask that the tone signal be transmitted. Adjust your receiver volume control for normal listening, and readjust *R1*, if necessary, for an indication of approximately 10 volts, as was done previously.

Disconnect the VTVM and set the battery switch to *on*. Using a voltage divider in the battery or B+ circuit, as the case may be, adjust the voltage until the neon lamp just fires, pulling in the relay contacts. Then hook up your alarm circuit to the relay contacts. The call monitor is turned *on* or *off* by operating the battery switch.

If you want the call monitor to be tripped by any incoming signal—voice, noise, etc.—simply remove the resonating capacitor (*Cx*) from the circuit and set *R1* to zero resistance. Or, you can remove *R1* entirely. By adjusting the battery voltage to a value just below the lamp extinction voltage, the relay will pull in on any incoming signal and drop out when the signal is removed. —30—

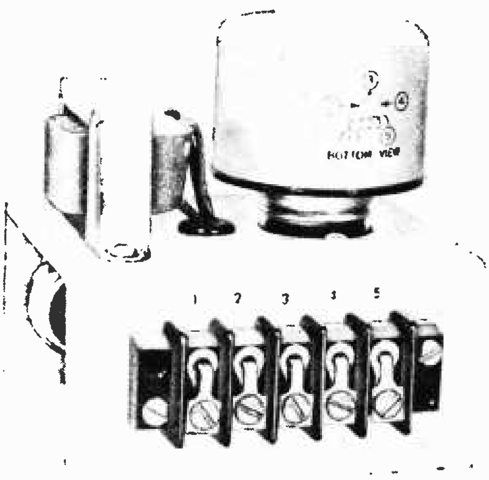


Fig. 3. This rear-view photo of the call monitor shows major components mounted on an open-end chassis. The operating controls are on front panel.

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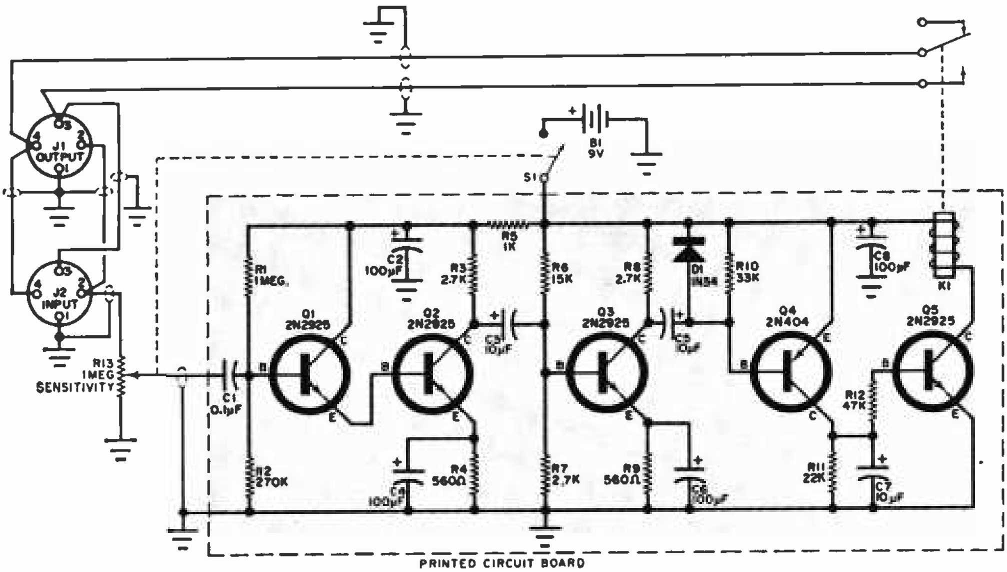
By CHARLES CARINGELLA, W6NJV

THE "Trans-Vox" will let you enjoy voice-controlled "hands-free" operation of your CB or amateur radio transmitter, your tape recorder, or other electronic or electrical equipment. When the "Trans-Vox" is used with a tape recorder, there is no wasted tape. Airport controllers, detectives, and other monitors depend upon this type of tape-saving feature to record what's going on over a long time period.

For most applications, this gadget can be used without modifying your equipment. You simply plug your microphone



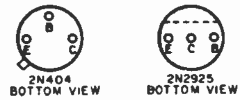


Fig. 1. The high-gain amplifier circuit converts sound to signal voltage sufficient to trigger the relay. Sensitivity can be varied to work distances up to 30 feet at normal voice levels. Unit is completely self-contained, and is plugged into the microphone input of a tape recorder, or a transmitter. No modifications of equipment are necessary. Push-to-talk as well as voice control can be obtained at the flip of switch S1. It's on for VOX.

into the Trans-Vox, and plug the Trans-Vox into your rig. All it takes to actuate the device is the sound of your voice. The circuit is extremely sensitive; normal conversation from as far away as thirty feet from the microphone will trip the works.

New low-cost plastic-encapsulated transistors are mounted on a printed circuit board (see Parts List), which greatly simplifies construction. An ordinary 9-volt transistor radio battery powers the unit.

How It Works. Transistor *Q1* (Fig. 1) serves as an emitter follower and provides a high input impedance to better match the output impedance of a ceramic or crystal microphone which is plugged into the unit at *J1* or *J2*. A portion of the sound picked up by the microphone is passed on to *Q1* through sensitivity control *R13*. The signal from *Q1* is direct-coupled to *Q2*. Both of these transistors (*Q1* and *Q2*) are cascaded in a unique manner—the combination of the voltage divider action of *R1* and *R2*, as well as *R4*, stabilizes both transistors.

Transistors *Q2* and *Q3* work as high-gain RC-coupled audio amplifiers and pass the signal on to *Q4*. But before the signal gets to *Q4*, it is negatively clamped by diode *D1* to place all of the signal below a certain d.c. (9 volts) reference level. A negative voltage is needed on the base of *Q4*, with respect to its emitter, and the clamping action places all of the signal in a better position to turn *Q4* "on and off."

When *Q4* conducts, it drives *Q5* into conduction and energizes relay *K1*. Capacitor *C7* takes on a charge while *Q4* is conducting, and discharges when *Q4* is quiescent. The length of time it takes *C7* to discharge, below the point where *Q5* is conducting sufficiently to hold in *K1*, determines the Trans-Vox's hold-in time.

The pull-in time (sometimes called attack time) of the circuit is just a fraction of a second. It is determined mostly by the travel time of the relay armature. When the Trans-Vox is used in

PARTS LIST

B1—9-volt battery
C1—0.1-µF, miniature ceramic capacitor
C2, C4, C6, C8—100-µF, 12-WVDC miniature electrolytic capacitor
C3, C5, C7—10-µF, 12-WVDC miniature electrolytic capacitor
D1—1N34 germanium diode or similar
J1, J2—Shielded 4-pin miniature chassis connector (Amphenol 78-PCG4 or similar)
K1—Relay, with pull-in current of 7.0 mA d.c. (Sigma 11F-1000-G/SIL or similar)
P1, P2—Shielded 4-pin miniature male cable connector (Amphenol 91-MPM4L or similar, to match J1 and J2)
Q1, Q2, Q3, Q5—2N2925 npn transistor, or similar
Q4—2N404 pnp transistor, or similar
R1—1 megohms
R2—270,000 ohms
R3, R7, R8—2700 ohms
R4, R9—560 ohms
R5—1000 ohms
R6—15,000 ohms
R10—33,000 ohms
R11—22,000 ohms
R12—47,000 ohms
(R1–R12: *all resistors, ½-watt*)
R13—1-megohm potentiometer, with switch S1
1—Printed circuit board, as shown
1—3¼" x 3" x 2⅛" metal chassis box
Misc.—Metal spacers, ½" long x ¼" O.D., tapped for 4-40 screw (4); knob; shielded cable; solder lugs; battery clip; etc.

An etched and drilled circuit board, complete with all mounting hardware, is available for $2.50, postpaid. A complete kit of parts, which includes the above circuit board as well as a pre-punched and painted chassis box, is also available for $18.50 postpaid. Order from Caringella Electronics Inc., Box 327, Upland, Calif. 91786. California residents add 4% sales tax.

conjunction with a transmitter for voice-controlled operation, a negligible portion of the first word spoken will be clipped; with a tape recorder, you'll find this clipping effect slightly intensified, because of the time it takes for the tape transport motor to reach operating speed.

Hold-in time is approximately one-half second when *C7* has a value of 10 µF. If you find that the relay drops out too quickly to suit your purposes, increase the capacitance. Conversely, you can shorten the hold-in time by decreasing the capacitance. For most purposes, the value of 10 µF provides enough hold-in time for short pauses between words and sentences, yet the relay drops out quickly enough when the talking has stopped.

The input and output connectors, *J1* and *J2*, are wired in parallel and can be used interchangeably.

If your microphone is equipped with a push-to-talk switch, wire the switch in parallel with the relay contacts (pins 3 and 4 on *P2*) as shown in Fig. 2, to obtain either push-to-talk or voice-controlled operation. For voice-controlled operation, you simply turn *S1* on, and talk into the mike; you don't have to touch the push-to-talk switch. For push-to-talk operation, turn *S1* off, and use the push-to-talk switch on the microphone in the usual manner. No other connections or disconnections need be made to switch from one mode of operation to another.

Construction. All of the components shown within the dotted line in Fig. 1 are mounted on a printed circuit board, as shown in Figs. 3 and 4. If you choose not to use a circuit board, then follow the layout of the illustrated unit as closely as possible. Consideration should be given to proper lead dress in order to prevent feedback loops and parasitic oscillations which are inherently possible in high-gain amplifier circuits, such as this one.

Mount the resistors and the diode vertically to conserve space. Exercise

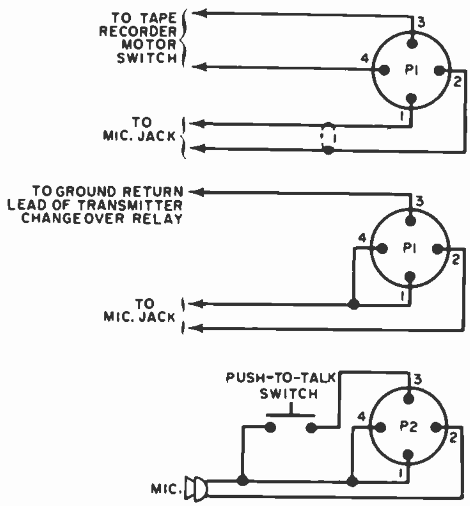


Fig. 2. Inputs J1 and J2 are in parallel, and can be used interchangeably, but the plugs must be wired in accordance with their specific function. Plug P1, top, serves as an output connector from the Trans-Vox, and is designed for a tape recorder. Plug P1, center, is for connection to a transmitter. Input plug P2 can be wired as shown; if your microphone does not have a push-to-talk switch on it, simply omit the connections to pins 3 and 4 on P2.

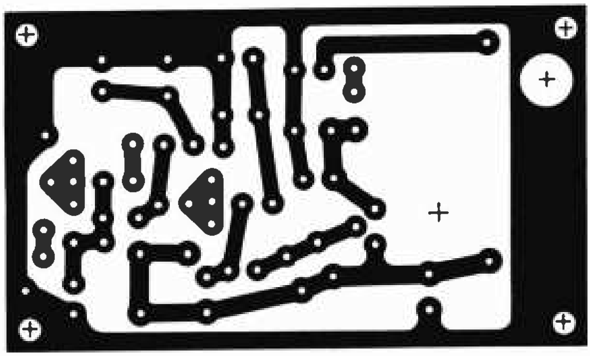


Fig. 3. Actual size of printed circuit board is shown to help you make your own. However, almost any type of wiring can be employed, but attention must be paid to proper lead dress to reduce inter-stage coupling in order to prevent parasitics.

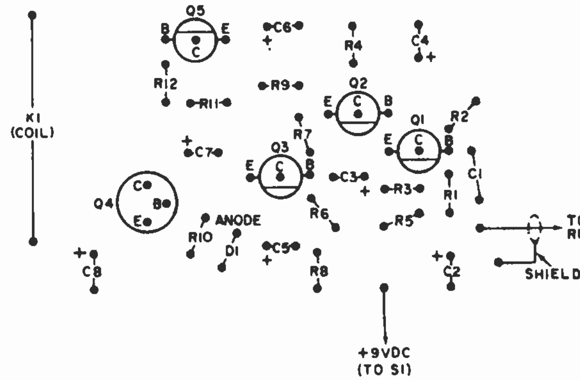


Fig. 4. Component side of board. Relay frame must clear the foil on the other side of the board. Observe polarity of the capacitors, diode, and proper transistor connections when installing components.

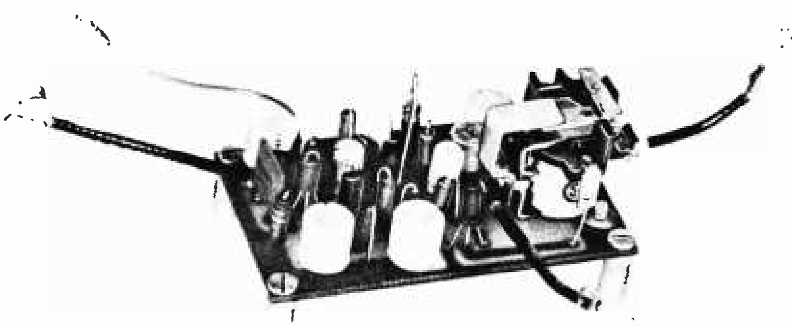


Fig. 5. Completed board assembly. Note use of shielded cable for input and output connections. Stand-offs are used to mount the board in the cabinet and to provide clearance. Components are stood on end.

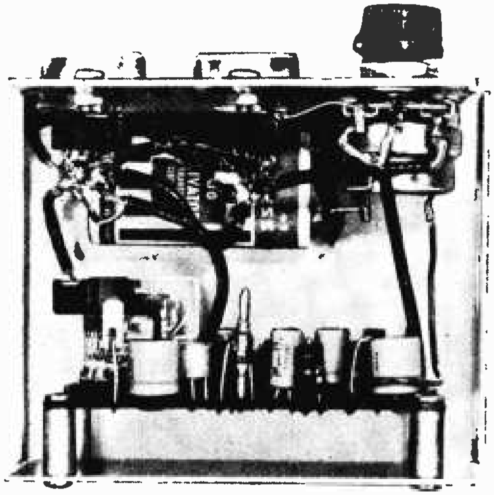


Fig. 6. Half the battle in stabilizing a sensitive high-gain amplifier circuit is neat construction and layout. Cable shields are connected on one end only to avoid setting up hum producing ground loops.

care, so as not to inadvertently connect the relay frame to the copper foil on the board. The relay frame on most relays is electrically connected to the armature. Shielded cable should be used as indicated in Fig. 1, and shown in Figs. 5 and 6. Connect the shield to the ground circuit only at one end, and trim the ends neatly to avoid short circuits. Probably the most difficult part of the project is to trim the shielded cables.

The completed circuit board assembly is housed in a small metal box. Mount the assembly on ½" spacers, and with suitable 4-40 hardware.

Operation. Once you have completed the unit, it is easy to check its operation. Relay idling current (when the relay is not energized) should be about 3 mA; pull-in current (depending upon the relay) is about 12 mA.

Watch out for stray noise and acoustical feedback; if you place the microphone too close to the Trans-Vox unit especially when the sensitivity control is turned up, the mike could pick up the clicking sound of the relay and cause continual "chattering." To eliminate this condition, turn the sensitivity control down or get more distance between the mike and the noise source.

If you find the normal clicking noise of the relay contacts objectionable, you can cement a lining of foam rubber, or other sound absorbing material, under the circuit board and along the inside walls of the box, to kill some of the sound.

Many tape recorders have a separate jack (or one or two leads in the mike cable) for external control of the tape-drive motor. If your tape recorder doesn't have a provision for remote control, you can install a jack and wire it in series with one of the motor leads. You will then be able to plug in the control to turn the motor on and off.

Tape recorders that are not internally operated by one or more relays require manual manipulation of a button or a control to engage the tape transport drive mechanisms. These driving elements are usually rubber-clad, and if allowed to retain contact under pressure while the motor is off, will develop flat spots sufficient to cause a thumping mechanical sound and irregular tape transport. Therefore, when you are through with your recording session, be sure to return all switches and controls on the tape recorder to their normally-off position.

Practically all CB and ham transmitters are wired for a push-to-talk switch

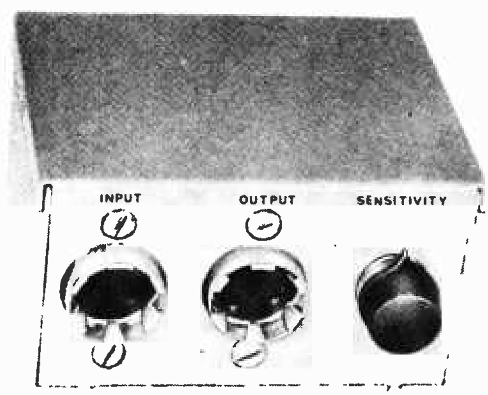
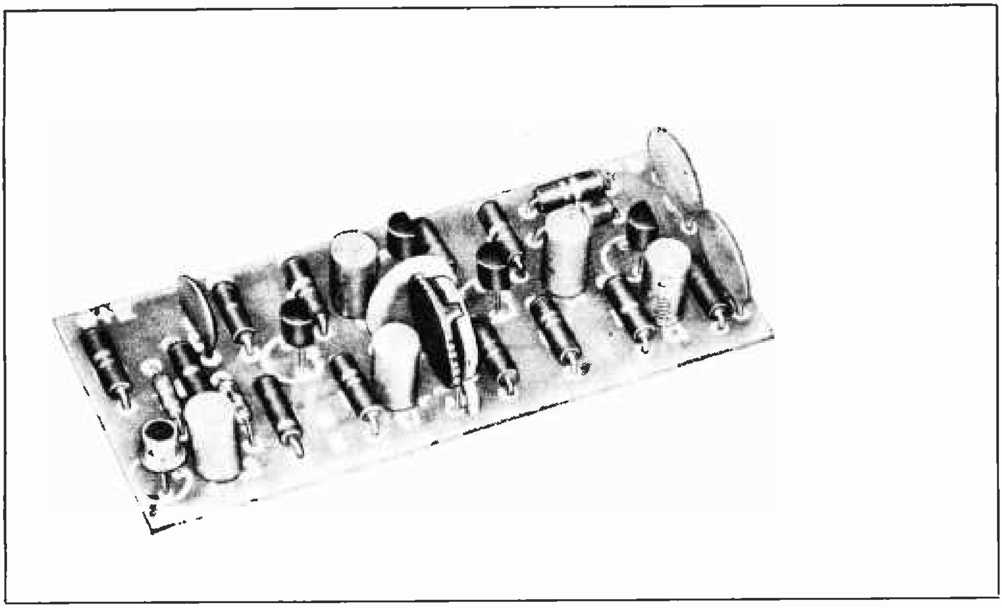


Fig. 7. Mounting of the on-off switch on the sensitivity control results in a simple, easy-to-operate, one-knob controlled unit. Input and output jacks and plugs can be of any design, but must be matching.

on the microphone. This switch simply grounds the ground-return lead of the transmitter's transmit-receive changeover relay. Select matching plugs and jacks to enable you to interconnect the control with your equipment. -30-



BUILD

CB "AUDIO LEVELER"

COMPRESSOR/PREAMPLIFIER BOOSTS CB MODULATION AND CURBS MIKE BLASTING WITHOUT DISTORTION

By DANIEL MEYER

HOW many times have you had to repeat a message during a CB radio conversation because you were too far away from the mike or weren't talking loud enough to put your message across clearly? Now you can come over loud and clear each time you hit the mike by merely adding an "Audio Leveler" to your CB rig.

The Audio Leveler is a low-distortion preamplifier which you connect between your mike—incidentally, it must be of the low-impedance variety used with transistorized equipment—and your transmitter MIC input to amplify weak signals while attenuating strong ones, thus producing a constant-level modulating signal to the transmitter. As a result, whether you talk very loud into the mike, or not loud enough when you move your head away from the mike, the transmitter "sees" a constant amplitude signal.

The Circuit. The Audio Leveler (Fig. 1) is a transistorized compressor circuit whose gain is automatically adjusted by the level of the speech input. It consists of *Q1*, the first amplifier; *Q2*, the gain-controlled stage; emitter follower *Q3*; a control amplifier, *Q4*; and a field-effect transistor (FET), *Q5*, which operates in the circuit as a varistor.

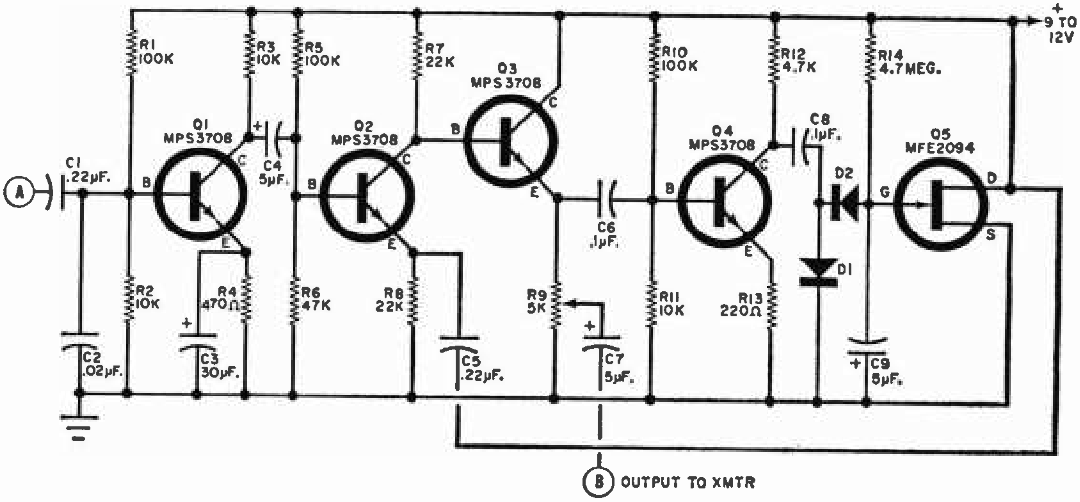


Fig. 1. The Audio Leveler takes advantage of the drain-source resistance characteristics of a FET, Q5, to control the amplifier gain automatically. Slightly more gain and slightly better compression may result from the use of a MPF-103 FET at Q5.

PARTS LIST

C1, C5—0.22-μF, 12-volt ceramic disc capacitor
C2—0.02-μF, 50-volt ceramic disc capacitor
C3—30-μF, 6-volt electrolytic capacitor
C4, C7, C9—5-μF, 15-volt electrolytic capacitor
C6, C8—0.1-μF, 12-volt ceramic disc capacitor
D1, D2—General-purpose germanium diode (1N34 or similar)
Q1, Q2, Q3, Q4—Motorola MPS-3708 transistor
Q5—Motorola MFE-2094 field-effect transistor
R1, R5, R10—100,000 ohms
R2, R3, R11—10,000 ohms
R4—470 ohms
R6—47,000 ohms
R7, R8—22,000 ohms
(*all resistors ½-watt, ± 10%*)
R9—5000-ohm PC-type trimmer potentiometer
R12—4700 ohms
R13—220 ohms
R14—4.7 megohms
*1—1½" x 3½" phenolic board, or etched and drilled printed circuit board (available for $1.50 postpaid from Southwest Technical)**

*A complete kit containing all parts, including the PC board, is available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216, for $9 postpaid in the U.S.A.

The audio input from your mike is applied to the base of *Q1* through capacitor *C1*. The amplified output at the collector is coupled through *C4* to the base of *Q2*, whose gain is controlled by *Q5*. The output at *Q2*'s collector is direct-coupled to *Q3*, hooked up as an emitter follower to provide a low output impedance to the transmitter through *C7*.

The signal at *Q3*'s emitter is also amplified by *Q4* and applied through *C8* to the junction of *D1-D2*. When this signal is large enough to cause the diodes to conduct, the bias voltage on *Q5* starts going negative. Since the drain-source static resistance of a FET is a function of the gate-to-source voltage, and since *Q5* is in series with *C5*, *Q2*'s emitter bypass capacitor, the resulting change in the resistance of *Q5* causes more or less bypassing action.

A negative-going bias voltage on *Q5*'s

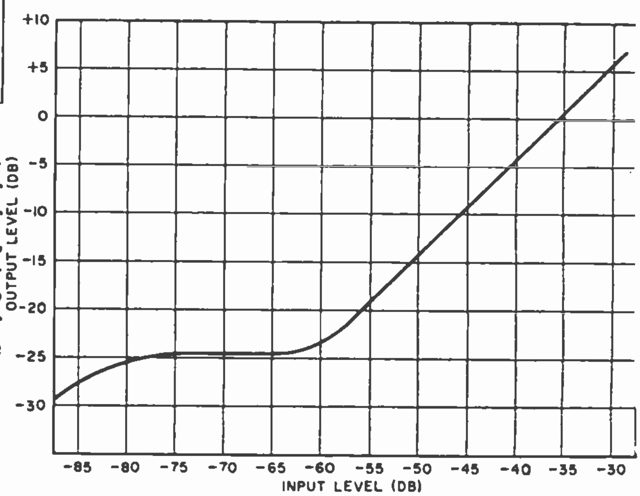


Fig. 2. Graphical representation of output signal level versus input signal level, in dB. The circuit has low distortion even with high-level inputs.

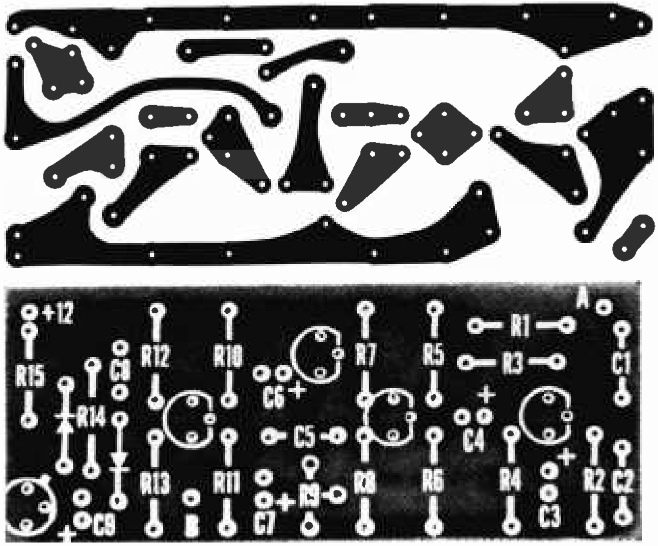


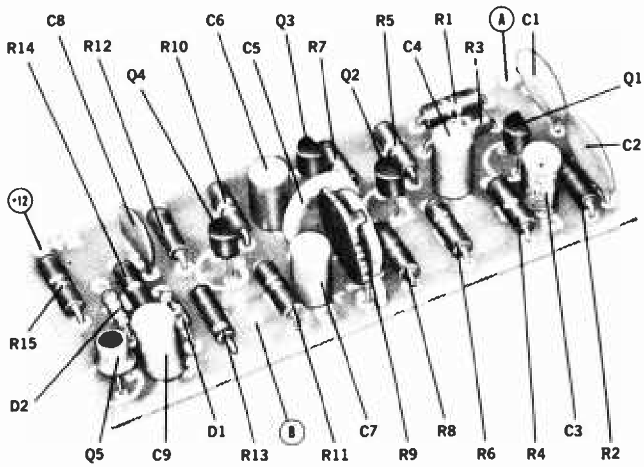
Fig. 3. Actual-size photo shows foil side of printed circuit board (upper left); component side of board is below it. Observe polarity markings when installing diodes and electrolytic capacitors. Also, position the transistors as shown. Resistor R15 has been deleted as the result of tests of this compressor. A wire bridge should be placed across the two holes originally designed for mounting R15. If you obtain the printed circuit board from Southwest Technical, you will get an up-to-date board and the MPF-103 in place of the somewhat lower gain FET MFE-2094.

gate results in a higher drain-source resistance, and this, in turn, acts to reduce the bypassing action of *C5* and limit the gain of *Q2*. Thus, as the signal level at the collector of *Q2* tries to increase, the control circuit acts to reduce the gain to its original value.

Figure 2 shows, graphically, the result of this action. The gain of the circuit increases only a few dB although the signal input level may be increasing by as much as 20 dB—about 10 times!

Construction. The entire Audio Leveler circuit can be assembled on a 1½" x 3½" printed circuit board or phenolic circuit board. An etched and drilled fiberglass printed circuit board (Fig. 3) is available (see Parts List). The board comes marked with the location of all components, and it is only necessary for the builder to insert the parts in the marked positions and solder the leads to the copper foil.

When installing the parts on the PC board, be sure to position the flat sides of *Q1* through *Q4* as shown in Fig. 3. Also, the locating tab on *Q5* must be oriented as indicated. The ground lead of this transistor (Fig. 4) must be cut off since it is not used. And be sure to observe the proper polarity when in-



Parts identification of the fully assembled printed circuit board includes input A, output B, and +12-volt supply connection point.

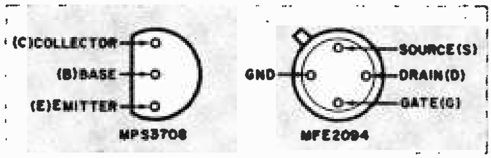


Fig. 4. These outline drawings show the terminal identification of the transistors used in the circuit. Ground terminal of the MFE2094 must be cut.

stalling the diodes and electrolytic capacitors.

If you prefer to make your own circuit board, you can still follow the parts layout shown, using the schematic (Fig. 1) as a wiring diagram.

Installation. Since the Audio Leveler goes between the microphone (remember, it can be used *only* with a low-impedance mike) and your transmitter's MIC input (see Fig. 5), it can easily be installed in any rig.

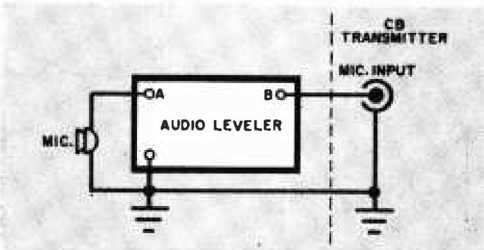


Fig. 5. Terminal A goes to the microphone and terminal B connects to the MIC input on the transmitter. The unit is grounded to the transmitter.

If there's room inside the unit, mount the circuit board in any convenient spot, supporting it on standoff spacers. The photo on page 154 shows the Audio Leveler installed inside a Heathkit GW-14 transceiver. If lack of room does not permit this type of installation, the unit can be mounted in a small metal case and installed outside of the transmitter or VFO enclosure. Connection is between points *A* and *B* on the circuit board.

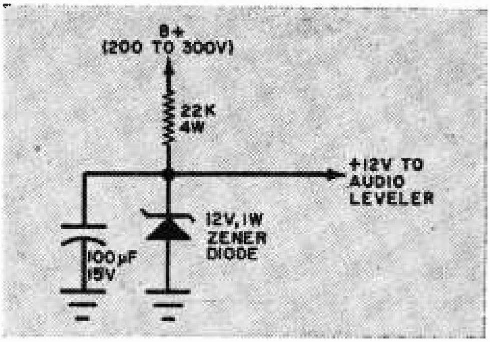


Fig. 6. This simple voltage divider can be used in a tube-type transceiver to obtain a 9-12 volt regulated output for operating the Audio Leveler.

To use the Audio Leveler with a transistorized CB radio, connect a lead from the +12-volt power source to the +12-volt terminal on the circuit board, and another lead from the *common* terminal on the circuit board (negative side of *C3*) to the transmitter ground.

If the Audio Leveler is to be used with a tube-type transceiver, a 9-volt battery can serve as the voltage source. However, if you would rather operate the Audio Leveler from your transceiver's power supply, a circuit similar to that of Fig. 6 will provide the 12-volt d.c. power. But be sure to connect the resistor to the cathode of the rectifier rather than to the load side of the power supply to avoid overloading the set's filter system.

(*Continued on page* 154)

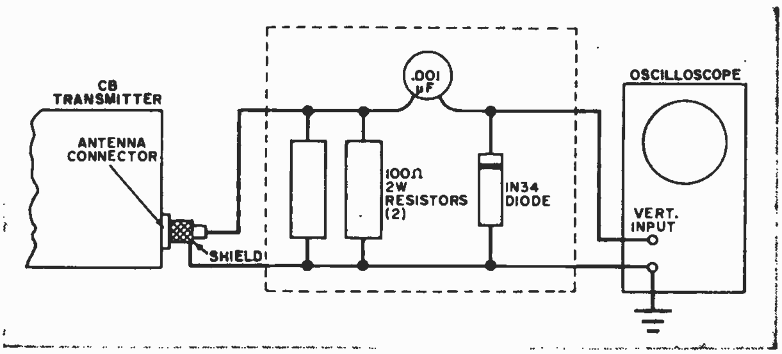


Fig. 7. The Audio Leveler can be tested and adjusted with an oscilloscope connected to the transmitter output through the network shown here. The gain is adjusted while observing the transmitter output.

NBFM Routs 6-Meter TVI

Hams! Simple Conversion Adds Frequency Modulation to 50-MHz VFO

By **R. L. WINKLEPLECK,** WA9IGU

YOU SAY your neighbors are up in arms because of the massive dose of TVI that blankets the valley when you work your six-meter rig, even though you've tried every type of filter in the book? Have you tried the sure-fire narrow-band FM solution?

Most TVI caused by the radio amateur operating on six, and which cannot be cleared up by the usual techniques, can be traced to high-level amplitude-modulated signals. Thus, if your carrier is clean and your neighbor's TV reception goes haywire when you talk, it's time for you to switch over to FM transmission. Conversion is easy, quick, and inexpensive.

Even if you are planning the construction of a 6-meter transmitter, you might consider going FM, exclusively. For the AM modulator is always a significant expense item; and if you're shooting for high power, the AM modulator will take a big chunk of your budget.

This article will describe an inexpensive solid-state FM modulator that is equally efficient when used with a half-kilowatt job or a measly one-watter.

Simple Approach to FM. The simplicity of the FM modulator is due largely to the use of a "Semicap," a solid-state voltage-variable capacitor that replaces the old-fashioned reactance tube modulator circuitry. Essentially a diode, the Semicap's capacity varies inversely as the magnitude of the reverse bias voltage across it. Thus, if this voltage is varied, as by modulation, the Semicap's capacity is also varied. The device can therefore be used to vary the transmitter's tank circuit by merely connecting it across the VFO's frequency-determining capacitor. Simple, isn't it?

This principle also disproves the claim of some old-timers who believe that diode detector-type communications receivers cannot fully meet the requirements of FM. Since frequency-modulated signals are reproduced by slope detection, it is only necessary to tune slightly off-frequency on an AM receiver to pick up these signals clearly. Putting it another

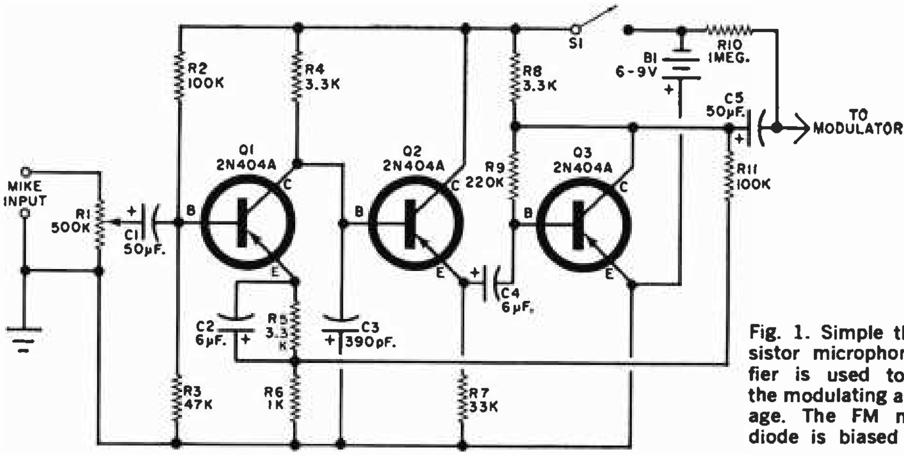


Fig. 1. Simple three-transistor microphone amplifier is used to provide the modulating audio voltage. The FM modulator diode is biased by R10.

way, if you tune in dead-on-frequency, you'll only pick up the carrier—which you'll hardly hear—but you'll pick up the modulated sidebands on both sides of the slope by off-frequency tuning. Of course, if you're too far off center and are tuning with a fairly selective receiver, your reception will be poor.

By means of on-the-air listening tests you can adjust the transmitter's sideband excursions for reasonably good reception on most ham receivers. Local contacts will have no trouble telling that you are coming over via FM since they must tune to one side of the signal peak to pick you up clearly. But the DX listener will hardly know what's going on. While DX'ing, you may note that occasionally, after several exchanges, your skip contact will give you a good signal report but add that there's something

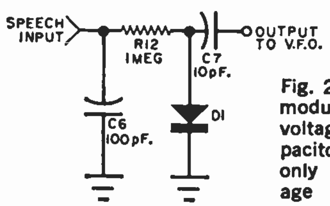


Fig. 2. Complete FM modulator, featuring voltage-variable capacitor D1, requires only a bias voltage for operation.

FM MODULATOR PARTS LIST

C6—100-pF mica capacitor
C7—10-pF mica capacitor
D1—6.8SC20 International Rectifier Semicap diode
R12—1-megohm, ½-watt resistor

AMPLIFIER PARTS LIST

B1—6- to 9-volt battery
C1, C5—50-µF, 12-volt electrolytic capacitor
C2, C4—6-µF, 12-volt electrolytic capacitor
C3—390-pF ceramic capacitor
Q1, Q2, Q3—2N404A transistor
R1—500,000-ohm potentiometer
R2, R11—100,000 ohms
R3—4700 ohms
R4, R5, R8—3300 ohms
R6—1000 ohms
R7—33,000 ohms
R9—220,000 ohms
R10—1 megohm
S1—S.p.s.t. switch
(all resistors ½ watt)

peculiar about your transmission he just can't quite describe.

Your transmitter must have VFO capabilities before it can be modified for FM operation—it's tough to swing a crystal. However, since 6 meters is rapidly becoming a VFO band, you might as well add an outboard VFO unit to your rig and change over to FM while you are at it. A six-meter VFO will start at some low frequency and then come up to 50 MHz by frequency multiplication. But bear in mind that as the basic VFO frequency is successively increased by a given factor, the amount of FM deviation due to modulation is increased by the same factor. Thus, it is important that a low-level signal be employed to drive the FM modulator to help cut down frequency deviation to a tolerable amount.

The Setup. To change over your AM transmitter to FM, you'll need a low-

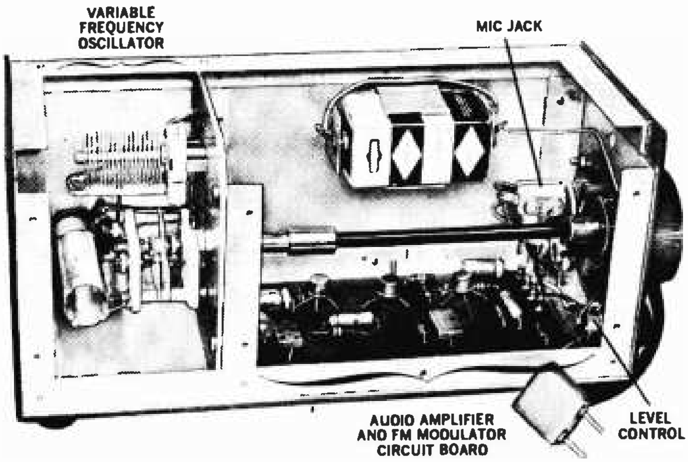
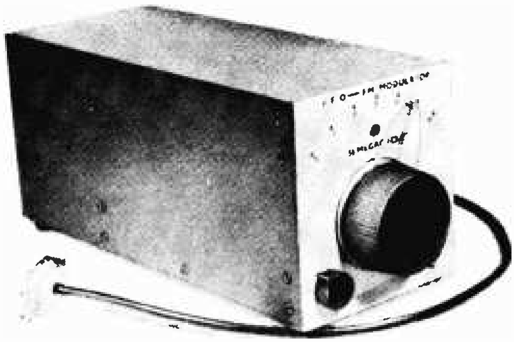


Fig. 3. The microphone amplifier and FM modulator are shown combined on a single circuit board in a passive variable-frequency oscillator case.

Shown below is the fully assembled VFO FM modulator with audio level control and connecting cable. A transmitter is converted from AM to FM by removing transmitter crystal and inserting cable plug in empty socket.



power microphone amplifier and, of course, the FM modulator we've been talking about. A simple one- or two-transistor audio amplifier of the inexpensive imported variety can be used as the mike amplifier. To get the needed high-impedance output, simply disconnect the output transformer leads and pick up your audio from the collector of the final stage through a 0.01-μF capacitor.

You may also consider using one of the new transistorized mikes to drive the FM modulator instead of getting a separate amplifier. If you prefer a home-built job, try the circuit shown in Fig. 1. It is a conventional three-transistor audio amplifier with limiting features. Limiting helps prevent excessive frequency deviation on audio peaks, and though not essential, generally improves signal quality.

Potentiometer *R1* allows you to adjust the microphone output for the correct frequency deviation before the audio is fed to the base of *Q1* through capacitor *C1*. Transistor *Q2*, hooked up as an emitter follower, drives output stage *Q3* through *C4*. Operating power is provided by *B1*, which also provides reverse bias for the modulator Semicap diode (see Fig. 2) through *R10*.

The FM modulator consists of capacitors *C6* and *C7*, resistor *R12*, and diode *D1*. Exhibiting a reasonably linear high-*Q* characteristic when reverse-biased, *D1* functions as a voltage-sensitive device. However, it conducts when forward-biased, causing both *Q* and linearity to deteriorate. It is important, then, to place a high enough reverse bias on *D1* to prevent high-level audio excursions from driving it into conduction. But since the applied audio voltage has a greater effect on *D1*'s capacitance at low bias levels, the bias should not be too high either. A satisfactory average voltage is that which powers the amplifier.

Since, in operation, the FM modulator shunts the VFO's tuning capacitor, the transmitter's r.f. must be kept from driving *D1* into forward conduction. This danger is minimized somewhat by the modulator design since *C7* is effectively in series with the VFO's tuning circuit and *D1*, thus dropping the r.f. voltage to a safe level.

Note from Fig. 1 that the modulator

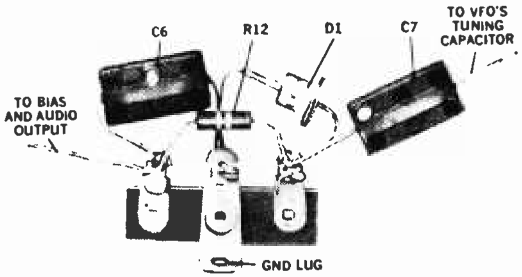


Fig. 4. Four components, when assembled on a terminal strip, comprise the complete FM modulator.

bias voltage is always *on* instead of being switched. This is so in order to maintain the VFO's calibration whether the transmitter is operating on AM or FM. The small leakage current produced has no measurable effect on the battery life.

Installation and Checkout. If space permits, the modulator and audio amplifier can be built on the same circuit board, and housed in the VFO unit (Fig. 3). Otherwise, the few modulator parts can be wired in the VFO as shown in Figs. 4 and 5, while the mike amplifier is put in its own enclosure and placed alongside of the VFO. Then these two units can be connected with a short length of shielded microphone cable or RG-58/U cable.

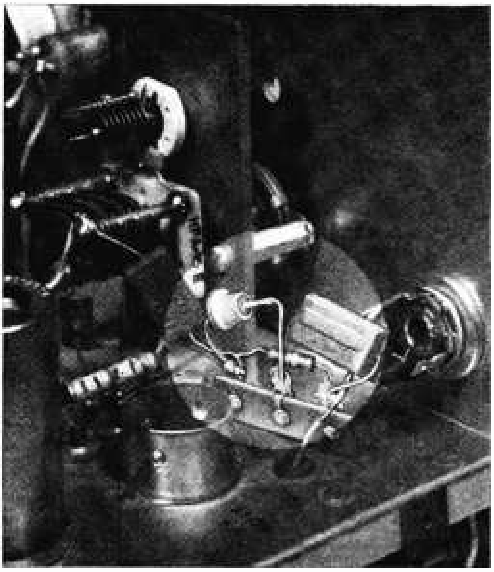


Fig. 5. The FM modulator (circled area) is shown installed in a Thor transceiver. The modulating audio signal is applied via the phone jack at right.

When you install the modulator, the added capacitance introduced will slightly lower the resonant frequency of the VFO. However, this circuit can be retuned by simply lowering the value of the VFO's calibrating capacitor.

If the FM modulator or amplifier is installed in a powered VFO, or in a transmitter with a built-in VFO, the bias and operating voltage can be taken from the transmitter's regulated plate voltage by using a voltage divider like the one shown in Fig. 6. The value of the dropping resistor may have to be increased or lowered to get the correct voltage. Try to get from 6 to 10 volts from the divider. And since this voltage is positive, it will be necessary to reverse the polarity of the diode (*D1*) from the position shown in Fig. 2. Otherwise, a 9-volt battery can be used as shown in Fig. 1.

After completing the conversion, call up a station on AM. When you make

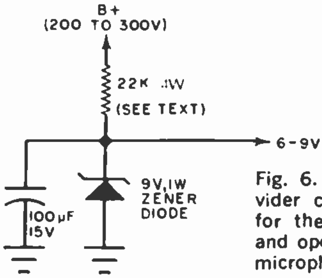


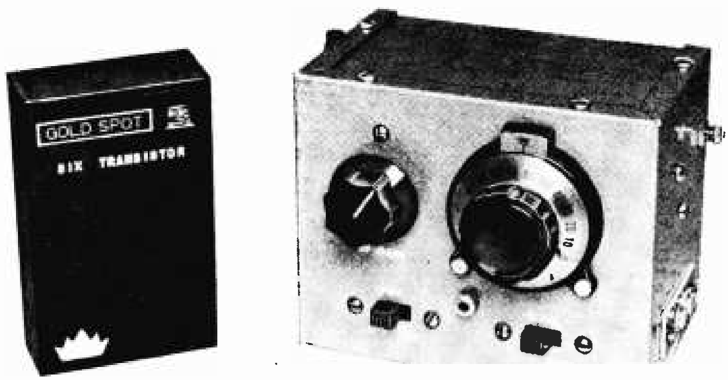
Fig. 6. This voltage divider can provide bias for the FM modulator, and operating power for microphone amplifier.

contact, switch the mike over to FM and set the amplifier level control to midpoint. If your contact reports weak audio, turn up the gain. If he reports overmodulation as evidenced by distorted or broken transmission, turn down the gain. If there's a slight roughness of the signal on FM that cannot be corrected with the amplifier level control, substitute a smaller capacitor for *C7* to drop more of the r.f. across it. This will usually do the trick.

Your final adjustment should produce a narrow-band FM signal that is legal to use anywhere on 6 meters, and you can operate freely with the assurance that those phone calls from the neighbors will be for one of the other members of the family. —30—

BUILD

The "Camper's Cuzzin"



SMALL CONVERTER SETS UP ORDINARY AM RADIO FOR 75- AND 80-METER HAM BANDS

By HARTLAND B. SMITH, W8VVD

THE "CAMPER'S CUZZIN" can convert just about any AM broadcast radio into a 75- and 80-meter ham band receiver to pick up CW, SSB, and AM phone signals. It will even work on your small transistor radio. No modifications or connections to the radio are needed. The converter and the radio need only be placed near each other.

While primarily designed as a companion to the "Camper's Special" 80-meter CW transmitter (Fall, 1966, EXPERIMENTER'S HANDBOOK), this unit will do an excellent job for the prospective ham who wants to tune in W1AW code practice transmissions, as well as for the SWL who would like to "dequack" single-sideband signals. It's the BFO in the converter that let's you hear CW and SSB as it should be heard.

Some of the features that make the "Camper's Cuzzin" suitable for camping, fishing and hunting trips are its small size, light weight, and small current battery operation. The low cost involved in building it, about $14, is also appealing.

How It Works. The signal from an antenna connected to *TS1* (see Fig. 1) is coupled to the base of *Q1*. Transistor *Q1* serves both as an amplifier and as a mixer. The slug in *L1* broadly tunes the input circuit for resonance at any frequency between 3.5 and 4.0 MHz; it protrudes through the front of the cabinet and is labeled *RF Gain.*

The r.f. signal is mixed with another signal coupled into *Q1*'s emitter from *Q2* by way of *C5*. The *Q2* circuit is a series-fed Hartley oscillator which can be tuned through a frequency range of 5.1 to 5.6 MHz simply by varying the setting of *C9*. A vernier dial drives *C9* and makes it possible to obtain the very wide bandspread needed for non-critical tuning of SSB signals.

When the oscillator signal mixes with the incoming signal, sum and difference frequencies are produced. The difference frequency, which is on the order of 1.6 MHz, is the one that is needed to feed into the broadcast-band radio. Tank circuit *L2/C2* is slug-tuned to resonate and radiate at this frequency.

If the converter is used in a transmitter and receiver setup, the jumper wire across *TS2* can be removed and a switch or the normally-closed contacts on a transmit/receive relay can be connected in its place. When the transmitter is on, the relay is energized and removes the forward bias voltage needed to operate *Q1*, and "silences" the converter. Notice that battery power to the other circuits in the converter is not affected. This eliminates the oscillator drift which would otherwise occur every time the power was turned on and off.

Transistor *Q3*, like *Q2*, is a local os-

PARTS LIST

B1—9-volt battery
*C1, C7, C13—75-pF NPO disc capacitor**
*C2, C5, C10—100-pF NPO disc capacitor**
C3, C6, C8, C11, C12, C14, C15—0.0047-µF disc capacitor
C4—0.001-µF disc capacitor
C9—15-409 pF variable capacitor (Allied Radio 43 A 3524, or similar)
L1—1.7-5.5 MHz antenna coil (J. W. Miller B-5495-A, or similar)
L2—540-1650 kHz loop antenna (J. W. Miller 2002, or similar)
L3—Slug-tuned oscillator coil wound on J. W. Miller No. 21A000RBI coil form—see text
L4—BCB transistor oscillator coil (J. W. Miller 2020, or similar)
Q1, Q2, Q3—2N1526 transistor
R1, R9—3900 ohms
R2—10,000 ohms
R3, R6, R8—1000 ohms
R4—100,000 ohms
R5—8200 ohms
R7—18,000 ohms
R10—22,000 ohms
(*All resistors ½ watt*)
S1, S2—S.p.s.t. switch
TS1, TS2—Two-screw terminal strip
1—5" x 4" x 3" metal box
Misc.—Transistor sockets (3); 2-lug terminal strip (1); 3-lug terminal strip with ground lug (1); ¾" spacers (2); vernier dial; short length of ¼" round insulated rod; knob; 6-32 hardware; solder; wire, etc.

*NPO disc capacitors: Sprague 10TCC, or similar

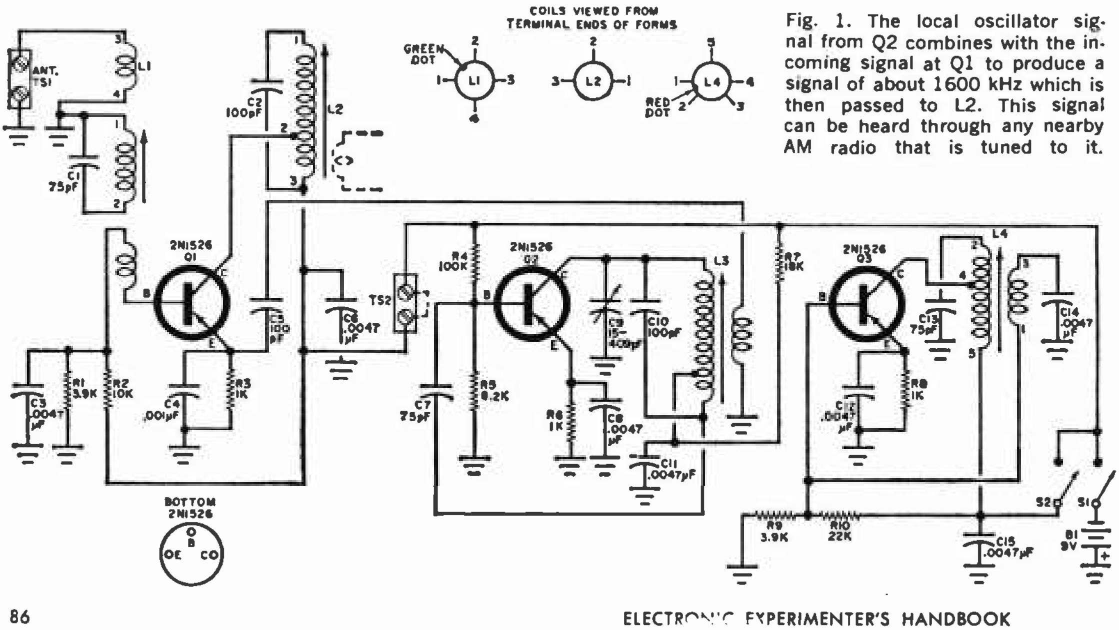
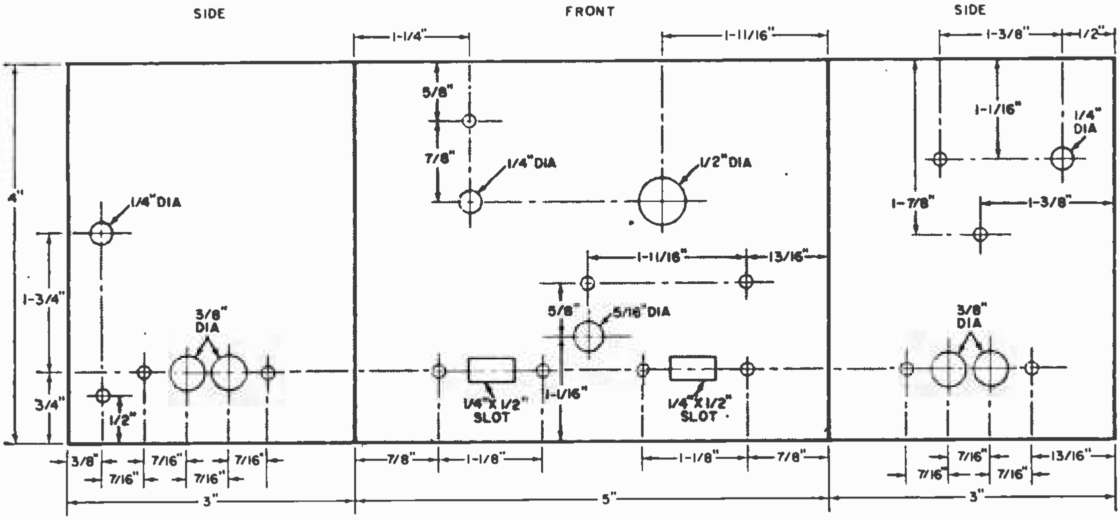


Fig. 1. The local oscillator signal from Q2 combines with the incoming signal at Q1 to produce a signal of about 1600 kHz which is then passed to L2. This signal can be heard through any nearby AM radio that is tuned to it.



ALL HOLES NO. 28 DRILL UNLESS OTHERWISE NOTED

Fig. 2. Prepare a 5" x 4" x 3" metal utility box exactly as shown. Pay particular attention to the mounting holes for C9 in the upper portion of the front and side.

cillator, but is tuned to approximately 1600 kHz, and serves as a BFO. When *S2* is switched on, the BFO reinserts a carrier to make SSB signals intelligible, or it beats with an incoming CW signal to make it readable. The BFO signal is strong enough to get into the *Q1* circuit without direct coupling. For AM phone reception, *S2* is left in the *off* position.

Power for the converter can be obtained from a 9-volt transistor battery, or from six 1.5-volt penlight cells connected in series.

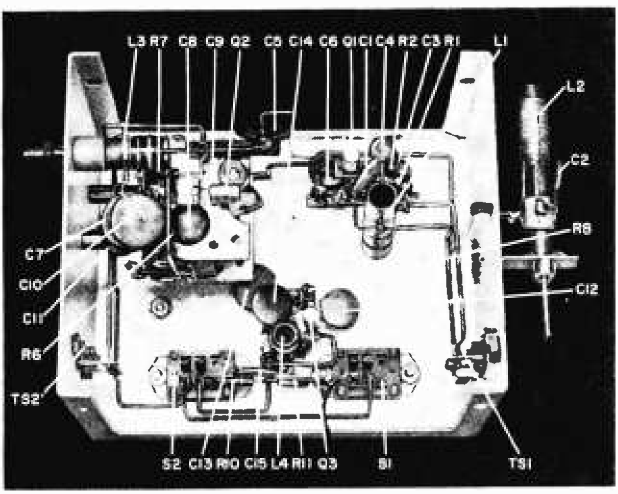


Fig. 3. All components associated with C9 and Q2 should be solidly mounted. For best results, keep leads as short as possible and dress wires neatly.

Construction. Prepare a 5" x 4" x 3" metal box as shown in Fig. 2. Follow the layout shown in Fig. 3. Pay particular attention to the mounting of variable capacitor *C9* and the vernier dial. Use 3/4"-long metal spacers to position *C9* securely in place.

Only two plates on the rotor of *C9* are needed. If your capacitor has a fiber spacer strip attached to one end of the rotor plates, carefully cut through this strip, between the second and third plates from the front. Use a pair of long-nose pliers to work the rotor plates free, one at a time. Remove all but the two plates at the front end. Do not do anything to the stator plates, and be careful not to bend or shift the position of the remaining plates.

Good SSB reception will only be possible if the tunable oscillator is mechanically rugged. All components associated with *Q2* and *C9* should be solidly mounted. When mounting *C9* on the chassis, keep your eyes on the ends of the mounting screws and avoid digging into and shorting out the capacitor's plates. If necessary, grind the ends of the screws down, or place washers under the screw heads. Mount *L3*, *C9*, and *Q2* as close to each other as possible in order to keep their leads short. (See Parts List for type of coil form needed for *L3*.)

The tapped primary winding for *L3* requires 23 turns of #28 enamel-covered wire, tapped 3 turns from the *C7* end.

Remove the enamel coating from the ends of the wire and solder the wires to the solder rings supplied with the coil form. Wrap one layer of electrical tape around the untapped 20 turns. The secondary winding consists of 4 turns of #28 enameled wire wound over the tape. Use coil dope to cement each winding in place. If you don't have any suitable cement, you can pour melted wax over the windings.

Modify coil *L1* by adding a 5-turn winding of #28 enamel-covered wire to the top end of the coil, over the secondary winding—this is the end away from the terminals. Use cement or wax to hold the windings in place.

Solder the ground leads of *C8, C11, R5*, and *R6* to a ground lug on the frame of *C9*. The ground leads of *C12, C13, C14* and *R8* go to a ground lug held in place by one of the nuts used to mount the vernier dial.

To mount the control knob for *L1*'s slug, drill a hole the same size as the diameter of the adjusting screw on the slug in the center of one end of a ⅜"-long by ¼"-diameter piece of plastic rod. Cement this end onto the adjusting screw and, when dry, secure the knob in place. Use a knob equipped with a setscrew.

Cut the transistor leads to about ⅜" in length and bend them to conform with the holes in the transistor sockets. Observe polarity when connecting the battery—it can be mounted inside the case. Close the cover before using the unit.

Adjustment. Tune your AM broadcast radio to a "dead" spot near 1600 kHz on the dial. Set the converter near the radio so that *L2* is close to the radio's loop antenna. (If the radio doesn't have a loop antenna, wind about five turns of #28 insulated wire around *L2* and connect one end to the receiver's antenna, and the other end to ground. Turn on the radio and crank up the volume control.

Switch on the "Camper's Cuzzin." Slowly screw the slug into *L2*. If the mixer is working properly, you'll begin to hear a hissing sound in the speaker. Adjust the slug for maximum hiss.

Connect a suitable 75- to 80-meter antenna, preferably fed by a coaxial cable or other 75-ohm lead, to *TS1*. Set the vernier control (*C9*) to its approximate midposition, and adjust *L3* to tune an AM phone amateur station. Move the radio away from the converter until the signal is very faint. (If you had to connect a 5-turn winding on *L2* to your radio, temporarily reduce the number of turns, to reduce the coupling.) Peak the *RF Gain* control for maximum signal.

Tune in an SSB station for maximum by adjusting the vernier control, with the BFO off. Switch the BFO on, and tune *L4* for clearest voice reception. Now jockey the slug in *L3* back and forth until you can hit the low-frequency edge of the band when *C9* is at or near maximum capacity. The high end of the band should come in where *C9* is at or near minimum capacity.

Then tighten the lock-nut on *L3*, and bring the radio back in close to the converter for normal operation.

Operating Hints. When searching for a weak station, adjust the *RF Gain* control for a maximum amount of background noise. For strong CW or SSB signals, you may find it advantageous to cut down the gain to prevent the incoming signal from overriding the BFO.

Putting a converter into operation for the first time is a relatively simple job if you understand what each part of the circuit is supposed to do. In case you encounter any problems, remember that *C1* and *L1* tune between 3.5 and 4 MHz. Coil *L2* should be peaked at 1.6 MHz, and *L3* should resonate at 5.4 MHz with *C9* at half capacity. If you have a general-coverage receiver, listen at 5.4 MHz for the signal generated by *Q2*. Transistor *Q3* oscillates at 1.6 MHz—you can hear its steady carrier on the broadcast set.

Transistor *Q1* is not supposed to oscillate. In the unlikely event that you hear birdies as *L1* is tuned through its range, reverse the leads on the winding you added to *L1*. If this doesn't help, remove a turn or two from the winding.

The "Camper's Cuzzin" is very sensitive. When hooked up to a good antenna, it will pull in any 75- or 80-meter station that can be heard on a top-quality communications receiver. Its ability to separate signals during periods of heavy QRM is dependent, of course, on the selectivity of the broadcast-band receiver with which it is used. Obviously, the sharper the receiver, the better will be the overall performance. —30—

BUILD A

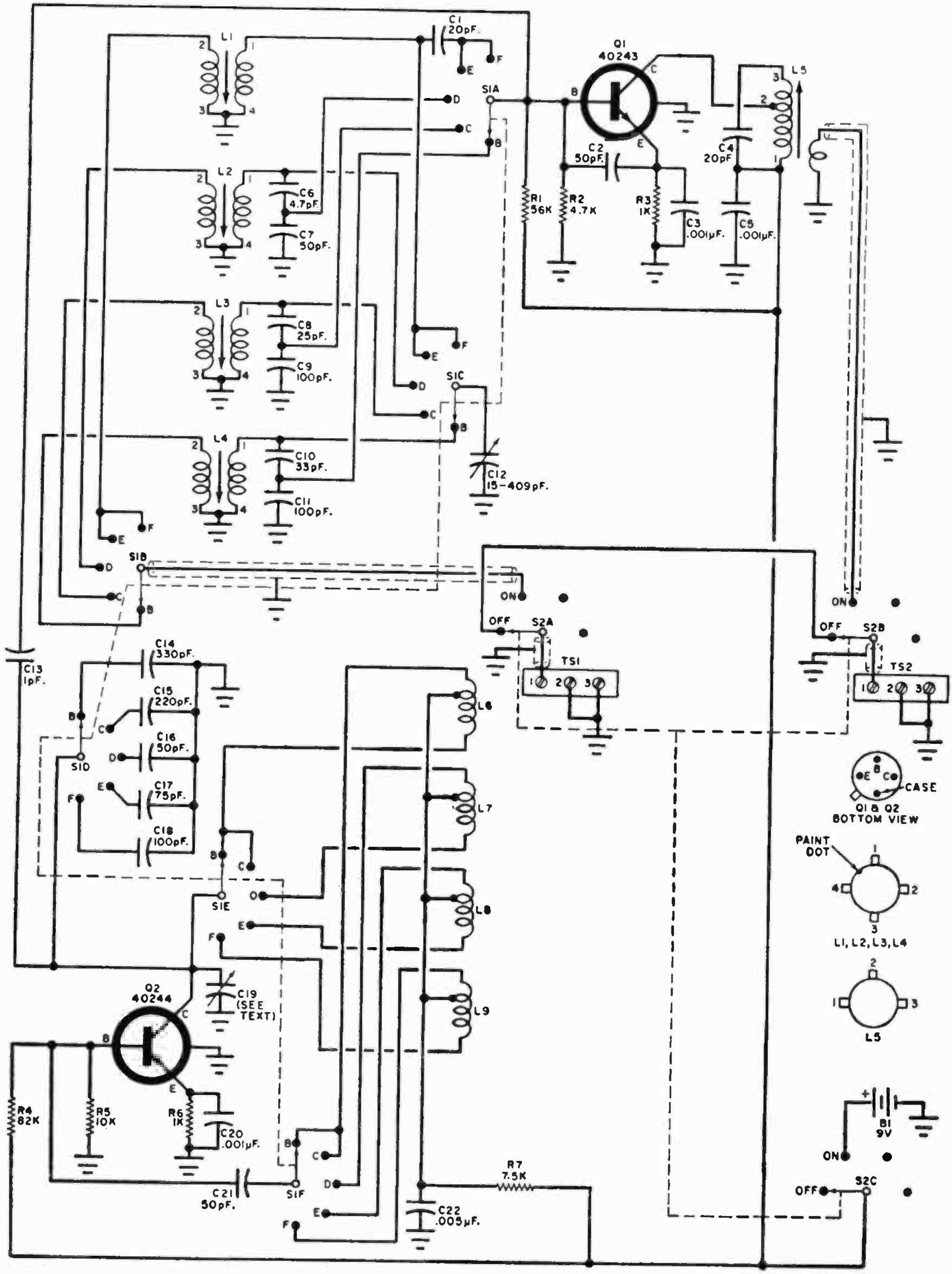
GC-2 DELUXE CONVERTER

FOR THOSE HAMS WITH RADIO AMATEUR BAND COMMUNICATIONS RECEIVERS WHO WANT GENERAL COVERAGE FROM 200 KHZ TO 18.0 MHZ

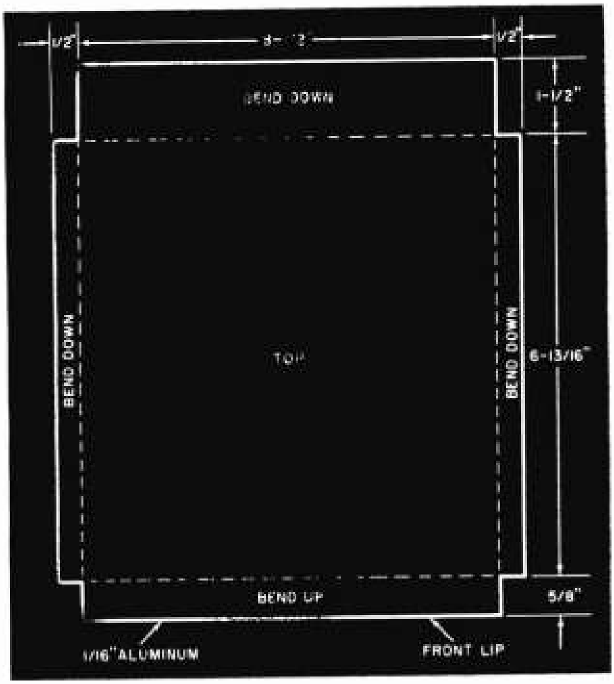
By HARTLAND B. SMITH, W8VVD

HERE'S A PROJECT that should have special appeal for those frustrated radio amateurs prevented from scanning the remainder of the radio spectrum because of the band-scanning limitations of their ham-band-only receivers. The *GC-2 Deluxe* is a general-coverage converter using just two transistors that tunes from 200 kHz to 18 MHz.

Whether you prefer to eavesdrop on international phone calls, hear the latest propaganda from London and Prague,



GC-2 Deluxe Converter uses two low-cost transistors in conventional circuit. Output is tuned to 3.5 MHz to feed ham-band-only communications style receivers. Coverage is 200-400 kHz and 0.55 to 18.0 MHz.



If you house the converter in the cabinet recommended by the author, a chassis must be formed from sheet aluminum as shown in the drawing above.

keep track of NASA ground-to-space communications, pick up the latest weather reports from an FAA station, check your watch against CHU, work MARS or CAP stations, or if you merely want to listen in on the Beatles' latest disc, the *GC-2 Deluxe* will admirably fill your needs.

The Circuit. Two inexpensive silicon planar transistors are used in the converter. The mixer, *Q1*, is an RCA 40243, and *Q2*, an RCA 40244, is the high-frequency oscillator. Any one of four factory-wound antenna coils (*L1* through *L4*) can be switched into the mixer's base circuit. The coils are resonated to the desired frequency of the incoming signal by *C12*.

The oscillator is tuned 3.5 MHz above the desired frequency in the *GC-2*. Unlike the mixer coils, the oscillator coils (*L6* through *L9*) must be hand-wound. Tuning capacitor *C19* is driven via a large two-speed Miller MD-8 vernier dial which supplies the smooth action and bandspread required for comfortable tuning on the crowded short-wave bands.

A 3.5-MHz signal appears in the collector circuit of *Q1*. Tank circuit *C4*, *L5* resonates at 3.5 MHz, and by means of the link on *L5*, the converter is fed to the antenna connector of the companion receiver which remains fix-tuned to 3.5 MHz whenever the converter is in use.

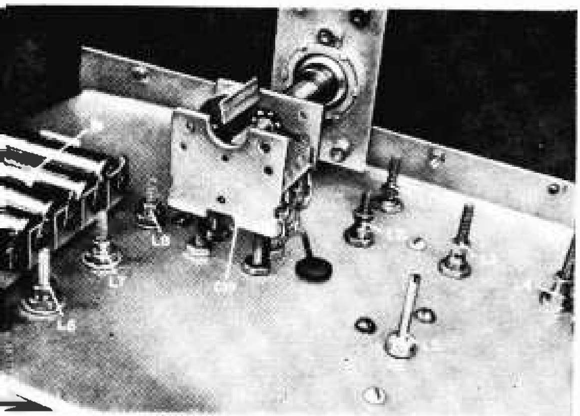
At very high frequencies, *C2* offers a low impedance between the base and emitter of *Q1* to minimize TV and FM signals which have a tendency to creep into the converter when it is operated within 5 or 10 miles of these super-powered broadcasters. Without *C2*, TV signals would mix with harmonics of the oscillator to produce unwanted birdies in the output of the converter.

Power for the *GC-2 Deluxe* is supplied by six penlight cells wired in series. Because of the converter's very low power requirements, an ordinary 9-volt transistor battery could be used for the purpose. However, penlight cells were chosen for the prototype because of their long life.

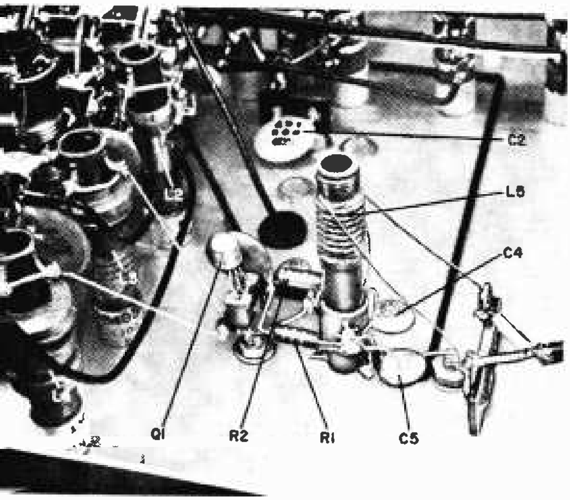
PARTS LIST

B1—9-volt battery (6 penlight cells in series)
*C1, C4—20-pF, NPO disc capacitor**
*C2, C7, C16, C21—50-pF, NPO disc capacitor**
C3, C5, C20—0.001-µF disc capacitor
*C6—4.7-pF, NPO disc capacitor**
*C8—25-pF, NPO disc capacitor**
*C9, C11, C18—100-pF, NPO disc capacitor**
*C10—33-pF, NPO disc capacitor**
C12—15-409 pF variable capacitor (similar to Allied Radio 13 U 524)
*C13—1-pF, NPO disc capacitor**
C14—330-pF silver mica capacitor
*C15—200-pF, NPO disc capacitor**
*C17—75-pF, NPO disc capacitor**
C19—15-409 pF variable capacitor (similar to Allied Radio 13 U 524) altered as described in text
C22—0.005-µF disc capacitor
Q1—RCA 40243 transistor
Q2—RCA 40244 transistor
R1—56,000-ohm, ½-watt resistor
R2—4700-ohm, ½-watt resistor
R3, R6—1000-ohm, ½-watt resistor
R4—82,000-ohm, ½-watt resistor
R5—10,000-ohm, ½-watt resistor
R7—7500-ohm, ½-watt resistor
S1—6-pole, 5-position miniature phenolic switch (similar to Centralab PA1021)
S2—3-pole, 4-position single-gang switch (similar to Mallory 3134J)
TS1, TS2—3-screw terminal strip
1—10" x 8" x 7" utility cabinet (similar to Bud CU-879)
1—9" x 10" piece of aluminum sheet for fabricating chassis
1—2-speed vernier dial (similar to J. W. Miller MD-8)
Misc.—Grommets, 6-32 machine screws and nuts, solder lugs, wire, solder, decals, transistor sockets, knobs (3), battery holder

**All NPO disc capacitors similar to Sprague 10TCC*



These close-up photographs show the locations of the principal components. Lead lengths are not critical, but should be direct and point-to-point.



Construction. Since the large tuning dial makes it necessary to house the converter in a fairly big cabinet, there is room to spare for all components. Unfortunately, no company seems to manufacture a suitable chassis, so the builder must fabricate one from sheet aluminum. Its dimensions are shown on p. 91. Bend the front lip of the sheet aluminum upward, and the side lips and rear apron downward.

Layout of the components should, in a general way, follow the prototype model. Orient *C12* as shown on p. 93. Fasten *C12* to the front panel with three *6-32* x ½" screws that pass through the tapped holes in the capacitor's frame. You'll have to grind (or cut) down these screws until they are short enough so that they will not interfere with the action of the rotor.

Support *C19* on four *6-32* x ¾" screws. Tap the holes in the bottom of the capacitor frame to accept the screws. WARNING: Don't screw them in so far that they contact and short out the stator plates of the capacitor! Remove ten of the 17 rotor plates from *C19* (five plates from the front of the rotor and five plates from the rear), leaving the remaining seven in the center of the shaft.

Do *not* connect the capacitor shaft to the dial mechanism with the insulated flexible coupling supplied with the MD-8 dial. Only a solid metal shaft coupler should be used at this point. Otherwise, you'll be plagued with backlash.

After adjusting the stops for 5-position operation, mount *S1* exactly as pictured at right, with the wafer support rods along the top and bottom of the switch.

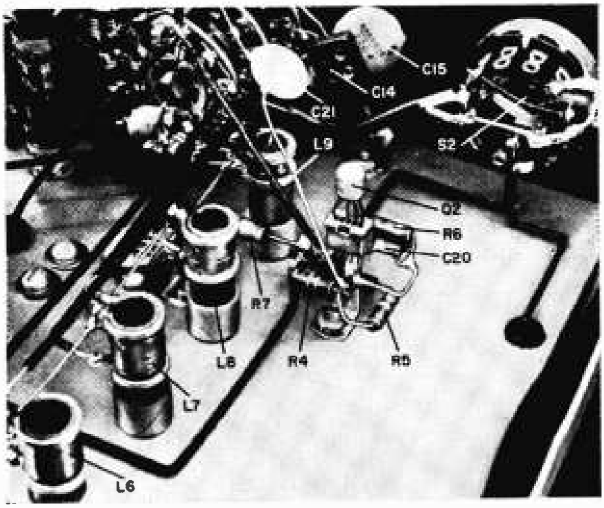
The transistor sockets are self-supporting. The case terminal of *Q1* is soldered directly to a ground lug, while the case terminal of *Q2* is soldered to the grounded mounting foot of a one-terminal insulated tie point. See photos on next page for details.

Shielded wire must be used wherever shown in the wiring diagram. Although ordinary RG-58/U coax can be used, it is rather bulky. A much better job will result from using RG-174/U, which is just 1/10 of an inch in diameter.

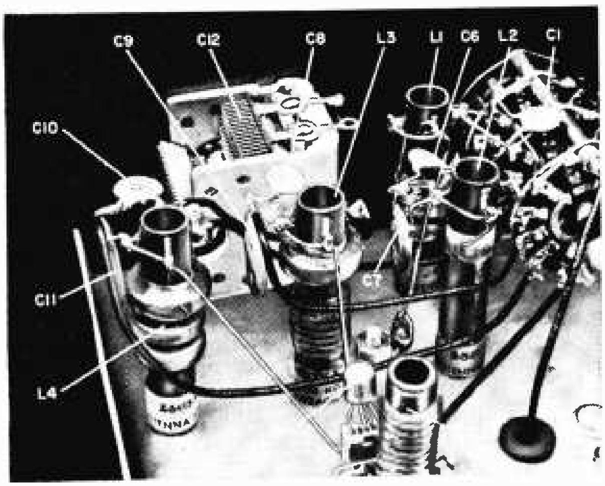
The Coils. As supplied by the manufacturer, *L4* has a 10-pF disc capacitor wired between terminals 1 and 2. Clip this capacitor out and discard it. Don't try to unsolder it, because you might damage the coil in the process!

Snip off the short antenna wire supplied with *L5*. Wind a 9-turn link with No. 28 enameled wire over the end of the coil form and fasten it in place with coil dope or polystyrene cement.

Wind coils *L6, L7, L8* and *L9* as specified in the Coil Table. When you reach the point on a particular winding where a tap is called for, scrape the enamel from the wire for approximately one-half inch. Make a "U"-shaped loop at this point, twist the loop several times, and then continue the winding. This operation will provide you with a tap



Transistor sockets are used in the GC-2 Deluxe as shown in these photos. The sockets are soldered in place (use case terminal) and are self-supporting.



approximately ½" long that you can solder to after the coil is mounted. A liberal application of cement will prevent the turns from shifting, once the coils are wound.

Only four sets of coils are required to cover the five tuning ranges of the *GC-2 Deluxe*. This is because a single oscillator coil is used for bands *B* and *C*, while a single antenna coil suffices for bands *E* and *F*. Why is there no band A? Well, the J. W. Miller dial has six semicircles already drawn on it, labeled *A* through *F*. However, the *A* portion of the dial was omitted by the author, who preferred to start with larger band *B* instead.

Adjustment. After carefully checking your wiring, plug in the batteries, attach an aerial to *TS1* and run coaxial cable between *TS2* and your ham-band-only receiver's antenna terminals. Then turn on the receiver and converter.

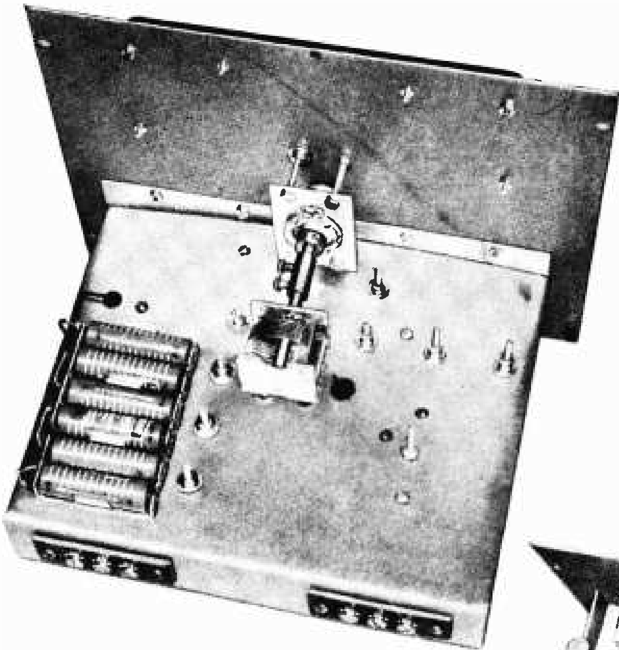
Set the receiver dial to 3.5 MHz and switch the converter to *Band C* (broadcast range). Mixer tuning capacitor *C12* should be at full capacity. The slugs in *L3, L5* and *L6* should be turned fully counterclockwise. If your ham-band receiver has an r.f. trimmer on the front panel, peak it for maximum hiss in the loudspeaker.

Now tune the converter oscillator main tuning capacitor, *C19*, through its range. If the oscillator and mixer are working, you should hear some weak broadcast signals. Tune in one of these and adjust the slug in *L5* for maximum receiver S-meter reading. You should be able to bring the signal in with a roar by rotating "Mixer Tuning" for maximum response. As you tune the main capacitor, you should hear other strong stations. It will be necessary to repeak the "Mixer" from time to time as you tune across the band.

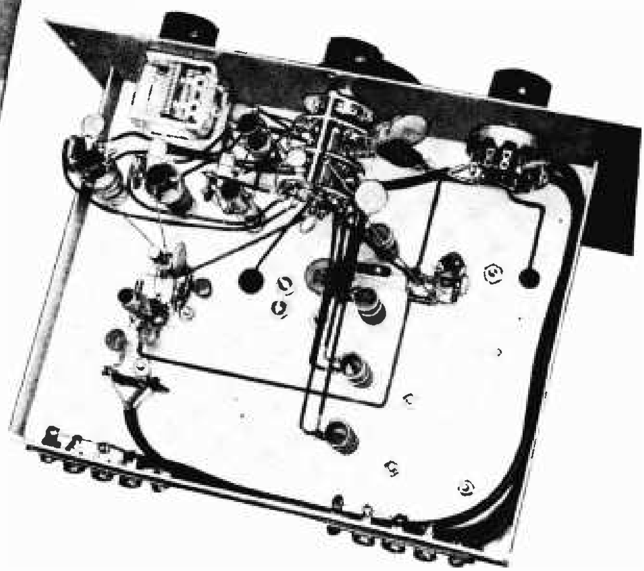
Tune in a station near 1600 kHz and screw the slug into *L6* while rotating the main tuning capacitor until the station comes in at approximately 11 on the red logging scale which is printed near the edge of the dial. Tighten the lock nut on *L6*. Then set the two panel tuning controls at minimum capacity and ad-

COIL TABLE

L1—3.5-18 MHz antenna coil (similar to J. W. Miller C-5495-A)
L2—1.7-5.5 MHz antenna coil (similar to J. W. Miller B-5495-A)
L3—550-1700 kHz antenna coil (similar to J. W. Miller A-5495-A)
L4—140-420 kHz antenna coil (similar to J. W. Miller X-5495-A)
L5—Ferrite loop antenna (similar to J. W. Miller 2002)—see text
L6—22 turns of No. 28 enameled wire tapped 4 turns from base end, close-wound on a ⅜"- x 1⅛" J. W. Miller 21AOOORBI form (cataloged by Allied Radio as 54 D 3909, 90¢)
L7—21 turns of No. 28 enameled wire tapped 5 turns from base end, close-wound on a ⅜"- x 1⅛" J. W. Miller 21AOOORBI form
L8—10 turns of No. 28 enameled wire tapped 3 turns from base end, close-wound on a ⅜"- x 1⅛" J. W. Miller 21AOOORBI form
L9—7 turns of No. 28 enameled wire tapped 3 turns from base end, close-wound on a ⅜"- x 1⅛" J. W. Miller 21AOOORBI form



Overall above- and below-the-chassis views give a general perspective of parts layout.

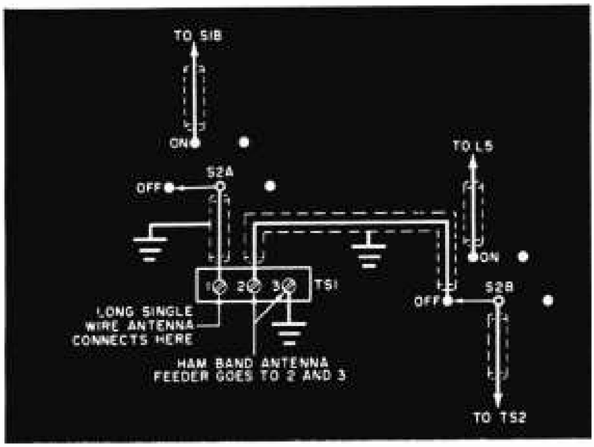


just the slug in *L3* for maximum background noise. Tighten the lock nut on *L3*. The converter is now aligned for the broadcast band.

As you tune back and forth across the dial, bear in mind that you must repeak "Mixer Tuning" for optimum reception of a specific station. And always approach this point by tuning the "Mixer" from maximum toward minimum capacity. Otherwise, you may be peaking an image rather than the desired station.

The Higher Bands. Alignment of the converter on the higher bands is done in a similar manner. Use the output from an r.f. signal generator to find the proper settings for the oscillator coil slugs. On *Band D,* adjust *L7* so that 4.0 MHz falls at 24 on the logging scale. On *Band E*, adjust *L8* for a 7.0 MHz logging scale reading of 53. *Band F* requires *L9* to be adjusted so that 14.0 MHz appears at 39.5 on the logging scale. No oscillator coil adjustment is required for *Band B*.

You should be able to hear airways beacons on a portion of *Band B,* and also some broadcast signals when the main capacitor is near minimum capaci-

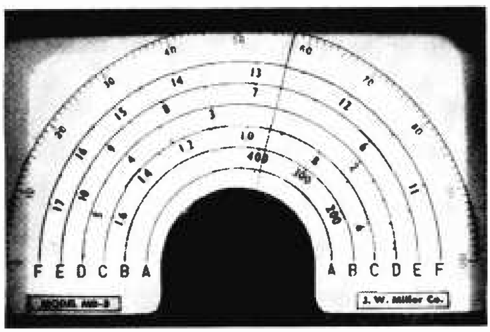


Alternative output switching arrangement will permit use of separate long-wire antenna for converter.

ty. Adjust *L4* so that the highest frequency beacon you hear (around 400 kHz) is loudest with "Mixer Tuning" at minimum capacity.

On *Band D*, *L2* should be set for maximum hiss when both panel controls are at minimum capacity. No antenna coil adjustment is required for *Band E*. On *Band F*, peak *L1* for maximum ignition noise with both panel controls at minimum capacity.

Your regular amateur transmitting and receiving antenna can be used with the converter. Results will be excellent if it is a 40- or 75-meter dipole. However, if you use only a 10-, 15- or 20-meter beam, performance on *Bands B*, *C* and *D* may be quite disappointing. Under these circumstances, use a separate single-wire antenna for the converter. Make it as long and high as possible and rewire the input sections as shown at left.



The author calibrated the dial using paste-up numerals supplied by the manufacturer. Its appearance is quite professional-looking. The "A" band on the dial was not used because of space limitations.

Results. Despite its low cost and relative simplicity, the *GC-2 Deluxe* will provide results comparable to those you'd expect from a general-coverage receiver.

At the author's lower Michigan QTH, the original unit has picked up aircraft weather forecasts on *Band B* from Detroit, Pittsburgh, Indianapolis, Cleveland, Milwaukee, and Windsor and Wiarton, Ontario. The broadcast band is alive with signals.

Interesting Great Lakes, Mississippi, and Coastal traffic is heard on *Band D*. *Bands E* and *F*, besides carrying International Broadcasting, are loaded with point-to-point telephone conversations. These latter signals are mostly SSB—a natural for the *GC-2*.

Anyone who has ever used a simple mixer-oscillator combination, without preselection, has experienced problems with images and other spurious responses. The *GC-2 Deluxe*, while not completely immune to these difficulties, is not seriously affected by them. However, on the rare occasion when a birdie does happen to fall right on top of the station you want to hear, merely move the receiver dial about 10 kHz and retune the converter dial to the desired signal. This will completely remove the offender. -30-

ALIGNMENT DATA

BAND	FREQUENCY RANGE	WHEN LISTENING TO A STATION ON	ADJUST OSCILLATOR COIL	FOR A LOGGING SCALE READING OF	WITH "MIXER" OPEN, ADJUST ANTENNA COIL	FOR MAXIMUM NOISE AT A DIAL SETTING OF
B	200-400 KHz	---	---	---	L4	56 (approx.)
C	5.5-1.7 MHz	1.6 MHz	L6	11	L3	0
D	1.6-5.5 MHz	4 MHz	L7	24	L2	0
E	4.5-11.5 MHz	7 MHz	L8	53	---	--
F	10.5-18 MHz	14 MHz	L9	39.5	L1	0

3 more features —all new

Here is RCA's new WR-50B RF Signal Generator—wired or kit. It looks just like the old WR-50A, but the resemblance ends there. It has all the features you liked in the older model...plus 3 new ones you'll find in red below:

- Wide frequency range from 85kHz to 40MHz in 6 overlapping ranges plus harmonics for higher frequencies
- Built-in crystal calibrating oscillator circuit with front panel crystal socket
- Internal 400 Hz audio oscillator
- *NEW—Sweep output at 10.7 MHz with return trace blanking for sweep alignment of FM receivers*
- *NEW—Sweep output at 455 kHz with return trace blanking for sweep alignment of new transistorized AM radios*
- Individual inductance and capacitance adjustments for each range
- Modulation level control
- Two-step RF attenuator switch plus a continuously-variable attenuator control
- *NEW—additional switch for further attenuation of crystal oscillator output*
- The Optional Distributor Resale Price is only $65.00. Kit Form, $45.00, includes pre-assembled range switch with pre-aligned coils and trimmers. See the RCA WR-50B at your authorized RCA Test Equipment Distributor.

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CHAPTER

4

LAB and TEST EQUIPMENT PROJECTS

In the first ELECTRONIC EXPERIMENTER'S HANDBOOK, there wasn't a separate chapter breakdown for test equipment projects. Nor, among the numerous construction projects published in 1957, were there any gadgets that could be classified as test equipment. It is difficult at this late date to clearly establish why—since certainly there were construction plans for VOM's, VTVM's, generators, etc., being published in POPULAR ELECTRONICS. Possibly the electronics experimenter was not as interested in building his own test equipment ten years ago as he is today, or possibly the burgeoning kit business had temporarily shelved the "build-it-yourself" crowd.

Certainly that can't be said for test equipment projects in 1967-68. The appearance of unusual solid-state devices at low prices has enabled a whole new generation of test instruments to be built by the experimenter. A prime example is the four-layer diode in the simplified circuit of the AMLIGNER which appears on the cover and on page 98. Costing less to build—with new parts, this tunable "signal" generator will enable the rough alignment of an AM broadcast-band receiver.

More sophisticated test equipment projects appear on pages 100 (Emitter Dipper) and 109 ("Square Deal" Audio Generator).

COVER STORY

BUILD THE AMLIGNER

By DON LANCASTER

. . . A MULTIPURPOSE TUBELESS, TRANSISTORLESS, CORDLESS BC-BAND SIGNAL GENERATOR FOR THE RADIO AFICIONADO

A BROADCAST-BAND AM signal generator without test cables or even a line cord? Yes! And what's more, it uses no tubes, no transistors, no integrated circuits . . . nothing but a diode, a resistor, a coil, and a couple of capacitors.

Yet, here's an r.f. signal generator that you can use to signal-trace radio receiver troubles, to align the receiver i.f. and front end—provided you first calibrate the unit—and which, in conjunction with any broadcast-band receiver, can be used as a code-practice oscillator by merely substituting the on-off switch for an ordinary telegraph key.

And what's the miracle ingredient that makes all this possible? Nothing more than a low-power, short-range radio transmitter that sends out an r.f. carrier modulated by a 800-hertz tone signal which is picked up by a receiver placed up to eight feet away. We call it, affectionately, the "AMLIGNER." You can build it for about $7.00.

How It Works. The AMLIGNER (Fig. 1) is basically a free-running relaxation oscillator operating at 800 hertz. The circuit is powered by a 22.5-volt battery,

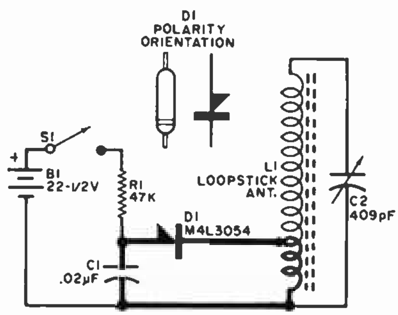
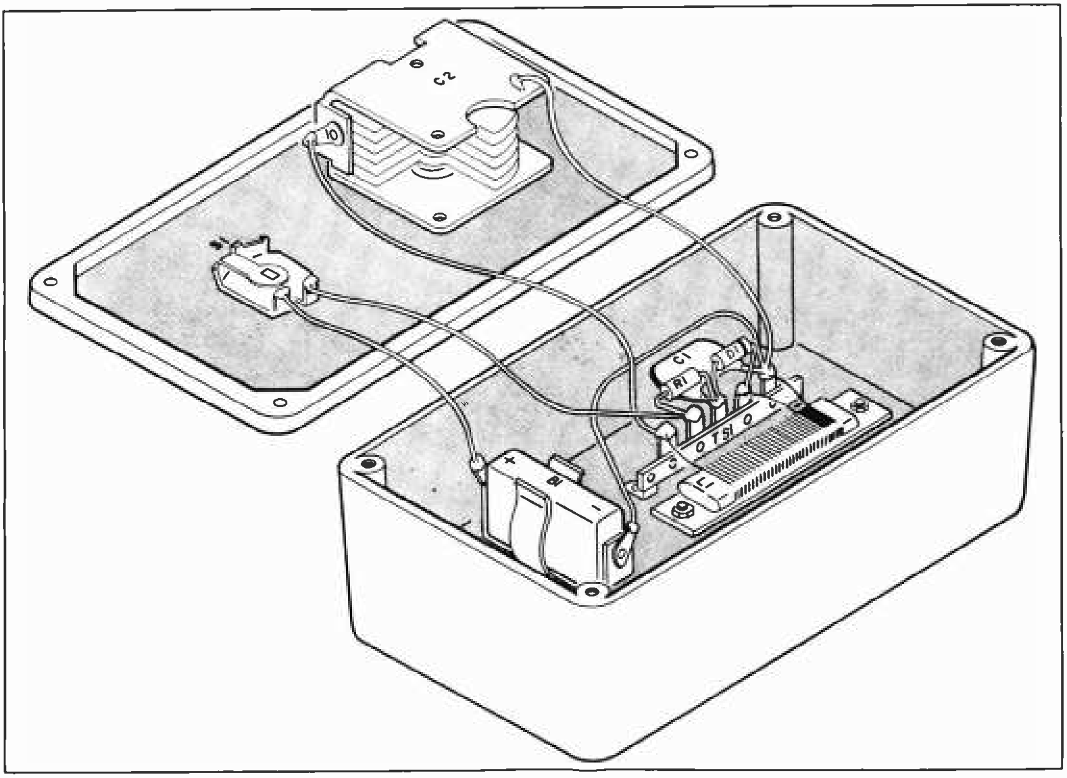


Fig. 1 The AMLIGNER is a free-running relaxation oscillator. Keep the bold line wiring leads as short as possible.

PARTS LIST

B1—22½-volt battery
C1—0.02-μF, 50-volt Mylar capacitor
C2—15 to 409 pF TRF variable capacitor (similar to Allied Radio 43 A 3524)
D1—Motorola M4L3054 four-layer diode (available from Allied Radio, Chicago, Ill.)
L1—Loopstick antenna (similar to J. W. Miller Company 2004)
R1—47,000-ohm, ½-watt resistor, ± 10%
S1—S.p.s.t. rotary switch
1—Plastic case and cover (similar to Harry Davies 240 and 241, or Allied Radio 42 D 7885 and 42 D 7887, respectively)
Misc.—¾" and 1¾" plastic knobs, #6 hardware or pop rivets, battery holder, 5-pin terminal strip, wire, solder, etc.



Housed in a plastic instrument case, the AMLIGNER can be assembled and wired in a matter of minutes. When wiring components to the terminal strip, be sure to observe polarity orientation of diode D1.

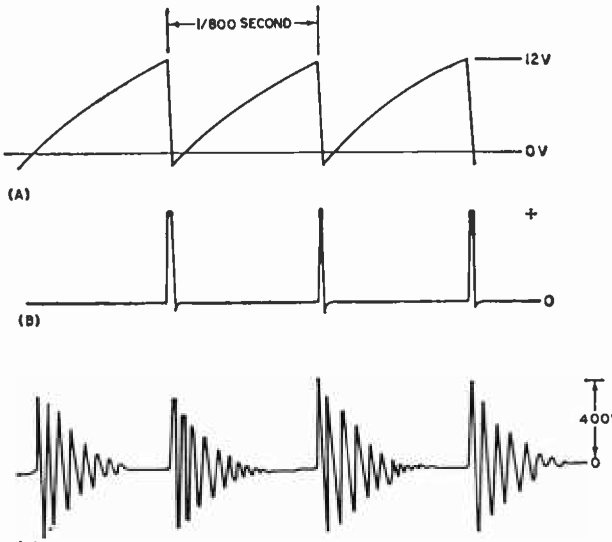


Fig. 2. Voltage and current waveforms include: (a) sawtooth voltage across C1; (b) a current pulse through D1; and (c) a ringing waveform across C2.

which is in series with switch *S1*, limiting resistor *R1*, and capacitor *C1*, shunted by *D1* and the primary of *L1*, a loopstick antenna. The "heart" of the circuit is *D1*, a four-layer diode which snaps on with a 12-volt forward bias and snaps off when the current through it drops below 1 milliampere.

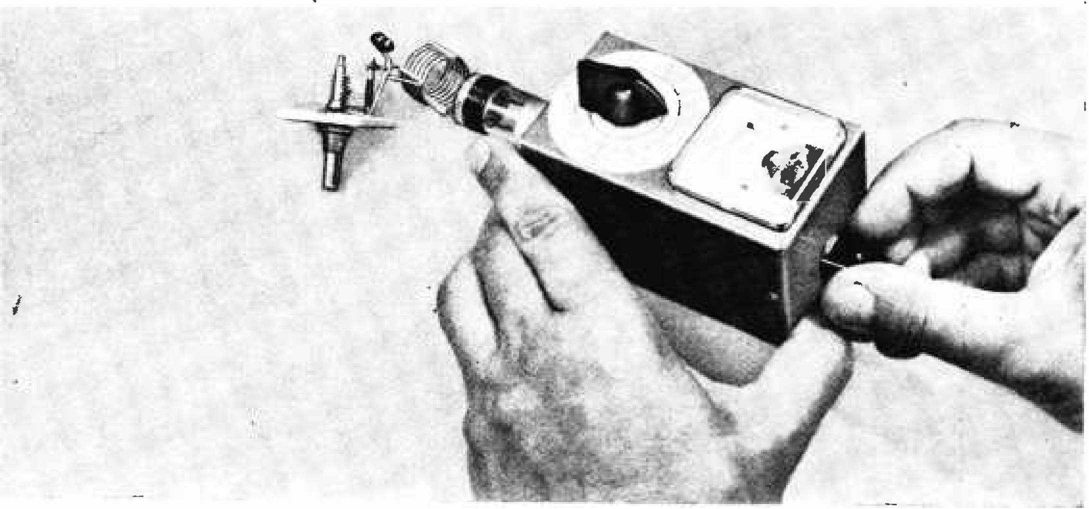
With *S1* closed, *C1* begins to charge through *R1*. When the capacitor charge reaches 12 volts, *D1* avalanches and the capacitor discharges through the primary of *L1*. With *C1* discharged, *D1* turns off and does not turn on again until *C1* recharges to 12 volts. This on-off cycle occurs at a rate of 800 times a second, producing a sawtooth voltage waveform as shown in Fig. 2(a). The waveform of the current through *D1* is shown in Fig. 2(b).

As *D1* turns off, the sudden decrease of current sets up an oscillating current of a few hundred microseconds duration,

(*Continued on page* 143)

BUILD THE

Emitter Dipper



SINGLE BATTERY-OPERATED 2-TRANSISTOR DIPPER SPANS 3 TO 30 MHZ ON 5 BANDS

By ROBERT N. TELLEFSEN
W7SMC/Ø

ONE OF THE MOST useful instruments a ham, CB'er, or experimenter can own is a Grid Dip Oscillator (GDO). The GDO is a versatile instrument which makes the job of finding the resonant frequency of an unknown tuned circuit a snap, as well as detecting oscillations, tuning and neutralizing transmitters, finding unknown values of coils and capacitors, and performing a host of other tests.

The *Emitter Dipper* (EDO) does all the things a GDO does, but unlike the GDO's with their a.c. line cords, the EDO operates on a small 9-volt battery. Its frequency range is continuously variable from 3 MHz to 30 MHz, and—for suitable bandspread—is divided into five different bands. A sensitivity control and more than adequate current flow lets you start with a full-scale reading on all bands. Inexpensive home-brew plug-in coils are used, and the entire project costs about $15 to build.

How It Works. The *Emitter Dipper* has two simple transistor circuits: a Colpitts oscillator (*Q1*), and an emitter-follower (*Q2*). Variable capacitor *C1* provides the EDO with a VFO capability, and any frequency within range can be quickly obtained. Frequency of oscillation is determined by the value of the plug-in coil (*L1*) and the setting of *C1* (see Fig. 1). Capacitors *C2* and *C3* form the feedback network to sustain oscillation. Capacitor *Cx*, mounted in four of the five plug-in coils, helps estab-

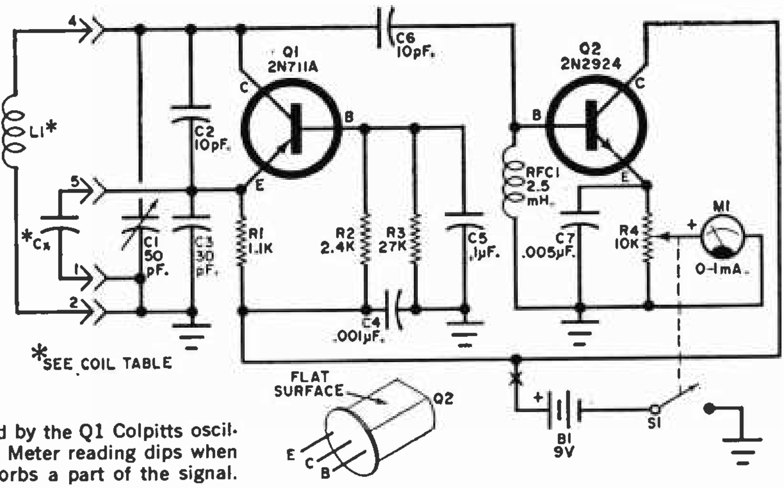


Fig. 1. Signal generated by the Q1 Colpitts oscillator circuit drives Q2. Meter reading dips when an external circuit absorbs a part of the signal.

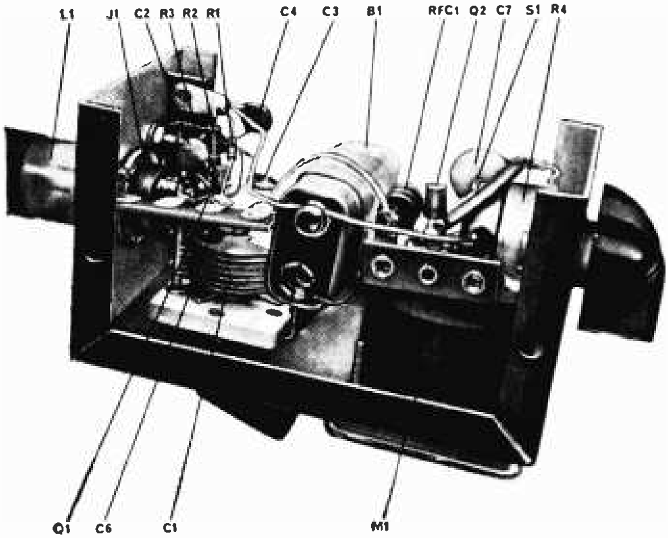
lish the proper level of feedback for each frequency range.

The r.f. signal from the oscillator is coupled to *Q2*. The meter across *R4* serves as an emitter current indicator. Variable potentiometer *R4* is used as a sensitivity control and is adjusted to obtain a full-scale meter reading when the plug-in coil is operating in the "clear."

When the coil is held close to a tuned circuit and the EDO is operating at the resonant frequency of the tuned circuit, some of the r.f. energy is absorbed by the tuned circuit. Amount of absorption depends on the degree of coupling. The resultant drop in signal strength from the *Q1* oscillator circuit shows up as a decrease in emitter current, and causes the meter pointer to dip. The meter reading will be maximum above and below the resonant frequency.

Construction. Except for the plug-in coils, all components are mounted inside a 4" x 2¼" x 2¼" metal box. Parts layout is not critical. Drill appropriate-size holes in the cabinet to accommodate the meter, jack, and other components. You can follow the layout shown in Fig.

Fig. 2. Parts layout is not critical, but avoid excess component lead length. Strap the battery firmly in place to prevent short circuits.



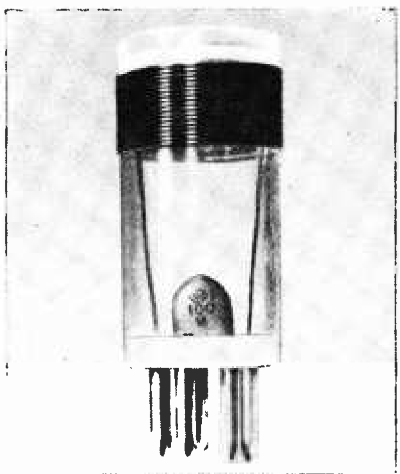


Fig. 3. Wind all coils as shown, and in accordance with the Coil Table. Four of the five coils require a small capacitor (Cx).

PARTS LIST

B1—9-volt transistor battery
C1—50-pF variable capacitor (Hammarlund HF-50)
C2, C6—10-pF disc capacitor
C3—30-pF disc capacitor
C4—0.001-µF disc capacitor
C5—0.1-µF, 10-volt disc capacitor
C7—0.005-µF disc capacitor
Cx—See Coil Table
J1—5-pin miniature socket (Amphenol 78-S5S)
L1—See Coil Table (Amphenol 24-5H)
M1—0 to 1.0-mA meter
Q1—2N711A transistor, or similar
Q2—2N2924 transistor, or similar
R1—1100-ohm, ½-watt resistor
R2—2400-ohm, ½-watt resistor
R3—27,000-ohm, ½-watt resistor
R4—10,000-ohm potentiometer, linear taper (Mallory U-20 Midgetrol)
RFC1—2.5-mH choke, 25 to 50 mA coil (Millen or Mallory)
S1—Add-on s.p.s.t. switch for R4 (Mallory US-26)
1—2¼" x 2¼" x 4" metal box
Misc.—3-lug terminal strip, center lug mounting; 3-lug terminal strips, end-lug mounting (2); pointer knobs (2); sheet metal or plastic strip, nuts and screws

L1 COIL TABLE

NUMBER OF TURNS	WIRE SIZE*	VALUE OF Cx	FREQUENCY RANGE (MHz)
47½	#28	470 pF	3 to 4.4
32½	#24	470 pF	4.4 to 7.6
17½	#24	100 pF	7.4 to 11.6
12½	#16	100 pF	11.5 to 18
6½	#16	none	18 to 30

**Enamel-coated solid conductor*

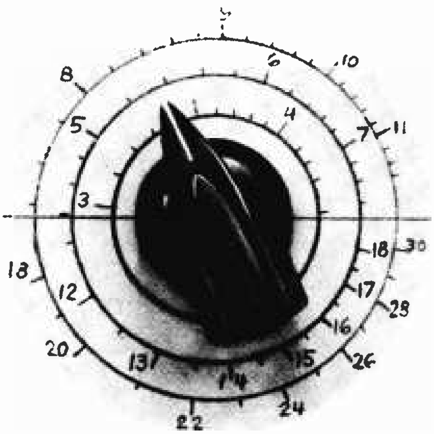


Fig. 4. Dial markings should be made when you calibrate your EDO. Align the knob pointer horizontally when C6 is fully meshed, and tighten knob in shaft. Photo shows actual size of dial scale on prototype.

2. You may have to modify a terminal strip to fit, but that is easily accomplished with a pair of cutters.

A 1" x 4" piece of sheet metal or plastic strap holds the battery in place. If you wire *S1* into the circuit at the point marked "X" instead of between the battery and ground, as shown in the schematic, you can connect the negative side of the battery directly to ground.

Wind the coils on ¾"-diameter polystyrene plug-in forms according to the information given in the Coil Table. See Fig. 3. Don't use a different wire size or make any other changes in the coil winding data if you want to obtain the indicated tuning range. Before soldering any of the pins, heat-sink them to prevent melting the coil form.

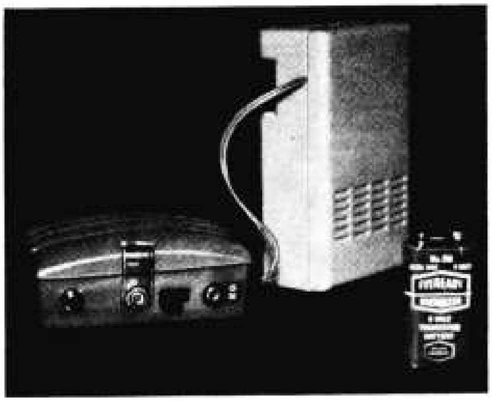
You can make a 2¼"-diameter circular dial out of a piece of heavy paper or cardboard. Draw three concentric circles on the dial, 3⁄16" apart, starting ¼" from the outer edge. The frequency range and intermediate points of the five plug-in coils can then be marked on these circles, without crowding. To mount the dial on the cabinet, cut a ½"-diameter hole in the center of the dial, remove the hex-nut from the shaft of *C1*, center and paste the dial over the opening, and replace the nut. Mount the knob securely on the shaft, and calibrate the dial. See Fig. 4.

Calibration. Accuracy of the EDO can be no better than the accuracy of your calibration procedure, or the calibration equipment you are working with. An accurately calibrated receiver or a crystal-controlled generator can be used.

If you are working with a receiver, turn on the receiver's BFO, plug in the 3-MHz to 4.4-MHz coil switch on the EDO and place the coil end close to the receiver's antenna. Tune the receiver to 3 MHz, rotate *C1* until you hear a tone in the receiver, and mark the EDO dial. (Tune for zero beat.) Advance the receiver's tuning in 100-kHz steps, advance *C1,* and mark the dial as you go. Do the same for the other coils.

Mark a different semicircle on the dial for each plug-in coil. It makes no difference which half of the dial you use. Mark the dial just like a ruler (short and long marks) with numerical callouts at 1-MHz positions. —30—

VOLTAGE-REGULATED BATTERY POWER SUPPLY

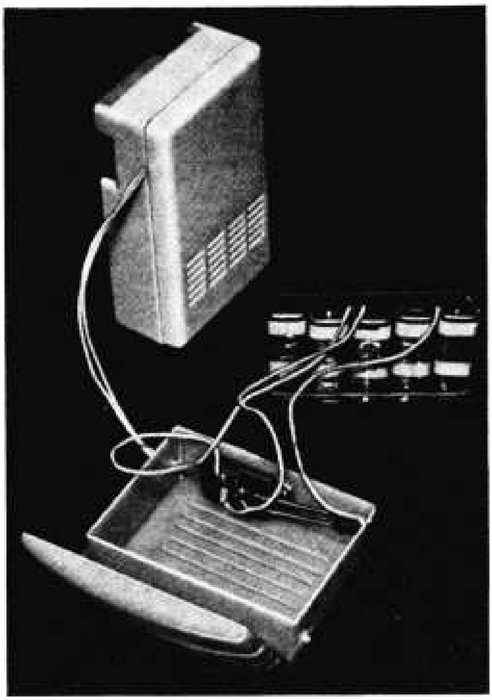


HOW TO OVERCOME INITIAL DECLINE OF PEAK VOLTAGE AND GET MORE BATTERY LIFE

By FRANK G. STIVER

HOW MANY TIMES, in an effort to achieve peak performance, have you replaced the 9-volt batteries in a transistor radio or CB transceiver only to find that in another two weeks you were doing the same thing all over again? Because the audio quality of some CB units suffers from low battery voltage, it is particularly important that this equipment be operated with the maximum rated voltage. Sensitivity is also affected and, needless to say, the transmitter power output takes a drastic drop when the battery is partially discharged.

You could parallel a number of batteries and extend the time it takes for the voltage to reach its mean level, but the drop still occurs at a relatively rapid rate. It's no secret that the output of a carbon-zinc type of battery drops rapidly after a few hours of operation, then levels off at a lower voltage, and maintains that level for about 75% of its useful life. The "Voltage-Regulated Battery Power Supply" will furnish a constant 9-volt output and extend useful battery life well beyond "end-point" voltage.



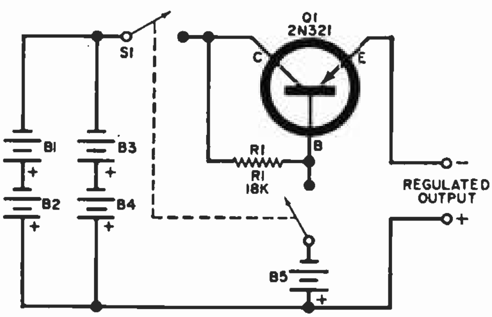
Simple "soap dish" battery pack can be assembled in minutes, and attached with rubber bands, or in any convenient manner, to equipment to be powered.

Essentially, the circuit is a series-type transistorized voltage regulator which compensates for variations in both load and voltage source. This type of regulator has inherently high-efficiency characteristics, especially in small-current applications, and because of transistor gain (only microamperes of base-emitter current are needed to control milliamperes of collector-emitter current), sensitive, quick-responding voltage regulation is obtained. However, care must be taken not to short out the regulated output even momentarily—to prevent destruction of the transistor.

How It Works. Four 9-volt batteries (*B1* through *B4*) connected in series-parallel serve as a power source and provide about 18 volts when new. Transistor *Q1*, (a 2N321, or similar unit) is in series with the load and the power source, and acts like a variable resistor, the value of which depends upon the 9-volt bias battery (*B5*) and the voltage across either or both the load and the power source. Regulated output voltage is essentially equal to battery *B5* voltage under reasonably normal load conditions.

Transistor *Q1* is an emitter follower and the regulated voltage across its external load is determined by the base-to-emitter voltage, in this case fixed at 9 volts by battery *B5*.

If the external load increases so as to reduce the output voltage, the current flow through the transistor automatically increases to maintain the output voltage level up to the power-handling capability of the transistor. Of course, a short circuit across the output will instantly cause the transistor to hit its maximum dissipation, and most likely burn it out.



Highly responsive, efficient series-type voltage regulator depends upon dynamic resistance of Q1 to compensate for load and battery voltage changes.

The same type of circuit, but one employing a high-power transistor (2N176 for example), can be used for higher current demand circuits such as the drive motors of a transistor tape recorder or a portable phonograph.

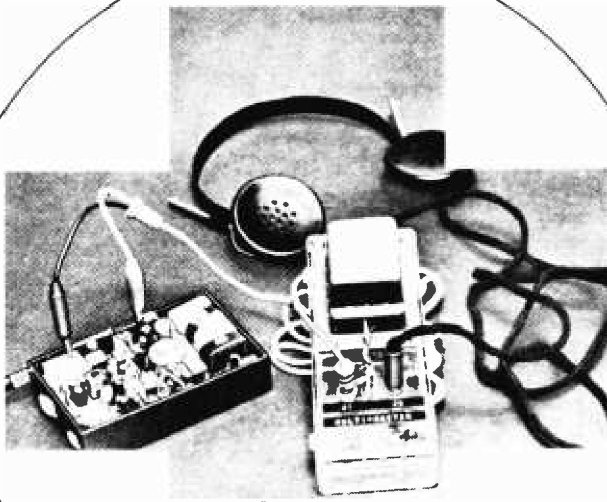
A 9-volt zener diode could be used instead of battery *B5*, but the diode would draw some current (about 4 or 5 mA) and reduce efficiency. The use of a bias battery provides better regulation at low values of collector voltage. This battery also goes to work when the power source drops down to 9 volts. As the collector voltage approaches the base voltage, the base-emitter junction—acting as a diode —lets current from *B5* get to the load and effectively places *B5* in parallel with the voltage source across the load.

Resistor *R1* preserves *B5* in a unique manner. During the useful life of the power source, a small current flows through *R1* which is available for base current and, if necessary, to charge *B5*. The result is that *B5* supplies almost no current until the power source approaches 9 volts; when the power source is 9 volts, each individual battery (*B1, B2, B3,* and *B4*) is down to 4.5 volts. It should now be evident that the output voltage will remain at 9 volts during the entire lifetime of the batteries, and then some.

Of course, the circuit would work the same way if only two batteries, say *B1* and *B2,* were used for the power source. However, this modification would require more frequent replacement of batteries. Standard 9-volt transistor radio batteries are used because they are readily available and they fit into a small case.

Construction. Almost any type of container that will hold the five 9-volt batteries can be converted for use as a "cabinet." The "unbreakable" soap dish (see p. 105) is just the right size for the job and looks clean. Both the transistor and the d.p.d.t. switch (*S1*) are mounted on the side of the soap dish. Wiring is straightforward and not critical, but pay close attention to polarity when interconnecting the batteries and output leads to the radio or other load. The output leads should be long enough

(*Continued on page* 145)



BUILD THE "Multi-Master"

By GARRY BOROSS

SOLID-STATE MULTIVIBRATOR MODULE MAKES MANY-PURPOSE TESTER

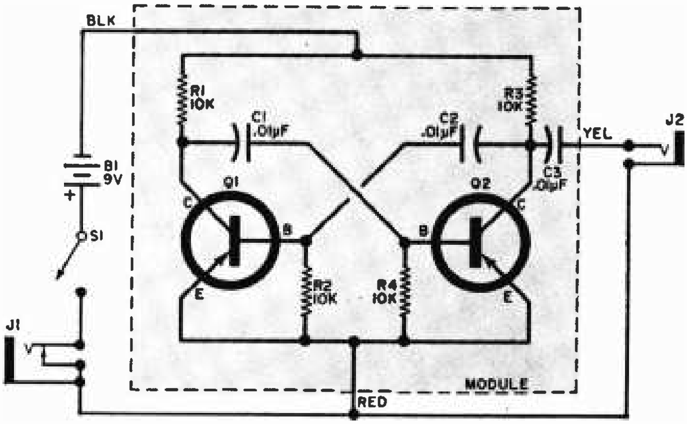
THE "MULTI-MASTER" generates a 1000-Hz tone and, because it is richly endowed with harmonics, can be used to troubleshoot a.f., i.f., and r.f. circuits in much the same way as a regular servicing-type signal generator—yet it weighs only a few ounces and needs no external power source. It can also be used as a code practice oscillator and to check continuity of components and circuits.

Low cost (less than $5) and short construction time (about an hour) are possible because all you need to do is connect a few easily obtained parts to a preassembled module. Current drain is only about 2 milliamps from a 9-volt source, which makes the "Multi-Master" as portable as a small transistor radio.

How It Works. The preassembled module consists of a free-running multivibrator and an output coupling capacitor, as shown inside the dotted lines on the schematic diagram. When *S1* is closed, power is applied to the multivibrator from *B1*. Transistors *Q1* and *Q2* fire alternately, setting up a symmetrical square-wave signal. The time constants of *C1*, *R4* and *C2*, *R2*, as well as the applied battery voltage, determine the frequency of operation. The signal across *R3* is coupled to jack *J2* through *C3*.

Construction. You do not have to use a commercial module for this project; just about any pair of *pnp* transistors can be used to build your own. If you would rather work with *npn* transistors, you can; simply reverse the battery leads. But you may find it more convenient to use the preassembled module.

Choose any metal or plastic box large



Parts inside the preassembled module are arranged to form a multivibrator oscillator circuit. Oscillator frequency is determined by C1, C2, R2 and R4.

PARTS LIST

B1—9-volt battery
*C1, C2, C3—0.01-µF disc capacitor**
J1—Closed-circuit phone jack, miniature-type
J2—Open-circuit phone jack, miniature-type
*Q1, Q2—See text**
*R1, R2, R3, R4—10,000-ohm, ½-watt resistor**
S1—S.p.s.t. switch
Misc.—High-impedance headphones, with miniature phone plug; test leads, with miniature phone plug; battery clip; solder; etc.

*Parts preassembled on module. (Module is available under different trade names and model numbers from numerous electronics distributors. Check your catalogs for prices.)

enough to hold the small 9-volt battery and the module. You can mount the module on the outside of the box, and connect its three color-coded leads as shown in the schematic.

A pair of regular test leads can be terminated in a single miniature plug to fit *J1* or *J2*. The cord from a pair of headphones can also be terminated in a similar plug to go into *J2*.

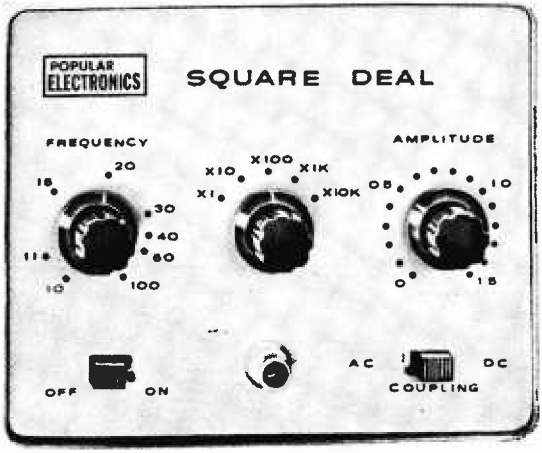
Operation. To use the Multi-Master as a signal injector, turn it on, and plug the test leads into *J2*. Connect the leads to appropriate check points on the equipment to be tested, and listen. Proceed in the same way as you would with a full-fledged service-type signal generator to find your trouble.

For checking continuity of components, remove the test cable from *J2* and plug it into *J1*, and plug your headphones into *J2*. Momentarily touch the test leads' alligator clips together; you should hear a clear tone in the headphones. Separate the clips, and connect them across the circuit or component under test. If there is continuity, you will hear the tone. If there is resistance, there will be a change in the tone's pitch—the higher the resistance, the higher the pitch. Resistors up to 10,000 ohms can be checked for "continuity" in this manner.

Capacitors can be checked in this way, too; but it takes a little experience to recognize normal and abnormal conditions. Depending on the value of the capacitor, you should hear silence for small values—or a click, or chirp which soon disappears in a rising tone for larger values. A steady low-pitch tone usually indicates a shorted capacitor.

Checking diodes and transistors is simply a matter of testing for "front-to-back" tones. As you reverse the leads, you should hear one tone one time, and a different tone another time. If you don't hear a tone when the leads are in one of the two positions, it can be a normal indication; but if no tone is heard in either direction, the component is open.

To use the Multi-Master as a code practice oscillator, connect a telegraph key to the test cable and plug the cable into *J1*, then plug the headphones into *J2*. If you prefer to listen to your code practice without headphones, simply plug a loopstick antenna into *J2*, and tune an AM radio to a blank spot on the band and adjust the volume. —30—



"SQUARE DEAL" AUDIO GENERATOR

PROFESSIONAL-TYPE TEST EQUIPMENT FROM INEXPENSIVE INTEGRATED CIRCUITS

By DON LANCASTER

LOOKING for a good audio generator? Here's a portable space-age, transformerless, integrated-circuit instrument with performance features not found even in commercial test gear. The *Square Deal* puts out symmetrical, high-rise-time square waves ranging in amplitude from 0 to 2.5 volts and in frequency from 10 Hz to 1 MHz. The output signal can be a.c.- or d.c.-coupled to equipment being tested, timed, triggered, or sounded.

Signal frequency is entirely independent of output loading; you can drive a speaker directly, or place a dead short across the output without "phasing" this project. You can use the *Square Deal* for general-purpose audio work—to make tone and hearing studies, and to test amplifiers and speakers. Add a phone jack and a speaker, and you'll come up with a code practice oscillator that is loud enough for group practice. And if you want to use the *Square Deal* as a remote annunciator, or as the heart of a burglar alarm, you can.

It will also serve as an oscilloscope calibrator to give you time and amplitude references accurate enough for practically all experimental purposes. When used with a scope, it easily reveals such dynamic amplifier characteristics as frequency response, damping, overshoot, ringing, and phase distortion. You'll also find it handy for digital logic experiments and demonstrations where you need a d.c.-coupled trigger source.

Best of all, the *Square Deal* is unexcelled for field operation; you can use it to check out those tricky mobile or marine installations. Only two D-size flashlight batteries will power the unit continuously for 40 hours or more.

Inside the case you'll find $2.30 worth of semiconductors and a special $2 potentiometer in a simple circuit easily put together in a few hours. Depending upon how fancy you get, and the parts you have on hand, your parts cost will run from $6 to $18. A professional pre-calibrated and imprinted aluminum front panel is available. (See Parts List.)

How It Works. Two of the four transistors "housed" in an integrated circuit (*IC1*), no larger than a few match heads, are hooked up in an astable multivibrator circuit that puts out a good, clean square wave which is direct-coupled to *Q1,* as shown in Fig. 1. Transistor *Q1*, hooked up as an emitter follower, serves as a buffer to prevent output loading conditions from affecting the oscillator frequency.

The signal from *Q1* is direct-coupled to the base of transistors *C* and *E* in *IC2,* where it is further isolated from the oscillator. Transistor *C* reverses the phase of the signal and passes it on to transistor *D*. Transistors *D* and *E* drive the load in a push-push manner. Operation is similar to a push-pull class B amplifier, but a push-push circuit is single-ended. The output signal appears across

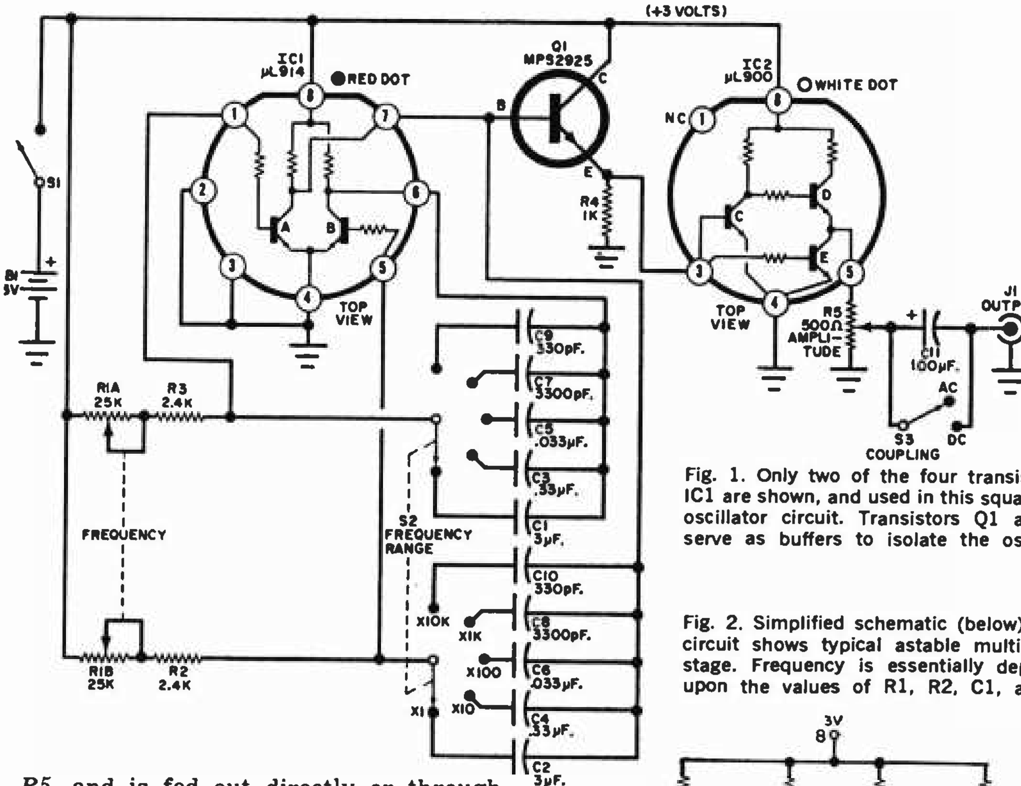
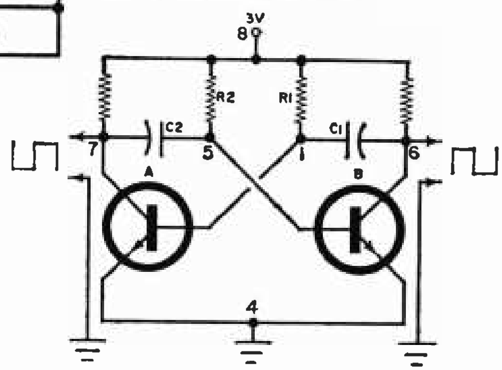


Fig. 1. Only two of the four transistors in IC1 are shown, and used in this square-wave oscillator circuit. Transistors Q1 and IC2 serve as buffers to isolate the oscillator.

Fig. 2. Simplified schematic (below) of IC1 circuit shows typical astable multivibrator stage. Frequency is essentially dependent upon the values of R1, R2, C1, and C2.



R5, and is fed out directly or through coupling capacitor *C11*, depending upon the position of *S3*. Integrated circuit *IC2* contains the equivalent of three transistors and five resistors.

Figure 2 is a simplified drawing of the multivibrator and some of the waveforms it generates. The multivibrator is free-running and does not require an external signal. When transistor *A* is conducting, transistor *B* is cut off, and when transistor *B* is conducting, transistor *A* is cut off.

The signals at the collectors of transistors *A* and *B* are identical, but of opposite polarity, as shown at terminals 6 and 7. Capacitors *C1*, *C3*, *C5*, *C7*, and *C9* in the project are represented by *C1* in the simplified drawing, and *C2*, *C4*, *C6*, *C8*, and *C10* are represented by *C2*. The length of time each transistor remains in the off state is a function of the values of *C1* and *R1* (for transistor *A*), and *C2* and *R2* (for transistor *B*). Because the values of the components are the same in both transistor circuits, the output waveform is symmetrical.

To change the repetition rate or frequency of operation, simply change the values of either or both of the capacitors or the resistors. In the actual circuit, capacitors *C1* through *C10* provide different frequency ranges in five decade steps from *X 1* to *X 10,000*, and the ganged potentiometer (*R1a* and *R1b*) provides a continuously variable selection of frequencies within each range.

Construction. Almost any type of chassis construction can be used to assemble the *Square Deal*. A deep-drawn aluminum case and a homemade aluminum chassis are shown in the photos. The chassis is a 10″ x 6⅜″ x 3/64″ piece of aluminum, cut, bent, and drilled as shown in Fig. 3.

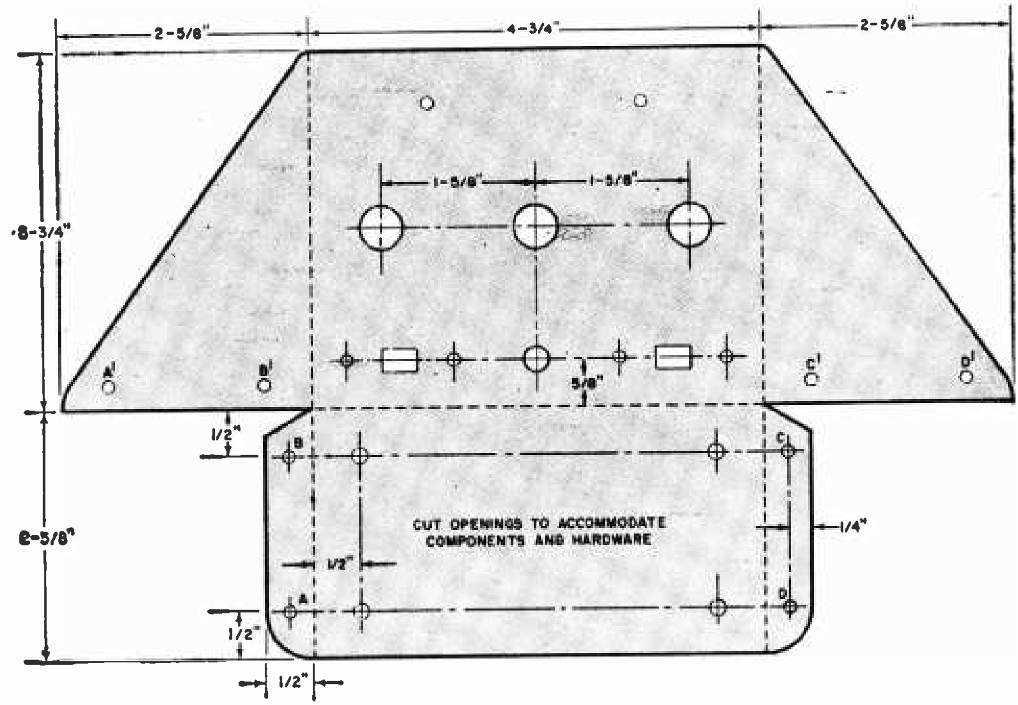


Fig. 3. Chassis can be formed from a thin piece of sheet aluminum. Drill and shape to size as shown.

Layout is not critical. If you get the ready-made front panel, you can use it to locate the holes on the front of the chassis. Pop rivets, or 6-32 x ⅜″ machine screws and nuts can be used to hold things together. A 4½″ x 1½″ x ⅛″ piece of aluminum is used as a spacer to "pull" back the controls so that the control knobs will fit closer to the panel, but you can mount an extra nut on the bushings before installing the controls, and adjust the nuts to obtain the proper spacing.

If you wish to conceal the screw heads or rivets that hold the terminal strip and switches in place, you will have to

PARTS LIST

B1—Two 1.5-volt, D-size cells
C1, C2—3-μF, 6-volt electrolytic or Mylar capacitor
C3, C4—0.33-μF, 100-volt Mylar capacitor
C5, C6—0.033-μF, 100-volt Mylar capacitor
C7, C8—3300-pF mica or polystyrene capacitor, any working voltage
C9, C10—330-pF mica or polystyrene capacitor, any working voltage
C11—100-μF, 6-volt electrolytic capacitor
IC1—μL914 epoxy micrologic dual two-input gate (Fairchild)*
IC2—μL900 epoxy micrologic buffer (Fairchild)*
J1—Phono jack (RCA type)
Q1—MPS2925 transistor (Motorola, or any npn silicon unit)
R1—Dual 25,000-ohm carbon potentiometer, linear taper (similar to IRC 45-D253-MD253)
R2, R3—2400-ohm, ½-watt resistor
R4—1000-ohm, ½-watt resistor
R5—500-ohm, ½-watt potentiometer, linear taper
S1, S3—S.p.s.t. slide switch
S2—Two-pole, five-position, rotary switch, non-shorting type (similar to Mallory 2236J)
1—3″ x 4″ x 5″ case (similar to Zero Z64-80A-48 or Bud Minibox CU-2105A)
1—10″ x 6⅜″ piece of 3/64″ aluminum stock
1—1½″ x 4½″ piece of ⅛″ aluminum stock (optional—see text)
1—Front panel (an anodized hard-aluminum METAL-PHOTO dialplate is available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014; in silver color for $2.75; in red, or copper for $3.25, postpaid in USA)
Misc.—Insulated Teflon standoffs (16) optional; 5-lug terminal strip; battery holder for 2 D-size cells; small knobs (3); nylon cup washers for feet (4), wire, solder, spacers, screws, etc.

*Appropriate data sheets and distributor lists are available from Fairchild Semiconductors, 313 Fairchild Dr., Mountain View, Calif., and Motorola Semiconductor, P.O. Box 955, Phoenix, Ariz. 85001

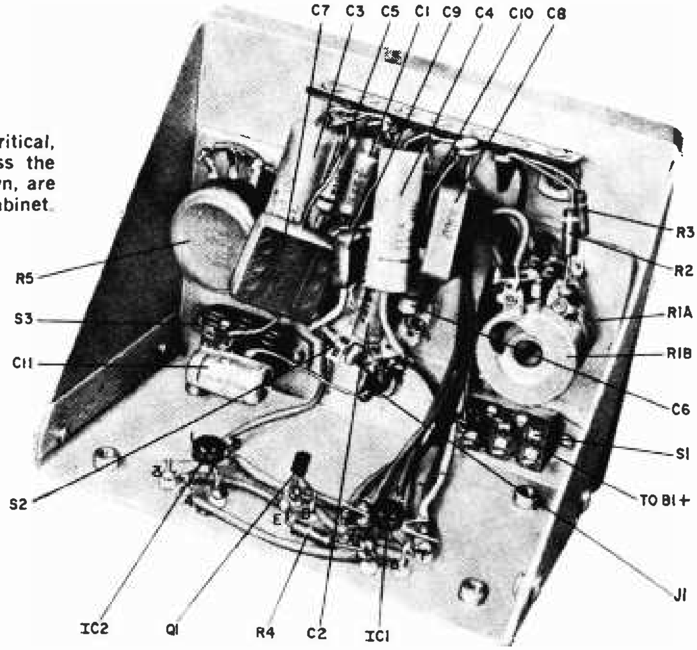


Fig. 4. Layout of parts is not critical, but be careful not to crisscross the connections. Batteries, not shown, are mounted on the back of the cabinet.

indent (dimple) the chassis sufficiently to clear the panel. Use flat-headed machine screws and countersink the holes if you are not equipped to do a good dimpling job. It's worth the extra effort . . . the front panel will lie flat, hide the hardware, and will provide you with a neat, professional-looking instrument.

Temporarily place the chassis inside the cabinet and drill four holes through the bottom of the cabinet and the chassis to accommodate suitable protective feet; nylon cup washers can be used. By drilling the cabinet and the chassis at the same time, you simplify hole alignment when the job is completed. You can use self-tapping screws, or install threaded rivet-on spacers on the chassis. Either way, the size of the holes should be appropriate for the hardware used. The screws that hold the feet in place also hold the cabinet and chassis together.

Mount a two-cell flashlight battery holder on the back of the cabinet in any convenient manner, but be alert to any clearance problems that may arise when the components are installed. Press-fit terminals, sockets, or a perforated board can be used to hold the transistor and the integrated circuits—modify the chassis to accommodate your fittings. Note: the flat, or color dot, on the integrated components identifies terminal 8; the other terminals are numbered counterclockwise when you're looking at them from the top of the epoxy case. The IC's are not interchangeable.

Rotary switch *S2* and a five-lug terminal strip anchor the capacitors. Be particularly careful not to confuse the circuit by wiring *S2* or *R1* to *IC1* improperly. If your project fails to operate, there's a good chance that you crossed the wires to these components. Follow the schematic and you won't have any trouble.

Instrument accuracy depends upon proper values of *C1* through *C10*. Without a special selection, you'll probably wind up with a full-scale accuracy of about ±15%. You can improve this figure by making a careful selection of capacitors. The *AMPLITUDE* scale is relative, and depends upon output loading and battery conditions.

Do not allow the instrument's output circuit to come across any external voltage while in the *DC* position, nor more than the rated voltage of *C11* while in the *AC* position. If you must couple into higher voltage ridden circuits, insert a suitable capacitor in series with *J1*.

Operation. There is a slight difference between *AC* and *DC* outputs. In the *DC* position, the signal is direct-coupled, and the square wave is clamped to the instrument's ground (0 volt). In the *AC* position, the signal is made to pass through a capacitor (*C11*), and the d.c. component is lost. There is as much signal above the zero-reference line as there is below it. In either case, the peak-to-peak voltage is the same.

If the d.c. component is not needed for your application, take advantage of the built-in coupling capacitor—it serves as a d.c. block, and minimizes upsetting voltage and resistance conditions in the input circuits of the equipment being worked by the *Square Deal,* as well as in the instrument's own output circuit. Audio equipment, amplifiers, speakers, etc., can be driven from the *AC* position. For logic experiments, counter circuits, and other pulse circuits, you will most likely use the *DC* position.

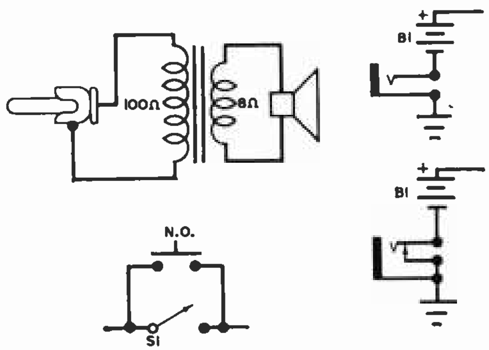


Fig. 5. Simple modifications you can make to extend the utility of the "Square Deal." See text below.

Modifications. If you add a phone jack in series with the battery, you can turn the multivibrator on and off with almost any switching device, for use in a code practice rig, annunciator, burglar alarm, or to make tone-burst tests (see Fig. 5). If you use a non-shorting type jack, the circuit will work only when the key, switch, thermostat, etc., is plugged in and completes the circuit. However, if a shorting-type jack is used, the circuit will work both ways.

Of course, you will have to plug a speaker or a set of headphones into *J1* to be able to hear the signal. Speaker volume can be increased by the use of a matching transformer. If the output of the instrument is allowed to "look" into, say, a 50-ohm load instead of an 8-ohm load, its amplitude will be significantly greater. You can use a multitapped transformer such as Stancor's TA39 for this purpose. -30-

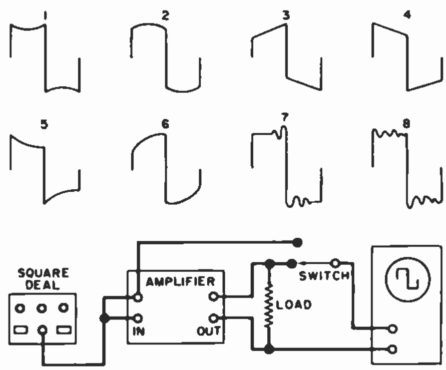
TESTING WITH SQUARE WAVES

A rapid indication of frequency response can be obtained by using two test frequencies; one low enough to reveal low frequency response and phase shift, and one high enough for some of the harmonics in the square wave to reach the upper limits of the amplifier under test. Other characteristics such as ringing or parasitics, damping, phase shift, and transient response can be determined.

Frequency response ranging from 1/10 to 10 times the fundamental frequency of the square wave can be predicted in one "shot." For example, if a 1000-Hz square wave is passed through the amplifier without distortion, the frequency response is at least 100 Hz to 10,000 Hz. To check the scope, to see that it does not distort the waveform, connect the scope directly to the generator. If the scope distorts the waveform, you can overcome this shortcoming by feeding the signal directly to the vertical deflection plates of the CRT.

An easy way to interpret the waveforms is to look for tilt and curvature. Tilt is primarily an indication of phase shift of the fundamental frequency. Square-wave testing for phase shift is quite sensitive. A 10% slope represents about a 2° phase shift. Curvature shows frequency response; a convex shape indicates good lows, a concave shape shows loss of lows. It is not unusual for the waveform to show both tilt and curvature.

Ringing is a piggyback oscillation (parasitic) sometimes caused by overboost of highs or other resonant conditions in the circuit. Not all ringing is parasitic. Some circuits, such as the horizontal deflection stage in a TV set, purposely set up a ringing condition. Damping is simply the ability of the amplifier to suppress ringing when it does occur.



Basic waveforms. Ideal shape is shown on scope. Other shapes are: (1) loss of lows; (2) boosted lows; (3) low-frequency phase lag; (4) low-frequency phase lead; (5) combination of loss of lows and phase shift; (6) combination of loss of highs and phase shift; (7) ringing, with good damping; and (8) ringing, with poor damping.

BUILD THE VOM RANGE SPLITTER

DOUBLE THE NUMBER OF VOLTAGE RANGES ON YOUR MULTIMETER FOR GREATER VERSATILITY AND UTILITY

By JULIAN ROSSNICK

FOR REASONS OF economy or size limitation, some multimeters do not have a sufficient number of voltage ranges for the test work on hand. While the four to six ranges available on most meters are sufficient for most jobs, there are times when additional or intermediate ranges are more convenient and more accurate.

When a voltage just about swings the meter's pointer beyond the maximum point on the scale on a given range, you must use the next higher range, and wind up in the lower portion of the dial. When the pointer falls in the lower third of the meter's scale, a greater amount of meter error is likely to be encountered. An "in-between" voltage range could overcome this problem.

Practical in-between ranges can be obtained with the Voltage Range Splitter (VRS), and without any internal changes of the meter.

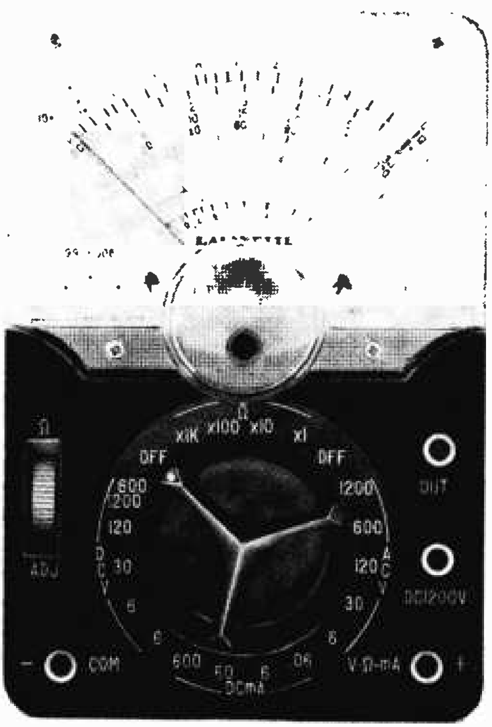


Fig. 1. Little variation exists among average VOM's as to number of voltage ranges available, but you can add in-between ranges when needed with VRS.

How It's Done. The project is as simple as it is practical, requiring only one additional resistor for each range you want to add. All you need to know to determine the value of each resistor is the meter sensitivity and the desired extension of an existing range. You multiply these two figures to get the value needed.

For example, suppose you want to read up to 12 volts on an existing 6-volt range, and the meter sensitivity is 20,000 ohms/volt. The resistor value needed is 120,000 ohms (6 × 20,000). Notice that the input resistance to the meter for the new 12-volt range is doubled (from 120,000 ohms to 240,000 ohms), and a significant benefit can be derived by the use of the higher range, even to read as little as 4 or 5 volts, especially if this voltage is across a high impedance.

Plan your new ranges, if possible, so that they are compatible with the meter dial markings. If your meter has the same scales as the meter shown in Fig. 1, the 6-volt range can be extended to 12 volts, and the 120-volt scale markings

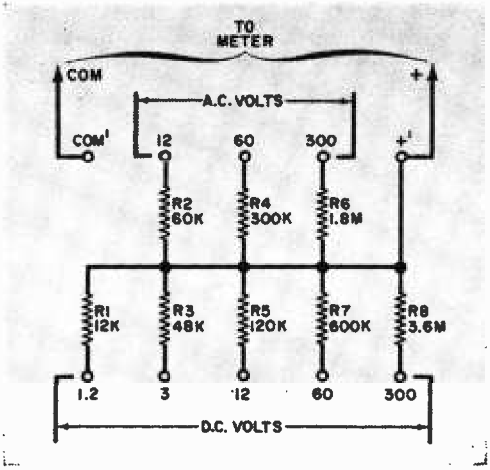


Fig. 2. Values shown are for meter sensitivity ratings of 10,000 ohms/volt on a.c. and 20,000 ohms/volt on d.c. For other meter ratings, see text.

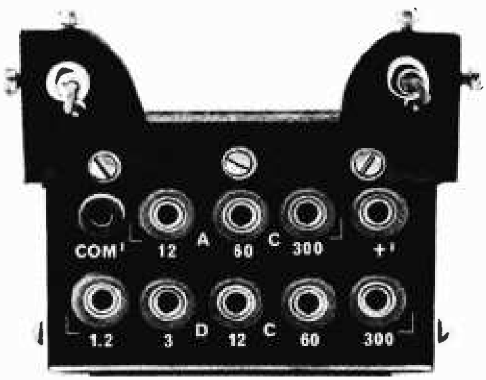


Fig. 3. Mount the jacks for d.c. voltage in lower portion of a piece of Bakelite; jacks for COM', +' and a.c. voltage can be mounted in upper portion.

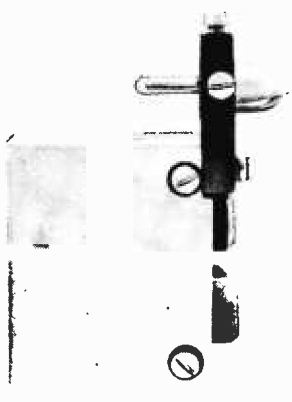


Fig. 4. The two plugs going directly to the meter are held in place by machine screws. Drill and tap the screw holes at right angles to each other.

PARTS LIST

R1—12,000 ohms
R2—60,000 ohms
R3—48,000 ohms
R4—300,000 ohms
R5—120,000 ohms
R6—1.8 megohms
R7—600,000 ohms
R8—3.6 megohms
(*All resistors ½-watt*)
Misc.—Five-way binding posts or jacks (10); test lead plugs, compatible with meter jacks (2); 5-lug terminal strips (2); small metal box

used to read out the 12-volt scale; just drop the zero. Similarly, the 30-volt range can be extended to 60 volts and the 6-volt scale read; this time, add a zero.

Construction. In order not to compromise the portability feature of your meter, build the VRS in a small metal box. The size of the box depends on the dimensions of your meter—or it can be quite a bit larger if you don't want to mount the VRS directly on your meter. In either case, the jacks or binding posts should be mounted on a piece of Bakelite or fiberboard or other insulating material.

Drill two holes large enough to pass the plugs on the back end of a pair of test leads to connect the VRS to the meter. Then drill and tap two machine screw holes at right angles to hold the plugs in place.

Mount the resistors between two terminal strips, in accordance with the schematic. Since no part of the metal case should come in contact with any part of the circuit, the terminal strips' mounting lugs should not be connected to any of the terminals. Notice that one end of each resistor is connected to a common bus, which is connected to the +' jack and lead. Now plug the VRS into the meter.

Operation. The resistor values shown in Fig. 2 are for a VOM rated at 20,000 ohms/volt for d.c., and 10,000 ohms/volt for a.c. meter functions. With the VRS plugged into the multimeter and the test leads plugged into the appropriate *COM'* and +' on the VRS, you can use the meter to measure a.c. or d.c. voltages in the normal manner.

(*Continued on page* 153)

CHAPTER

5

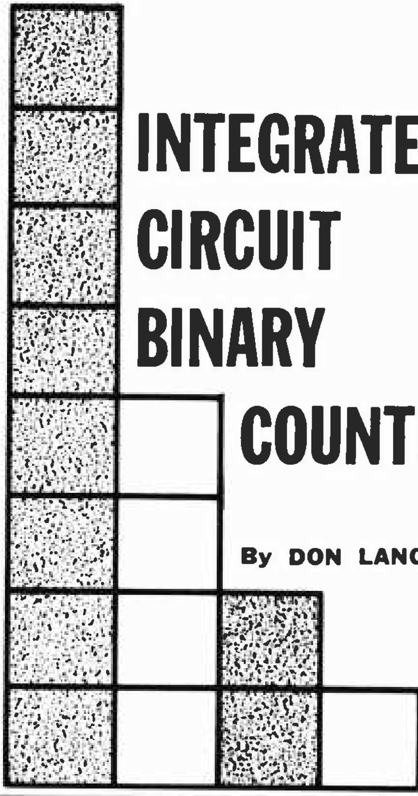
SCIENCE FAIR PROJECTS

It probably all started with the launching of the first Soviet Sputnik in 1957, when Americans began taking a serious interest in science teaching in their local high schools. In any case, almost overnight, the Science Fair blossomed into an important event in each school year. Participation soared and the demand for novel projects by high school students reached astonishing proportions in the early sixties and is still going strong in 1968.

The first edition of this HANDBOOK contained little of particular interest to the Science Fair audience. But the same cannot be said for the present edition, with its variety of attention-getting projects that readily serve a dual purpose: they demonstrate certain electronic theories and also permit the builder to use his initiative in project construction.

WANT TO BUILD AN

INTEGRATED CIRCUIT BINARY COUNTER?



By DON LANCASTER

10 = 1 0 1 0

COUNTING IN THE BINARY SYSTEM IS SIMPLE: YOU START WITH "ZERO, ONE" . . . AND YOU'VE USED UP ALL OF THE BINARY DIGITS

NOW you can build a demonstration binary counter using inexpensive integrated circuit (IC) industrial flip-flops with ordinary pilot lamps serving as readout devices. The binary counter described on the following pages can be used to demonstrate basic digital computer principles including the addition of binary digits. It also provides an opportunity to utilize integrated circuits for storing binary information.

In order to use the binary counter, however, you must understand the concepts of binary arithmetic. Most of us are familiar with the decimal number system which needs just 10 symbols—digits 1 through 9, and 0—to express any quantity. And while some earlier computers did use this system for computing, the complexity of the circuits dictated the need for a simpler system, one requiring fewer digits. So a number system using two digits only—1 and 0—was devised: the binary (base-2) number system.

Binary Number System. To learn how the binary (base-2) system works, consider Fig. 1 in which four groups of blocks are shown. The first one-block on the right is preceded by a group containing two blocks, which is preceded by a group containing four blocks, preceded by an eight-block group.

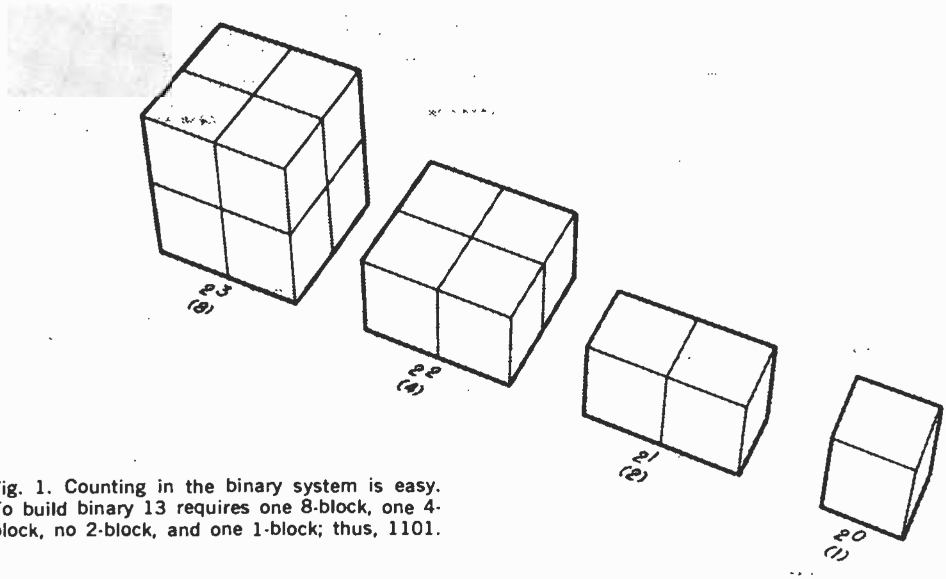


Fig. 1. Counting in the binary system is easy. To build binary 13 requires one 8-block, one 4-block, no 2-block, and one 1-block; thus, 1101.

Now, since we are working with a base-2 number system, we could change things a bit by writing the same group of blocks in this order: 2^3, 2^2, 2^1, 2^0. The superscript numerals (3, 2, 1, and 0) are referred to as the powers of the base number which, in this case, is 2. The power of a base tells the number of times the base must be multiplied by itself or, putting it another way, the power to which it is raised. For example, $2^3 = 2 \times 2 \times 2 = 8$. The mathematicians tell us that a number raised to its 0 power is 1; thus, 2^0 becomes 1. But we can also write: 8, 4, 2, 1 to represent the blocks.

To express 3 in the binary system, we need *no* 8 block, *no* 4 block, *one* 2 block, and *one* 1 block. In binary notation this is written as 0011. Similarly, the number 10 is written as 1010. And that is all there is to the binary number system.

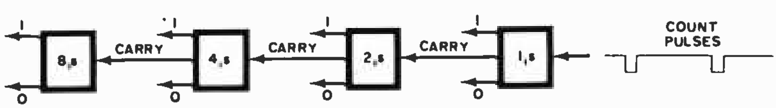
The convenience of this system is immediately apparent, considering that any number in the decimal system can be converted to a series of 1's and 0's. Thus, to "write" a number on a punched card, you either have a hole or no hole —a 1 or a 0. Putting it another way, a YES or a NO. If lights are used as a readout device, it could be established that if the lamp lights it means a 1, and if it doesn't, it means a 0.

Binary Addition. Adding 5 and 3 gives us 8 in the binary system just as it does in the decimal system, except that the numerical process is different. The following decimal-to-binary conversion table will save you some time in working out a few examples of binary addition.

DECIMAL NUMBER	BINARY NUMBER
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111
8	1000

Three basic rules govern binary addition: (1) 0 plus 0 equals 0; (2) 1 plus 0 equals 1; and (3) 1 plus 1 equals 0 with a 1 carry to the next left-hand column. Applying these rules to the sample problem 5 + 3 will give you

Fig. 2. Four-stage flip-flop has counting limit of 15. Adding stages increases count capacity.



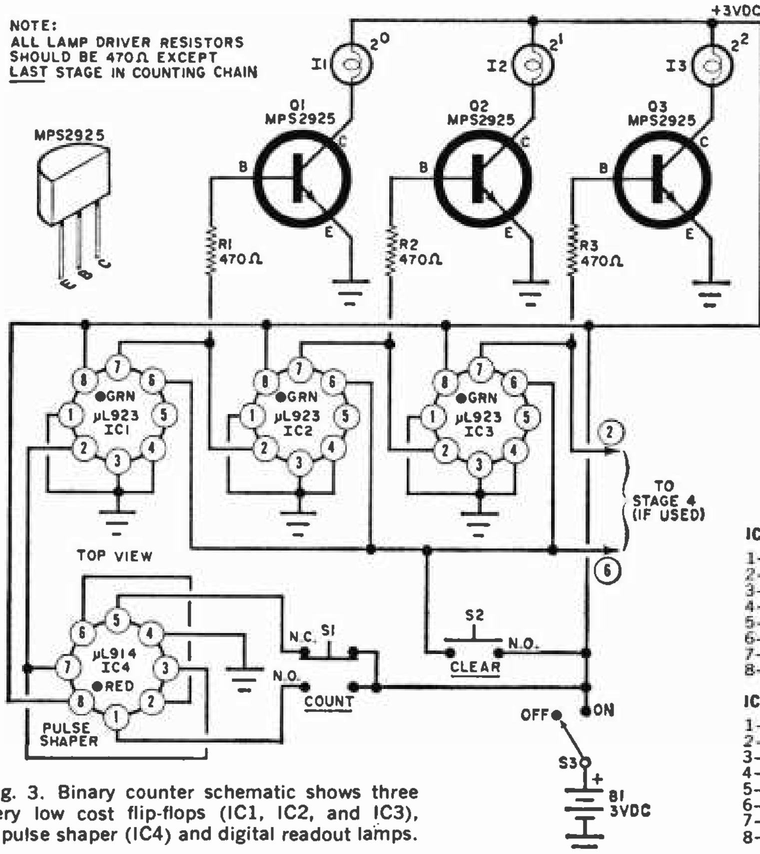


Fig. 3. Binary counter schematic shows three very low cost flip-flops (IC1, IC2, and IC3), a pulse shaper (IC4) and digital readout lamps.

IC μL914 IDENTIFICATION

1—Gate A, Input 1
2—Gate A, Input 2
3—Gate B, Input 1
4—Common
5—Gate B, Input 2
6—Gate B, Output
7—Gate A, Output
8—Vcc + 3 Volts D.C.

IC μ923 IDENTIFICATION

1—Set Input (Gnd.)
2—Count Input
3—Reset Input (Gnd.)
4—Common
5—Not used
6—Clear Input
7—Output
8—Vcc + 3 Volts D.C.

PARTS LIST

B1—1.5-volt, C-size cells (2)
I1, I2, I3 —#49 pilot light (2.0-volt, 60-mA)
IC1, IC2, IC3 —μL923 epoxy JK flip-flop (Fairchild)*
IC4—μL914 dual two-input gate (Fairchild)*
Q1, Q2, Q3—MPS2925 transistor (Motorola)
R1, R2—470-ohm, ¼-watt resistor
R3—1000-ohm, ¼-watt resistor—see text
S1—S.p.d.t. push-button switch
S2—S.p.s.t. push-button switch
S3—S.p.s.t. slide switch
1—6" x 4½" x 1¼" aluminum box with cover (Zero Z64-104A-20 and Z64-104A-COT-5) or 5" x 7" x 2" box chassis (Bud AC-402)
1—METALPHOTO dialplate, hard anodized aluminum, with POPULAR ELECTRONICS trademark, available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014; in silver color for $2.75; red or copper for $3.25; postpaid in U.S.
1—2" x 3" sheet of aluminum or perforated phenolic board
1—1⅛"-diameter aluminum disc (optional)
Misc.—Teflon insulated terminals (52, optional), insulated feedthroughs (4, optional); battery holder for two C-size cells, ½"-o.d. rubber grommets (3), pop rivets or #6 hardware, 6-32 x ⅜" threaded spacers (4), rubber feet (4), wire, solder, #6 mounting screws (4)

$$\begin{array}{r} 101 \\ +\ 011 \\ \hline =1000 \end{array}$$

To define the above addition, starting with the right-hand column you have 1 + 1 = 0 with a carry of 1. Place the carry above the second column so that it now contains 1, 0, and 1. Thus, the second column is also 0 with a 1 carry. The carry added to the third column also produces a 0 with a 1 carry. Since there is no fourth column in the problem, the carry is brought down as the fourth or most significant digit of the sum. The answer then becomes 1000 or 8.

When adding more than two binary numbers to produce a single sum, the numbers should be added in pairs. In other words, the sum of the first two

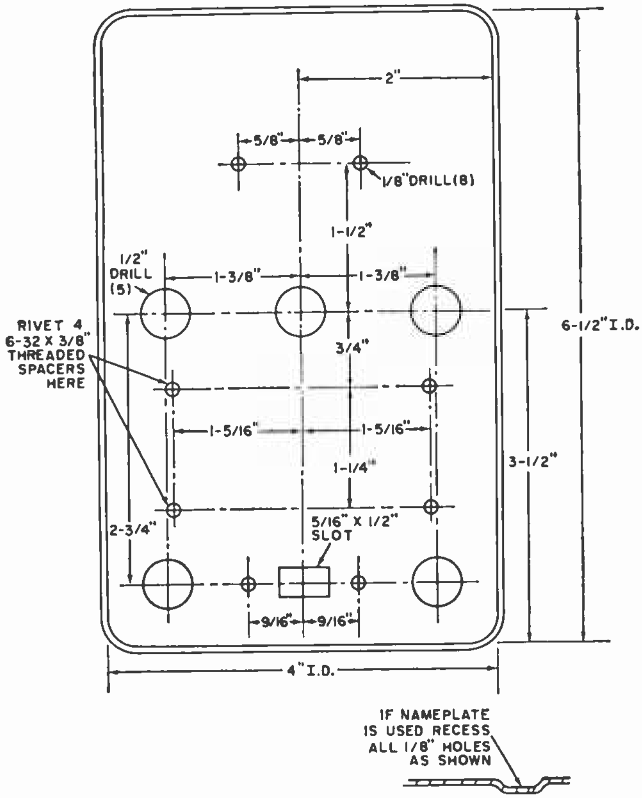


Fig. 4. You can use these dimensions to duplicate the front cover layout. Hole sizes should be made to accommodate your hardware and fittings.

numbers is added to the third number. The fourth number is then added and so forth until the last number is added to the sum of the previous two numbers to produce the total sum.

Electronic Counters. The essential difference between an electronic counter and earlier counters with mechanical wheels is that the electronic counters add pulses instead of gear teeth. But in addition to its ability to add, a counter must also have a way of storing the discrete digits representing the numbers.

A decimal counter, for example, must be able to store ten counts—0 through 9—before the next count resets the counter to 0 with a 1 carry. Similarly, a binary counter is required to store only two counts—1 and 0—before it is reset. The electronic circuit used for counting is a simple flip-flop with its "set" state representing a 1, and its "reset" representing a 0.

The block diagram of a four-stage flip-

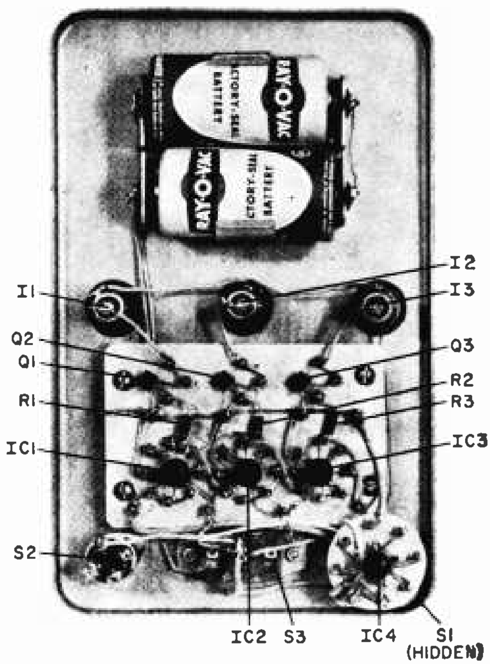


Fig. 5. The flip-flop IC's, and transistors and resistors, are first mounted on a subassembly supported on standoff spacers. IC4, shown on an aluminum disc, is supported by the push-button COUNT switch (S1).

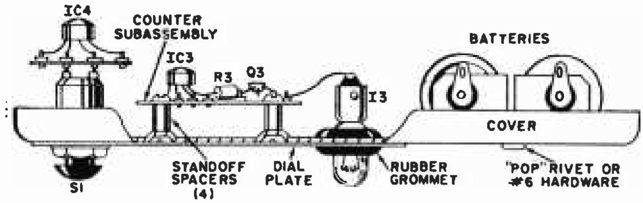


Fig. 6. This cutaway view of the front cover shows how the subassembly is mounted on the spacers. Observe that the mounting screw holes are recessed a bit so the dialplate can lay flat on the cover assembly.

flop binary counter that provides a count of up to 15 is shown in Fig. 2. Additional stages can be added to increase the count limits. For example, if one more stage is added, the count is increased to 31, while adding two more stages increases the count to 63.

During operation, pulses are applied to the count input of the 1's stage. A carry output from this stage is passed on to the count input of the 2's stage, and so on down the line to the last stage. With each incoming pulse, the 1's counter is alternately set to one, then reset to 0, set to 1 again, and so on.

The 2's counter also alternates between 1 and 0 each time it receives a count, but this happens only during every other input pulse when the 1's counter develops a carry signal. This process continues to activate each counter up to the last pulse in the string.

The IC Counter. Figure 3 shows the schematic of the IC counter. The innards of *IC1-4* have been deliberately left out to simplify matters. *IC1*, *IC2*, and *IC3* are the counting flip-flops, while *IC4* is a medium-power dual two-input resistor-transistor logic gate serving as a pulse shaper to eliminate the effects of contact bounce when the *COUNT* push button (*S1*) is pressed to produce the count pulses.

The modified output from the pulse shaper is applied to the count input of first counter stage *IC1*. The output of *IC1* is applied to the count input of *IC2*, whose output in turn is applied to *IC3*. Indicator lamps *I1* through *I3*, driven by *Q1* through *Q3*, visually denote the presence or absence of a 1 in each counting circuit. When a flip-flop circuit goes into its 1 state, a positive voltage is applied to the base of its respective output transistor through the proper base resistor (*R1*, *R2* or *R3*). The voltage causes the transistor to conduct, lighting the lamp.

CLEAR switch *S2* provides immediate reset capabilities by simultaneously applying a "1" pulse to the *CLEAR* input of each counter, resetting it to the 0 state.

Construction. The binary counter can be assembled in any small metal, wood, or plastic container. It is shown assembled in a 6" x 4½" x 1¼" aluminum box. A prefabricated METALPHOTO dialplate (see Parts List) can be put on the container cover to give the project a professional appearance. Layout and dimensions for drilling the cover are shown in Fig. 4. You can, however, lay out the counter differently, if you wish, since neither parts arrangement nor lead dress will affect operation of the unit.

Use a low-wattage soldering iron when assembling the unit to minimize the possibility of overheating and destroying the transistors and IC's. For ease of assembly, the IC's and transistor circuitry can be preassembled on a 2" x 3" aluminum plate, or phenolic circuit board. Then the plate or circuit board can be mounted on standoffs in the container cover. Interconnection is made from the preassembled circuit board to the readout lamps, push-button switches, and supply battery.

The IC's and the transistors can be mounted on insulated Teflon press-fit terminals as shown in the layout of Fig. 5, or on "flea" clips (push-in terminals) if a perforated phenolic board is used.

The IC packages are coded by a flat side or a green or red dot indicating pin 8. When viewed from the top, the pins are counted counterclockwise.

Figure 5 shows *IC4* mounted directly on one of the push buttons by means of a circular plate with feedthrough terminals, but you may find it more convenient to mount *IC4* on the same circuit board with the other units.

Switch *S3* and the battery holder can

(*Continued on page* 150)

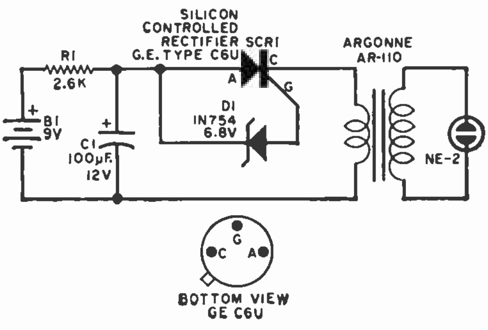
A LIGHTHOUSE FOR SHORT PEOPLE

By RUSSELL J. BIK

WHAT IS THAT?
IT'S A FLASHING LIGHT
YES, BUT WHY DOES IT FLASH?
SO YOU CAN FIND IT WHEN YOU LOSE IT AT NIGHT

YOU CAN have lots of fun with the *Lighthouse for Short People.* A conversation piece for electronic buffs, it is small enough to fit in the palm of your hand and will flash continuously for weeks before exhausting a single 9-volt battery. It can even be made to "go to sleep" (stop flashing) at night.

The *Lighthouse* also has practical uses. For example, its flash rate can be varied so that it functions as a strobe, light source, or timer. And, by placing an earphone in series with the neon bulb, an audio output can be obtained, making the *Lighthouse* useful as a visual-aural metronome.



Battery-powered flashing circuit consists of only seven miniature parts. See photo on next page for layout of components. Transformer is rated with a 10,000-ohm primary winding and 16-ohm secondary.

How It Works. The *Lighthouse* circuit consists of a high-voltage output relaxation oscillator coupled to a neon bulb. Capacitor *C1* is charged through resistor *R1* by the 9-volt battery. At 6.8 volts, the zener diode, *D1*, avalanches, triggering *SCR1*. The SCR, in turn, discharges *C1* through the transformer primary. Once the capacitor has discharged, the sudden cutoff of power causes the transformer to produce a counter e.m.f. (electromotive force) which turns off the SCR. The cycle is then repeated.

The *Lighthouse* circuit has a very high efficiency due to the almost complete lack of bias current. The only current greater than 0.1 μA flowing is that charging the capacitor.

The "Lighthouse" can be fitted into a metal can if care is taken not to short-circuit the active components. The best method to prevent a short is to line bottom of can with a cardboard sheet cut to fit. Tape wire leads of neon bulb to inside of lid so that lid can be lifted off to expose circuit.

Construction. A small, round, metal can (of the type that once contained shoe polish or electrical tape) was used to house the *Lighthouse* prototype. However, anything suitable—including a small plastic box—could be employed. If a similar metal can is used, cut and fit a circular piece of cardboard to the inside bottom of the can to prevent circuit board shorts.

Layout is not critical, but care should be taken when soldering the diode and SCR leads to avoid overheating. A transistor socket is convenient to use and eliminates the possibility of ruining the SCR.

The polarity of the diode and capacitor leads must be observed. Also, use of a cheap poor-quality zener diode is not advisable as the reverse conduction current may exceed that charging the capacitor.

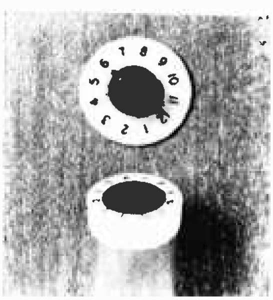
Operation. The flash intensity is proportional to the size of *C1* and the flash rate to *C1* and *R1*. With the values specified, a flashing rate of 40 times per minute is obtained. However, by changing the value of *R1*, it can be varied from one flash every couple of minutes to nearly 60 flashes per second.

An interesting characteristic of the *Lighthouse* is that it has two modes of operation. When in the presence of day or room light, neon bulbs become partially ionized. Thus, the amount of power required to ionize (light) neon bulbs in total darkness is greater. The *dark effect,* as it is called, varies with each bulb and changes as the bulb ages.

Unless you happen to get a neon bulb in which the dark effect is not prevalent, using the component values specified will cause your light to "go to sleep" at night. If you would rather have it flash, you can do so by increasing the flash rate or substituting an NE-23 for the NE-2. In tests made at POPULAR ELECTRONICS, a "regular" 9-volt battery lasted about 5 weeks and an alkaline battery was going strong after 7 weeks. -30-

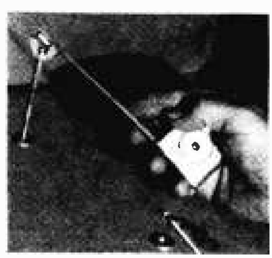
FROM PILL BOTTLE CAP TO POSITION INDICATOR

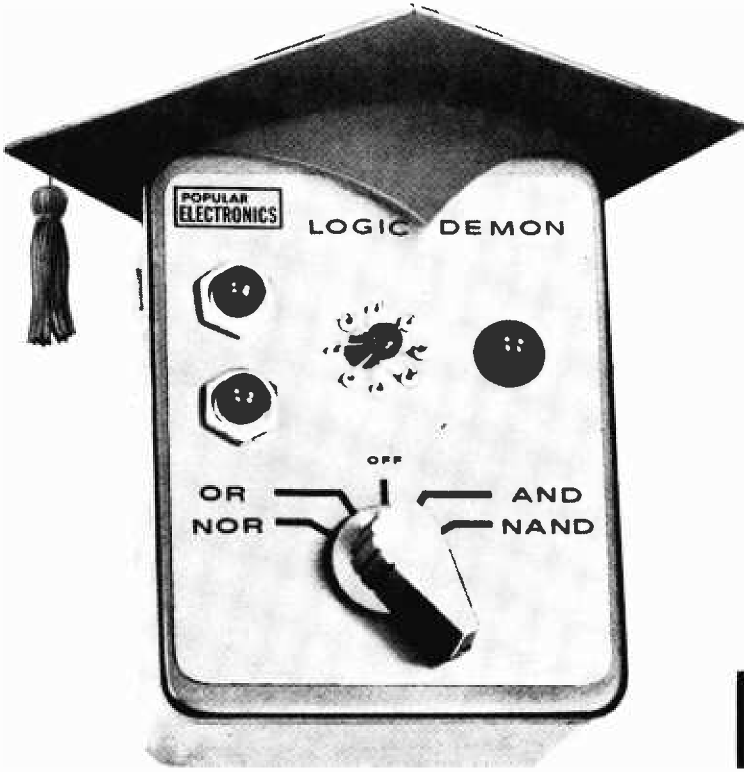
Those seemingly useless pill container caps with a pointer to remind you when it's time to take your next pill can also be used as shaft position indicators on your electronic projects. To make such an indicator, remove the pointer disc from the lid and drill a ⅜"-diameter hole in the center of the cap. Then slice off the dial portion of the cap, using a sharp knife or razor blade. Slip the dial onto the potentiometer shaft and secure it in place with a nut. Now place the indicator knob on the dial. —*Art Trauffer*



MAGNETIC "FISHING" ROD RETRIEVES SMALL OBJECTS

Screws, washers, nuts, and other small objects that accidentally fall into your wired chassis or along the inner walls of an electronic equipment cabinet can easily be retrieved with a simple "fishing" rod made by gluing a small bar magnet to one end of a steel measuring tape. If the object is nonmagnetizable, wrap a bit of masking tape—sticky side out—around the magnet. The flexibility and slimness of the steel tape enables the magnet to be positioned in extremely close quarters to pick up the fallen object. —*Glen F. Stillwell*





SCIENCE FAIR PROJECT

THE LOGIC DEMON

USING INTEGRATED CIRCUITS (IC'S), THE **DEMON**STRATOR DUPLICATES THE LOGIC FUNCTIONS OF GIANT ELECTRONIC COMPUTERS

By DON LANCASTER

EVER wondered how is it that electronic computers are able to exhibit such a distinctively human characteristic as making logical decisions? Ask the "Logic Demon" and it will tell you that, very simply, the answer lies in the truth of logic—computer logic.

The Logic Demon, utilizing the latest in resistor-transistor logic (RTL) circuitry, can serve as a demonstrator/trainer in computer logic—the same logic used by the giant sophisticated digital computers. And you can build the Logic Demon for under $10 to show off at your next Science Fair.

Computer Logic. Computer logic, also known as Boolean Algebra, can be used for reasoning out problems. Developed by Augustos De Moran and George

Boole over 100 years ago, Boolean Algebra (computer logic) was crystalized in 1938 by Claude E. Shannon who, while studying for his Master of Science degree at M. I. T., applied it to the solution of switching problems.

As an example of Shannon's application of computer logic to solve practical problems, consider the simple series circuit shown in Fig. 1. Two switches (*A* and *B*) are in series with lamp *I* and a battery. If you ask which switch must be closed in order for current to flow and light the lamp, the answer would be that *both* switches—*A* AND *B*—must be closed. Thus, the circuit is called an AND *gate*. A gating circuit is one that operates as a switch to apply or eliminate a signal.

Following a logical procedure, a table can be made listing all possible switch combinations to prove that switches *A* and *B* must be closed at the same time or current will not flow. Thus,

Switch "A" Closed	Switch "B" Closed	Lamp "I" Lights
No	No	No
No	Yes	No
Yes	No	No
Yes	Yes	Yes

As shown in the table, a "yes" appears in the lamp column only when a "yes" appears in both switch columns. The table can be simplified by substituting a "0" (zero) for a "no" and a "1" for a "yes." This allows us to establish a convention to symbolize that a statement or condition is *false* when a 0 is represented, while a 1 can be used to denote that a statement or condition is *true*. The simplified table is as follows:

Switch "A" Closed	Switch "B" Closed	Lamp "I" Lights
0	0	0
0	1	0
1	0	0
1	1	1

In computer logic (also called symbolic logic), the preceding table is known as a *truth table* for the logical AND for it represents the simple true statement that the lamp lights only when both *A* AND *B* are closed at the same time.

If the same switches are rearranged and connected in parallel as shown in Fig. 2, the following table can be pre-

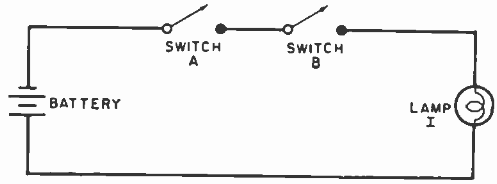


Fig. 1. Switches A and B in series with a battery and lamp can represent the logical AND circuit.

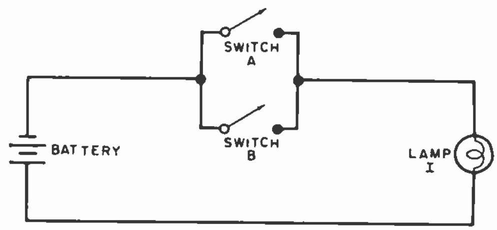
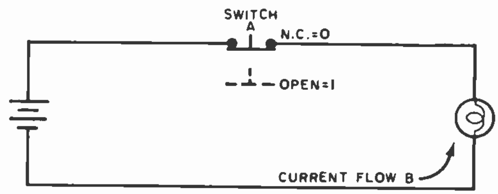


Fig. 2. In the logical OR circuit, current flows if either switch A or switch B, or both, are closed.



SWITCH A	CURRENT B
0	1
1	0

Fig. 3. In this circuit, the lamp lights when A is NOT pushed; the circuit is called a NOT gate.

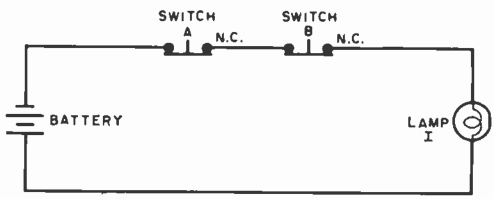


Fig. 4. A NOR gate is represented by adding one or more switches to the NOT gate described above.

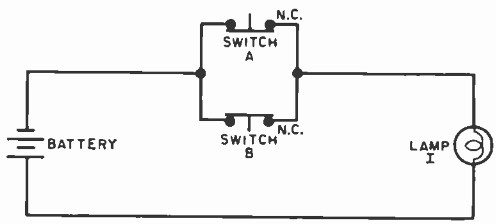


Fig. 5. The NAND function can be depicted by normally closed parallel-connected switches A and B.

pared to show for what switch combination the lamp will light:

Switch "A" Closed	Switch "B" Closed	Lamp "I" Lights
0	0	0
0	1	1
1	0	1
1	1	1

The lamp lights when either one or both of the switches are closed. Thus, logically, *I* is 1 (true) whenever *A* OR *B* (OR *A* and *B*) is true (closed), and the circuit is called a logical OR gate.

Consider the circuit of Fig. 3. Unactuated, normally closed (NC) switch *A* represents a 0, but when pressed, the switch represents a 1. The corresponding truth table asserts that *B* (current flow) is 1 whenever *A* is 0, and that *B* is 0 whenever *A* is 1. In other words, the lamp lights (is 0) when the switch is NOT pushed, and is extinguished when the switch is pushed (1). The circuit is characterized by a single switch, and is called a NOT gate (inverter).

By adding one or more switches to the NOT circuit, we come up with what is called a NOR gate (Fig. 4). A truth table for this circuit would state simply that *C* (current through the lamp) is true only if both *A* and *B* are false, and that *C* is false if either *A* or *B* is true. Since these conditions represent the opposite (negative) of the OR—NOT OR—it is called simply a NOR gate.

The opposite (NOT) of the AND gate can be represented by the circuit of Fig. 5. The NOT AND, or briefly, NAND, function can be depicted by the normally closed parallel-connected switches (*A* and *B*). The lamp lights if *either* or *both* switches are left in their "0" position. But it will be extinguished if both switches are "1" (pressed) at once.

Applying Computer Logic. A computer is capable of carrying out a long string of YES-NO decisions without having to repeatedly ask for more information as the operation progresses.

Depending on the complexity of the problem to be solved, thousands upon thousands of such decisions, may be needed for mathematical problems requiring addition, subtraction, multiplication, and division. Programmed instructions, stored in the computer's memory, coordinate all operations, time them for proper sequence, and route the information in the proper sequence to the various registers and output devices.

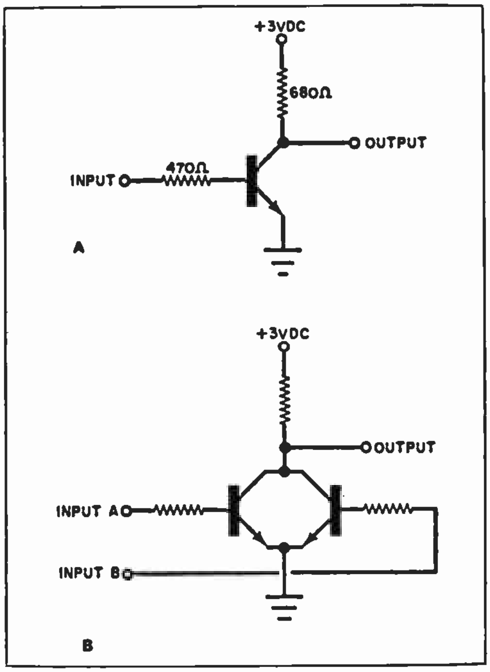


Fig. 6. NOT operation can be performed by a one-input RTL gate shown in (A). A two-input gate (B) can serve either as NOR or NAND circuit.

Logic gates can be constructed with such devices as relays, switches, tubes, and transistors. But in this era of microminiaturization, integrated circuits (IC's) offer the greatest advantage because they occupy very little space, consume little power, are extremely reliable, are quick-acting, and inexpensive.

Of the many varieties of logic IC's on the open market, the *resistor-transistor logic* (RTL) variety is probably the most popular. It can easily drive other

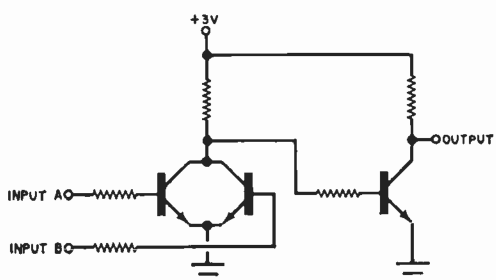


Fig. 7. The AND function is obtained by the addition of a NOT gate to output of a NAND gate.

IC's, and operates with voltage levels that are compatible with the requirements of external circuits. Typical one- and two-input RTL gates are shown in Fig. 6. If additional inputs are required, more transistors are added.

Operation of the gates is simple. If a transistor receives an input, it turns *on* to produce 0 output at the collector. The one-input gate, shown in Fig. 6(a), is the NOT circuit. If +3 volts are applied to the input, the output becomes 0.

PARTS LIST

B1—1.5-volt size "D" flashlight cell (2)
I1—3.2-volt, 160-mA pilot light (GE #1490 or similar)
IC1—Fairchild μL914 epoxy micrologic dual two-input gate
Q1—Motorola MPS 2925 transistor
S1, S2—S.p.d.t. switch or two-circuit NO/NC push-button switch
S3—4-pole, 5-position non-shorting selector switch (similar to Mallory 1325L)
1—5" x 4" x 3" cabinet (similar to Bud CU-2105A or Premier PMC-1005)
*1—Metalphoto dialplate (optional)**
Misc.—Battery holder, bracket for Q1 (optional—see text), bar-type knob, 5/16"-i.d. rubber grommet, transistor socket for Q1, nylon or rubber feet with hardware (4), rivets or screws for battery holder

*Available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014; in silver color—$2.75; red, or copper—$3.25; postpaid in the U.S.A.

The absence of a voltage at the input produces +3 volts at the output. Observe that the output is always opposite in state to the input.

Now consider the two-input gate shown in Fig. 6(b). By first establishing that the presence of +3 volts at the input represents a 1, and the absence of this voltage represents a zero, the gate will function as a NOR gate since a 1 at either input produces a 0 at the output. If an OR gate is desired, a NOT circuit (one-input gate) can be added to the output to reverse the state.

If, on the other hand, it is established that the presence of +3 volts at the input represents a 0, while the absence of this voltage represents a 1, then the circuit will function as a NAND gate so long as the +3 volts appears on *both* inputs. Once again, the adding of a NOT circuit reverses the function to produce an AND response. See Fig. 7.

We can now proceed to build the "Logic Demon" around the circuits discussed so far by including a suitable selector switch and a transistor lamp-driver stage. After designing and building the Logic Demon, it can be used to perform real computer logic operations.

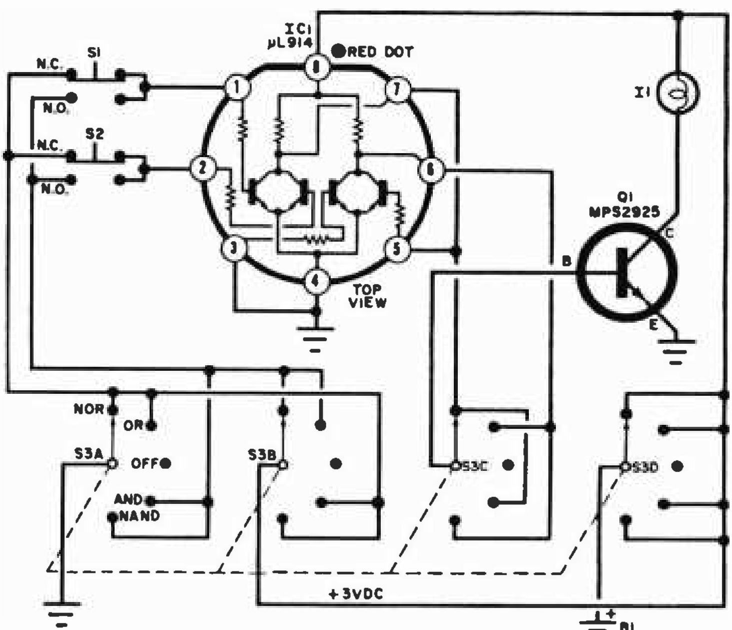


Fig. 8. Through exclusive use of dual two-input gate elements, any logic function can be generated from basic NAND/NOR gates in a fully integrated monolithic circuit.

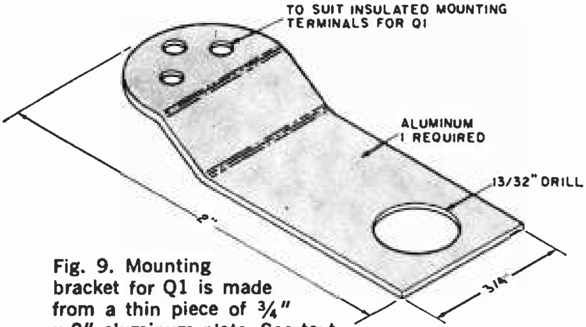
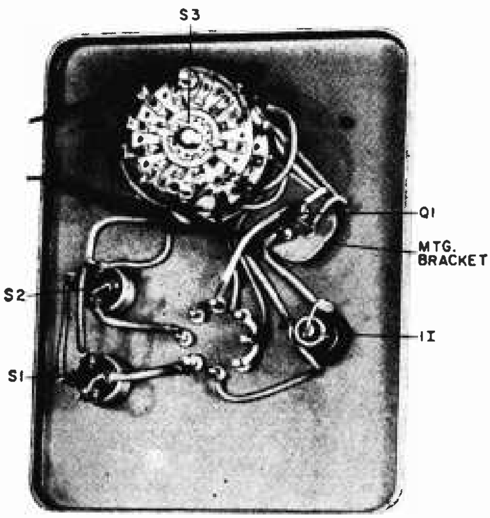


Fig. 9. Mounting bracket for Q1 is made from a thin piece of ¾" x 2" aluminum plate. See text.

About the Circuit. The "brain" of the Logic Demon is the 80¢ integrated circuit *IC1* which contains dual RTL two-input gates (Fig. 8). One input is eliminated from one of the gates by grounding pin 3. Thus, a two-input gate and a one-input gate remain.

When the output (which drives *Q1*) is taken directly from the two-input gate, the circuit performs the NOR/AND functions. However, by feeding the output of the first gate to the one-input gate (which acts as an inverter or NOT gate) and then taking the output from the latter gate, the OR and NAND functions are obtained.

A selector switch defines the input logic states and routes the lamp-driving transistor (*Q1*) to the appropriate gate output.



The Logic Demon can be wired using the schematic diagram and component layout shown in this photo.

Construction. The unit can be assembled on a metal chassis or in a wooden or plastic container. However, the use of a 5" x 4" x 3" metal box will give the project a neat appearance.

Except for the two dry cells which are mounted in battery holders that can be pop-riveted or screwed to the base, the switches, IC, and indicator lamp are mounted on the enclosure cover. If you use the prefabricated dialplate (see Parts List), the appearance of the project will be enhanced, and the dialplate can also serve as a drilling template for the holes that must be made in the cover to accommodate the switches, lamp, and the IC. The mounting hardware for the switches can be used to hold down the dialplate on the cover.

The IC shown here is mounted on individual Teflon insulated feedthrough connectors. Pin 8 of the IC case is usually coded with a red dot, or it may simply be beside the flat side of the case. Viewed from the top of the case, the pins are counted counterclockwise.

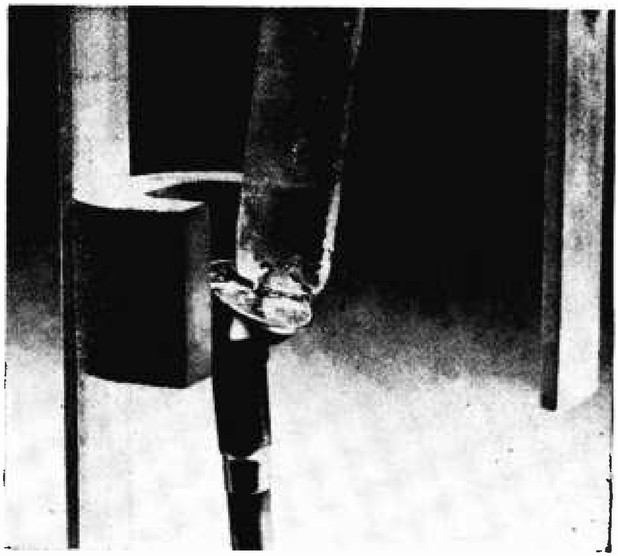
Transistor *Q1* is mounted on stand-off insulators inserted in a fabricated aluminum bracket (Fig. 9) which is secured on the inside of the enclosure cover by the rotary switch.

The pilot lamp fits in a 5/16"-i.d. rubber grommet that mounts in a hole through the dialplate, and leads are soldered directly to the bulb. After making all the wiring connections (Fig. 8), you can proceed to test the unit.

Operation. If the unit is wired correctly, it will obey all the logic rules indicated on the dialplate. With the switch in the NOR position, the bulb lights and is extinguished by pressing either push button. In the OR function, the bulb lights when either push button is depressed, while in the AND function, both push buttons must be pressed at the same time for the light to come on. With the switch in an NAND position, both push buttons must be simultaneously pressed to put out the light.

The Logic Demon can be used in a classroom or at a Science Fair to demonstrate the practical application of computer (symbolic) logic. The Logic Demon also demonstrates some practical applications of the use of integrated circuits in computer technology. —30—

SCIENCE FAIR PROJECT



TESLA'S THERMOMAGNETIC MOTOR

A LITTLE-KNOWN INVENTION BY THAT CONTROVERSIAL GENIUS

By ARTHUR S. COOKFAIR

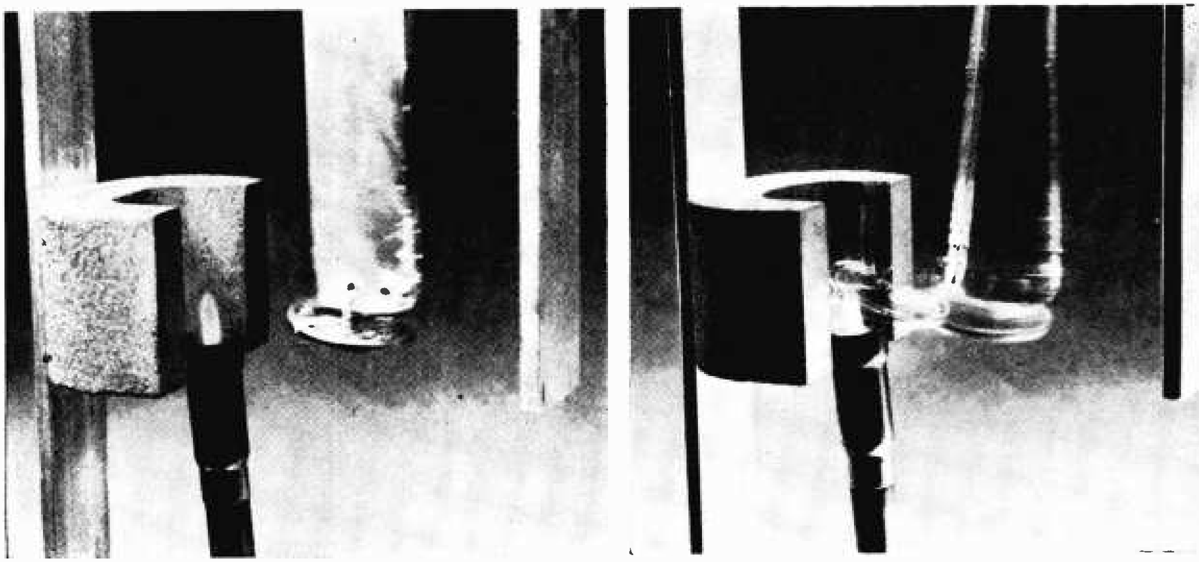
MENTION Nikola Tesla to any electronics hobbyist and the chances are his first thought will be of the Tesla Coil. Upon reflection, he may recall that Tesla had something to do with developing alternating current power transmission, or the invention of the induction motor. The fact is that in the early days of electricity and magnetism, Tesla's active mind was probing in many directions to find ways of putting these forces to use. The thermomagnetic motor was one approach.

Unlike the induction motor (Tesla's most useful contribution), the thermomagnetic motor was destined to obscurity. It is a little known invention buried among the millions of inventions in the archives of the U.S. Patent Office. The motor itself is easy to construct and provides a simple—yet interesting—science fair project or demonstration device to show the effects of temperature on magnetism.

Theory. Tesla's thermomagnetic invention is based on the phenomenon known as *Curie temperature* (after its discoverer, Pierre Curie—of radium fame). The Curie temperature is the point at which permanent magnetic properties of certain metals go down the drain.

A Curie temperature transformation occurs in both *hard* and *soft* magnetic materials. Hard magnetic materials—such as alnico or hard steel—are those which are used in the manufacture of permanent magnets. Soft magnetic materials, such as soft iron, are those metals which are easily magnetized when placed in a magnetic field, but tend to lose their magnetism rapidly when removed from the field. Since permanent magnets can be damaged by excessive heat, Tesla's thermomagnetic motor was designed so that heat would be applied only to a soft magnetic material.

The Curie temperature varies for different metals. Iron loses its magnetism at 770° C, nickel at 360° C, and cobalt



The above sequence shows how Tesla's motor operates. As the gas flame heats the nickel, a point is reached when the attraction to the alnico magnet is cancelled. A weak spring pulls the arm and nickel away from the flame. When the nickel cools, the magnetic attraction is restored and the nickel returns to its original position. This oscillation should be at a rate of about 20 strokes per minute. Be careful not to heat the magnet.

at 1120° C. Alloys such as nickel-iron may lose their magnetism at temperatures ranging from below room temperature as high as 770° C, depending on the ratio of nickel to iron. Place any one of the above metals or alloys near a magnet, at ordinary temperatures, and it will be attracted. Heat it above the Curie temperature and the attraction is lost. As it cools, the magnetic attraction returns. Alternate heating and cooling creates an alternating magnetic force.

How It Works. In operation, a facsimile of Tesla's motor consists of a movable rider made of a soft magnetic material that is pulled in one direction by a spring and in the opposite direction by a magnet—the magnet being the stronger of the two forces. The rider is pulled by the magnet to a position where it can be heated by a flame (or other heat source).

When the rider reaches the Curie temperature, it is no longer attracted by the magnet and is pulled away from the flame by the spring. The rider cools rapidly to below the Curie temperature, regains its magnetic properties, is again attracted by the magnet to a position over the flame; and the cycle repeats itself.

The frequency of the rider oscillation depends on the heating and cooling cycle. Once the operation has started, the magnetic rider will remain close to the Curie transformation point and will lose and regain its magnetic properties by variations of only a few degrees above or below that temperature.

A Bunsen burner or hand propane torch will do an excellent job of heating. If these are not available, a candle will serve the purpose. Or, if you want to keep up with the latest trends in science, you can demonstrate the conversion of solar energy by heating the rider with a small magnifying glass.

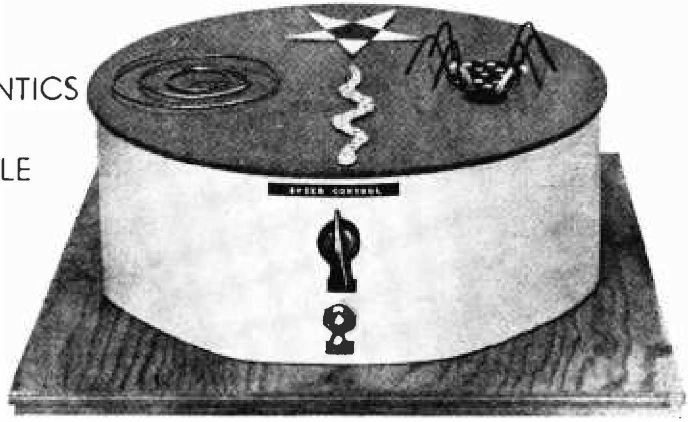
Construction. The frame of the motor shown (above and on page 154) was made of aluminum since it is easy to work and the non-magnetic qualities of aluminum will not be attracted by the magnetic field. You can build the motor to operate with almost any size of magnet. Small alnico magnets are available in hardware stores. Naturally, a more powerful magnet is easier to use—it will pull from a greater distance, and it also permits the use of a heavier spring. In a model similar to that shown, a 2-ounce

(*Continued on page* 154)

BUILD A "MAGIC" MOTOR

ROTATING MAGNET CREATES INTRIGUING ANTICS THAT CAN ATTRACT AND ASTOUND PEOPLE

By WALTER B. FORD



MEET THE "MAGIC" MOTOR. It can rotate odd-shaped figures without gears or belts, and will keep both youngsters and oldsters occupied for hours. You can use it to attract people, conduct a contest to see who can describe how it works, or dream up your own special applications. The gadget consists of a small battery-operated motor and a small but powerful cylindrical magnet mounted on the motor's shaft.

When a metal object, such as one of those shown above, is placed in contact with the magnet and the motor is turned on, the object will "slither" its full circumference and will appear to be traveling back and forth, or in a circle, or in random fashion, depending upon its shape. The secret is in the magnetic clutch action between the magnet and a metallic object. The magnetic force holds the object against the magnet; and as the magnet rotates, it drags the object along.

Imagination is really what makes this gadget a winner. Gaily painted and grotesque figures like giant insects, reptiles, and monsters—or even a practical display such as merchandise for sale—can be set up to attract attention.

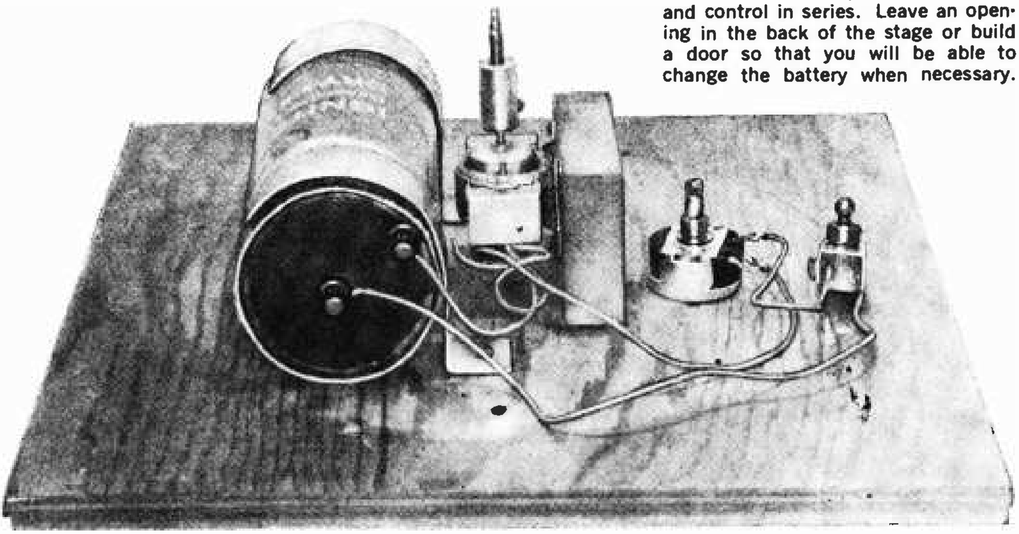
Construction. Center and draw a 9¼"-diameter circle on a ⅜" x 12" x 12" square piece of plywood or other suitable board, and mark off eight equally spaced divisions on the circle. Then cut a ½"-thick piece of plywood or other suitable board to 10" in diameter, and drill a ½"-diameter hole in its center. The first piece of wood is the base; the second is the stage for the project. Smoothly sand one side (top) of the stage.

Mount the battery on the base in any suitable manner—you can shape a metal strap to hold it down. The motor can be mounted on a block of wood, or on a metal bracket. Position the motor so that the shaft is directly over the center of the circle drawn on the base. Use wood screws to hold the motor in place.

Another metal bracket is needed to support the speed control and the switch. Mount the bracket on the underside of the stage, close to the edge, so that the control and switch will project out of a "curtain" which you will wrap around the stage to hide the inner works.

Cut and mount eight ½"-diameter by 6½"-long wood dowels over the divider markings on the circle drawn on the base, to support the stage.

A coupler to mount the magnet on the motor's shaft can be made from ½"-diameter x 1"-long aluminum or brass rod. Drill a ¼" hole, about ½" deep, in one end of the rod to accommodate the



Connect the battery, motor, switch, and control in series. Leave an opening in the back of the stage or build a door so that you will be able to change the battery when necessary.

BILL OF MATERIALS

*1—Battery-operated motor**
1—Dry cell battery, No. 6
1—25-ohm rheostat
1—S.p.s.t. toggle switch
*1—¼"-diameter x 1¼"-long magnet**
1—½"-diameter x 1"-long piece of brass or aluminum rod
1—12" x 12" sheet of ⅜" plywood
1—10" x 10" sheet of ½" plywood
6—½"-diameter x 6½"-long wood dowels
1—6½" x 36" cardboard—see text
Misc.—Hookup wire, wood screws, solder, cement, brackets, etc.

*Battery-operated motor and magnet can be obtained from Edmund Scientific Co., Barrington, N.J. (Motor: Catalog No. 30,305, 70 cents; magnets, Catalog No. P-40,418, $1.05 for two; minimum order must be $2.00)

magnet. Determine the diameter of the motor shaft and drill a ⅜"-deep hole in the other end of the rod to fit over the shaft. These holes must be centered or you will run into some pretty wild action when you turn the motor on. Excessive off-centering may cause you more trouble than you bargained for, but if you slow down the motor enough, you may wind up with a usable and possibly more interesting effect.

You can cement the coupler in place or do a little more machine work and install setscrews. Do not finalize the position of the coupler until the stage is set, as you may find that you'll have to raise or lower the magnet.

Finishing Touches. Set the stage on the upright dowels and check to see if the magnet is centered in the stage's opening. If necessary, you can shift the position of the motor, but if you followed instructions, things will fit right from the start. Adjust the height of the magnet to about ¼" above the top of the stage. Now connect the switch, control, motor and battery in series, using ordinary hookup wire. Turn on the motor and check the action; if you are satisfied, glue the stage in place.

The curtain comes next. Cut a strip of heavy but flexible cardboard about 30" long by 6½" wide. Cut two holes in the curtain to fit over the switch and the control. Drape and cement the curtain in place around the stage.

You can fashion your reptiles, insects, monsters, and other geometric figures from just about any thin piece of metal that has magnetic properties. A coiled snake (as shown) can be made from a length of iron wire, with a piece of sheet metal for a head. Avoid shapes or angles that will trap your figure so that it can't move. The movement of your figure can be lazy or aggressive, depending on the rotating speed of the motor. -30-

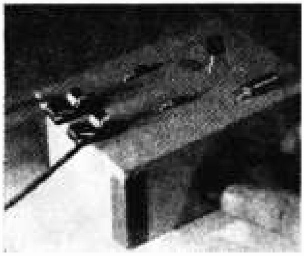
METHODS

THE BEST OF TIPS & TECHNIQUES

GADGETS

CARDBOARD BOX SERVES AS QUICKIE ELECTRONIC CHASSIS

Small cardboard boxes can be turned into quick, temporary chassis for electronic projects such as the one-transistor radio shown in the photo. Component leads are pushed through appropriately spaced holes in the cardboard, and potentiometers, switches, and other hardware are mounted in the normal manner. Batteries can be taped inside the box. You can also use this cardboard box idea to optimize component layout before assembling a project on a more permanent type of chassis. —*Robert E. Kelland*



ELECTRIC TIMER TURNS OFF SOLDERING IRON

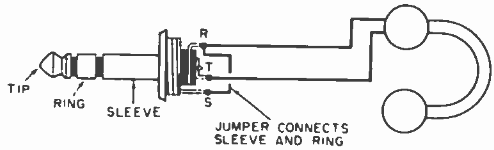
Ever forget to unplug that soldering iron before turning in for the night? You can prevent this from ever happening again—and also remove the possibility of a fire—by operating your soldering iron through an electric timer. If the timer cuts off before you're through, simply reset it again. If you forget to unplug the iron, the timer acts like a backup to turn it off for you. —*Wilfred Beaver*

ALLIGATOR ADAPTERS FOR TEST PROBES

Ever try to hold two test probes and switch a VOM range at the same time? Of course it can't be done, so why try? I made up two of these alligator adapters for my probes using standard tip jacks (E. F. Johnson 105-800) and Mueller 60-HS clips. You remove the plastic sleeve on the back end of the clip and spread the collar-like opening wide enough to take the tip-jack body. Then solder a short length of wire from the tip jack connector to the clip and reclose the collar. Stick the probe tip into the jack, bite into the circuit under test with the alligator clip, and look, Ma, no hands. —*Arthur Neil Jensen*

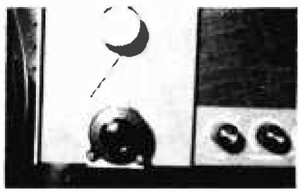
THREE-CONDUCTOR PHONE PLUG HOOKUP FOR MONO HEADSETS

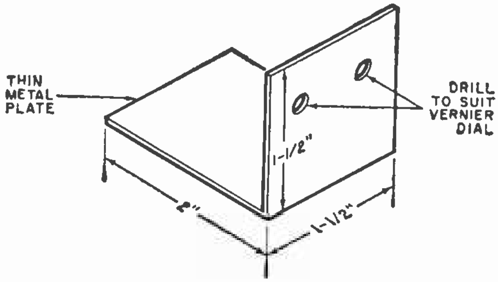
If you are in need of a 2-conductor phone plug and you happen to have only a 3-conductor type, you can try this simple modification. All you have to do to convert a 3-conductor plug for use with a 2-conductor mono headset is to jump the plug's sleeve (S) and ring (R) connectors as shown. Solder the headset leads to the ring and lug tips (T). —*Carl Dunant*



VERNIER DIAL PROVIDES MECHANICAL BANDSPREAD

If you own one of those inexpensive communications receivers with stations crowded on the dial, you can improve station separation dramatically with a modest investment of about 89 cents, and a few spare moments of your time. All you do is replace your existing fine tuning or bandspread knob with a vernier dial that you can get at most electronic supply houses. If you cannot mount the dial directly on the panel over the control shaft, first mount the dial on a small support panel fabricated from light-gauge aluminum or sheet metal as shown in the drawing. Then secure the panel, with the installed dial, to the bottom of the chassis or cabinet after slipping the vernier dial over the bandspread or fine tuning shaft. You'll be pleasantly surprised by the change in tuning ease. —*Bruce Carlin*





"GIVE ME A LEVER LONG ENOUGH . . . AND I'LL MOVE THE WORLD"

You may not need to move the world . . . but an extension lever on that hard-to-get-at toggle switch can come in mighty handy in an emergency. A piece of rigid tubing—copper, brass, aluminum—or the sleeve from an old ballpoint pen slipped over the switch level will provide greater convenience when you're reaching for and throwing that switch in a hurry.

—Glen F. Stillwell

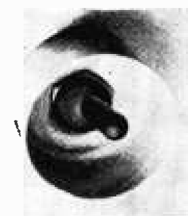
MAKE YOUR TRANSISTOR RADIO A WRIST-STRAP SWINGER

If your pocket-size portable radio doesn't have a wrist strap, you're just not with it. All you need to join the swingers are a camera wrist strap and a suitable size solder lug. Remove the back of the radio, unsolder the earphone jack connections, and slip the jack out of its mounting bracket. Place the solder lug over the threads, secure the jack, and resolder the wires. Then bend the lug to accommodate the strap, but leave enough room for the earphone plug. You can cut a notch in the plastic case if necessary, to prevent the solder lug from interfering with the back cover.

—S. E. Gohl

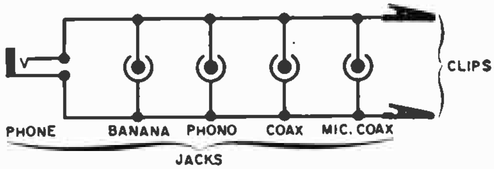
SWITCH PROTECTOR MAY BE LIFE PROTECTOR

Here's an accident-proof switch protector that'll keep you from leaning or brushing against an equipment switch you just can't afford to turn on—accidentally. Take a small empty tin or plastic container—a salted peanut can, spray-paint can, or coffee can will do and drill a hole the size of the switch shank through the bottom of the can. Remove the switch mounting nut and slip the can opening over the switch shank. Then replace and tighten the nut. Now the switch can still be turned on and off—but never accidentally. For more drama, you can place a cover with a warning note on the can. *—Charles C. Brock*



UNIVERSAL MATCH-PATCHBOX QUICK-RIGS MIKES, PHONES, AND ANTENNAS

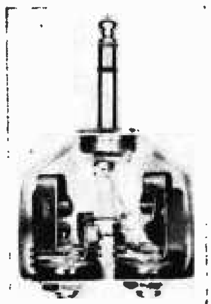
Have you ever found yourself hastily re-soldering your microphone plug to go from that super deluxe breadboard project back to your rig, only to find that you have muffed your schedule? Don't scrap your creative urges or get a new mike. Build a match-patchbox and install as many different kinds

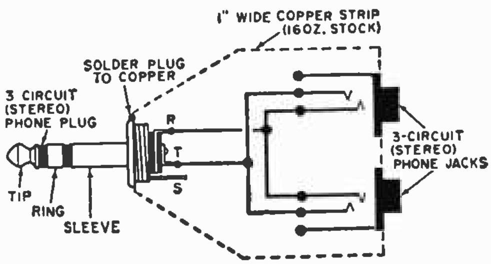


of jacks as you are likely to need—there's no law against including duplicates. Almost any kind and size of box can be used to patch in your mikes, antennas, headphones, etc. For critical circuitry, shielded cable can be used to prevent crosstalk, hum, and on-the-air unmentionables. *—D. E. Hausman*

TWO STEREO HEADSETS FROM ONE STEREO JACK

The cone-shaped adapter in the photo below is of the home-brew variety through which two audiophiles can simultaneously plug in their headsets to a single stereo jack. The adapter is made from a 1"-wide copper strip (16-ounce or heavier stock) bent as shown, with the two overlapping ends soldered together. Make the adapter frame as small as possible with just enough clearance for the jacks to avoid shorting against the frame when the plugs

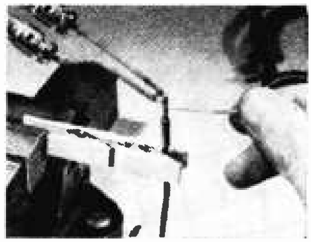




are inserted. Then drill and ream out openings for the jacks. To insure a good ground, solder the master plug directly to the copper frame. And it's a good idea to use lockwashers between the jacks and frame to keep the jacks from turning and shorting out the wires. The diagram shows the simplicity of the internal wiring. If desired, a cover can be placed on both sides of the frame to conceal the wiring. *—Art Trauffer*

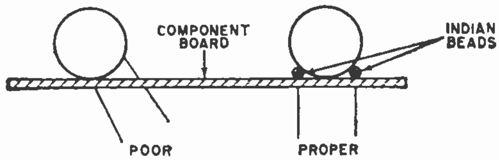
SPRING-TYPE CLOTHESPIN LENDS A GENTLE THIRD HAND

When you hold a soldering iron in one hand, and solder in the other, you may need a friend to lend another hand to hold the component. A spring-type clothespin will do it for you. Just cut off one end of clothespin and clamp the adjacent end in a vise as shown. The opposite end will hold the component. When you want to support two components or wires, two clothespins clamped back-to-back can be employed. If you don't want to use a vise to hold the clothespins, you can mount one or more pins on a small block of wood.—*Robert E. Kelland*



INDIAN BEADS KEEP 'EM STRAIGHT AS AN ARROW

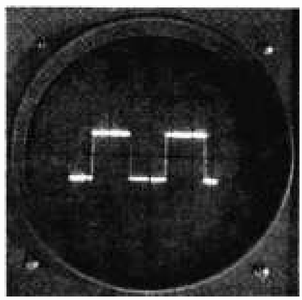
If you've had the occasion to mount a ceramic disc capacitor on a circuit board, you might



have wound up soldering the capacitor in an ungainly position, giving your project a "biased" appearance. To insure correct posture of the component, and an overall improvement in the project, slip a small-sized Indian bead onto each lead of the capacitor before soldering it. —*Jan Rosenbaum*

TAKE THE REFLECTION OUT OF SCOPE TRACE PHOTOS

For reflection-free photographs of oscilloscope traces, cut a piece of clear acetate to the diameter of the oscilloscope screen. Coat one side of the acetate with artist's matte spray. When you are ready to snap a photo, place the acetate in front of the screen, sprayed side out. The trace will be slightly subdued, but perfectly readable. *Tri-X* film, shot at f3.5, and 1/15-second shutter speed produced the photo shown with only normal room lighting. —*William S. Gohl*



(*Continued on page* 140)

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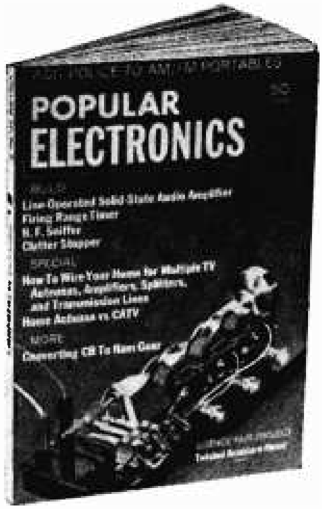

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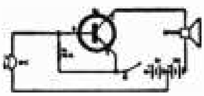

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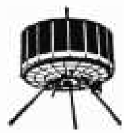

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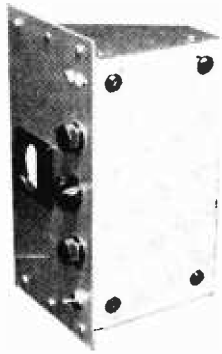
TIPS & TECHNIQUES

(*Continued from page* 136)

SINK WASHERS HELP KEEP TABLE TOPS CLEAN



You can avoid scratching your workbench or table top simply by installing small "bumpers" on the bottom of your radio or other electronic equipment. Ordinary sink washers and countersunk flathead machine screws or self-tap screws can be used. Drill a hole in each corner of the base of the chassis or cabinet and attach the washers. Be sure that the screws are countersunk deep enough to prevent contact with the table top. Almost any size of washer will do. Actually, you could use almost any other type of rubber, plastic, or nylon washer. —*R.A. Boyll, W9IFG*

STEREO PREAMPLIFIER

(*Continued from page* 51)

unwanted feedback, crosstalk, and stray leakage paths. Component layout on the printed circuit boards is shown in Fig. 6.

The photographs (Figs. 7, 8, and 9) show the preamp mounted in a metal cabinet, but you can house the circuits in any type of enclosure. The input and output jacks are mounted on the back panel. Wire them in and leave enough length to reach the selector switch (*S1*) on the front panel.

Connect the voltage divider resistors (*R27* and *R29*) directly to the AM and FM inputs respectively. One end of resistors *R28* and *R30* can be tied to a single ground terminal mounted on the chassis next to the input jacks. It's a good idea to use shielded leads between the input jacks and the switch. If you do use shielded wires, connect only one end of the shields to ground, near the input jacks. Do not connect the shields to ground at the switch end of the wire.

Drill holes in the chassis to mount the circuit boards, using the boards as templates. Cut a notch in the chassis to

SPECIFICATIONS

Frequency Response	10 to 100,000 Hz ± 1 dB (tone controls set for flat response)		
Sensitivity (input needed for 1.0 volt rms output)	Phono:	20 millivolts	
	Tape:	12 millivolts	
	Mic:	15 millivolts	
	AM-FM:	0.95 volt	
Maximum Input (before clipping occurs, measured at 1 kHz)		12-Volt Supply	24-Volt Supply
	Phono:	30 mV	60 mV
	Tape:	25 mV	50 mV
	Mic:	25 mV	50 mV
	AM-FM:	1.25 V	2.5 V
Maximum Output	12-Volt Supply: 1.5 V rms		
	24-Volt Supply: 3.0 V rms		
Distortion (measured at 1 volt rms output)	Less than 0.06%, any frequency from 20 to 20,000 Hz		
Noise	Phono, Tape, Mic Inputs:	−65 dB	
	AM, FM Inputs:	−70 dB	
Input Impedance	At least 200,000 ohms, any input		
Output Impedance	Less than 10 ohms		
Without Compensation Networks	Frequency Response:	50 to 10,000 Hz ±3 dB	
	Gain:	60 dB	
	Input Impedance:	10,000 ohms	
	Output Impedance:	100 ohms	
Power	12 to 24 volts, d.c., 4 to 8 milliamperes		

clear the selector switch and wire the input leads to the switch before assembling the chassis to the front panel. The boards are mounted on ½-inch threaded spacers. Wire the controls and upper section of the rotary switch and the job is done.

Finishing Touches. A balance control could be included in the "Two-By-Two" to optimize adjustments for stereo programs. However, adjustment for balance is easily obtained by the use of concentrically-stacked volume controls which can be individually adjusted.

And, of course, you can dress up the front panel of the cabinet with self-sticking vinyl plastic such as the material used for shelf covering. Decals can be applied and sealed with a clear plastic spray. –30–

"COMPAC" IGNITION SYSTEM

(*Continued from page* 24)

ooze out and keep the transistor securely in place.

Do not use an insulator when mounting *Q1;* its collector is grounded to the case. However, use an ohmmeter on the low ohms scale to check for clearance (short) between the case and the base and emitter elements of *Q1*. Depending upon the polarity of the meter, it may show a reading, but should not show a dead short. If a dead short is noted, move the transistor a little to clear up the condition.

Do not make the holes in the metal any larger than necessary; the more metal there is, the better the heat sink capability. The wires from the board can be connected to the terminal strip after the board is in place.

Connect the wires as follows: from *B* to the base, and from *E* to the emitter on *Q1;* from *A*+ to *A*+ on the terminal strip; from *P* to *PTS;* from *C* to *Coil* + and from *X* to *GND*. Connect another wire from the transistor lug to *GND* on the terminal strip.

A 3″ x 4″ x 5″ standard stock box can be used as a cabinet to hold all the parts. However, the original unit is shown in a special cabinet built for the purpose.

Final Check And Installation. Before installing the Compac, you may want to bench-check it. All you need is a 12-volt battery and an ignition coil.

Hook up the system in the same way as it would be connected in the car, except for the points. A wire from the high-voltage terminal should be gapped about ¾″ away from the ground lead of the coil. Instead of using breaker points, connect a wire from the *GND* terminal and brush it along the *PTS* terminal. Do not touch the ignition coil or high-voltage lead when making this test, or you will get a nasty jolt.

You can make the same test while the unit is installed in the car. Install the unit as far from the manifold as possible. A good place is in front of the radiator or in the air stream of the fan. Up to 12 feet of wire can be used to connect the system. Although the unit works well at higher than normal engine compartment temperature, never mount it with the transistor facing up toward the hood. The transistor should be on a vertical surface when the unit is mounted.

To connect the unit, remove all the wires and capacitors from the ignition coil. Connect the wire and capacitor that were on the plus mark of the coil to *A+* on the terminal strip. Connect a wire from the distributor to *PTS*. Connect a wire from the ignition coil plus to *Coil +* on the terminal strip. And connect a wire from *GND* on the terminal strip to the other terminal (negative) on the ignition coil.

Check the wiring, and make sure that the connections are tight and well insulated. The low current drain of the new ignition system will not be affected by a ballast resistor; if one is used in the car, it can be left in. A slight hum will be heard from the unit when the ignition key is turned on.

Start your engine. -30-

THE AMLIGNER

(*Continued from page* 99)

and at the natural resonant frequency of the *C2-L1* tank circuit, producing the ringing waveform shown in Fig. 2(c). Also, the discharge of *C1* through the primary of *L1* induces a rapidly changing voltage in the coil. This voltage is stepped up by transformer action, placing a potential of several hundred volts across tuning capacitor *C2*.

Adjustment of capacitor *C2* determines the frequency of the r.f., carrier which is independent of battery voltage. Since *L1* is an antenna as well as a transformer, it radiates an r.f. energy that can be picked up on any nearby broadcast receiver. The power radiated is well within the limits allowed by FCC regulations.

Construction. The circuit must be housed in a non-metallic box. A plastic instrument case is just about ideal for this purpose, but you could use a Masonite or wooden case. Simply follow the pictorial diagram (p. 99). Be sure to keep the leads on *C1, D1,* and the primary of

L1 as short as possible to prevent excessive signal losses in the middle of the band. And, of course, observe polarity when hooking up the battery and diode.

The circuit should perform well with just about any loopstick you care to use, but you'll no doubt encounter performance variations from loopstick to loopstick. The one in the Parts List is quite suitable for this application. You'll also find some performance variations in tuning capacitors, requiring that you custom-calibrate your own dialplate against the frequencies of local radio stations, or with the aid of a signal generator.

Operating Hints. When using the AM-LIGNER, place it as far away from the receiver as you can so that it will operate on the weakest signal possible. This procedure will insure sharp tuning.

For best results when making oscillator tracking adjustments or car radio antenna trimmer adjustments, always use frequencies at the high end of the dial (around 1600 kHz). —30—

"RELAXATROL"

(*Continued from page* 20)

bly. Slip a piece of spaghetti over each of the leads to insulate them and prevent short circuits.

Exercise care and work slowly when drilling holes in the plastic case. Use a file to shape the opening for the switch. A bottom cover for the case can be made from a thin piece of plastic or stiff cardboard, if you don't already have one. Two precautions should be taken: observe polarity of the diodes or proper connections of the rectifier module; and don't compromise the insulation—the rectifiers and *S1* are connected directly to the a.c. line.

Operation. When the unit is completed, check the wiring for any errors, then secure the bottom cover. Plug the a.c. line cord into a wall outlet and switch on the unit. After a slight delay, the relay should pull in and out at a regular interval. Rotate *R2* to change the interval. Range should be from very fast (approximately 15 seconds) to very slow (approximately 2 minutes). If desired, the time intervals can be marked on a dialplate placed under the control knob.

Connect the push-button leads from the projector to *PL1* through a mating socket. Use a small caliber plug and socket for this purpose to prevent confusion with the a.c. line cord. Set up your projector as usual, and allow the Relaxatrol to go to work. If you want to view a particular slide for a longer period of time, simply turn the unit off until you are ready to start again. If you want to quickly dispose of a slide without upsetting the timing sequence, hit the push button just once.

You can shift the range of speeds by using a smaller or larger resistor in place of *R1* or by changing value of *C2*. —30—

BATTERY POWER SUPPLY

(*Continued from page* 106)

to prevent stressing connections and wires. Clips for the batteries can either be salvaged from old batteries or purchased separately. The output leads can also be equipped with appropriate snap-on battery terminals.

Operation. From time to time, measure the voltage (under load) across the collector of *Q1* and the positive side of the regulated output. For peak performance, a reading of 10 volts or more is desirable.

To obtain full benefit from the voltage-regulated power supply, replace the batteries when the power source voltage drops down to about 10 volts. Do not put good and bad batteries in parallel with each other; the bad battery would rob power from the good one. Occasionally move *B5* to one of the other battery positions and substitute a new battery for it. Switch *S1* should be in the "off" position when the unit the power supply is serving is not in use.

The power supply can be attached to the back of your radio or recorder with an elastic band or in any other convenient manner. And if you want to go back to the original battery setup in the equipment at any time, you can. —30—

METAL LOCATOR

(*Continued from page* 38)

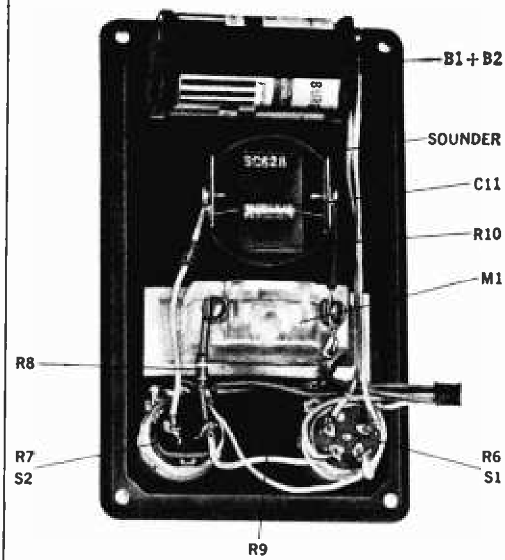


Fig. 14. Sounder, meter controls, and batteries are all mounted on cover of receiver. While most of the space is accounted for, layout is not cluttered.

Third, set the locator on a wooden stool (outdoors) and adjust the microbalance slightly off the null position with the *Gain* control at maximum. Hold a silver dollar or similar-sized piece of metal 4" above and centered on the receiver loop. As you rotate the coin slowly, it should produce at least one division of meter variation.

If any of these tests fail, you'll have to "ring" out the circuit with a good oscilloscope and an r.f. signal generator to find the stage or stages which are either off resonance or malfunctioning. All stages should peak at 455 kHz. You can check the receiver response independent of the receiving loop simply by shunting the loop with a 10-ohm resistor and injecting a signal.

Operating Hints. Become familiar with your instrument and its behavior with known objects before attempting any treasure hunts. Try some sample targets—cookie sheets, pots, coffee cans, water pipes, etc.

You'll find that the microbalance con-

(*Continued on page* 149)

trol is best set at *one-half turn clockwise* from the null position to give you maximum sensitivity to changes in field pattern. Any time you change the operating height, you'll have to readjust this control. Normally, you can carry the instrument at arm's length, but for deepest penetration, you should hold it closer to the ground. Once you have located a target, keep backing down the *Expansion* control until your target is just barely detectable—to obtain the sharpest possible "outline."

To find the exact position of a target, approach it from several directions and average out the results. With proper use of the *Expansion* control, you should be able to pinpoint a target to within a few inches. When tracing pipe, always cross the pipe at right angles to get a distinct response. For unknown targets, cover an area first East-West, then North-South, traveling slowly and steadily, and repeating the "dosage" at two-foot intervals.

To test your batteries, turn the *Expansion* control all the way up. The receiver batteries are good if the meter reads at least 0.8 mA. Replace the transmitter batteries if the signal "drops out" in the *Low* position at any time.

Happy hunting. —30—

THE "BRUTE-70"

(*Continued from page* 63)

First, short input jack *J1* with a clip or dummy plug. Do not as yet connect a speaker, or other load, but do connect a d.c. voltmeter across the output terminal *TS1*. Plug in the line cord and turn on the amplifier. Little or no d.c. voltage should be measured, even with the voltmeter switched to the lowest range. If a d.c. voltage is measured, adjust *Zero Adjustment* control *R13* to reduce this voltage as close to zero as possible. If you are unable to obtain a low voltage setting, there is either a wiring error or one of the components is defective. Check out the circuit and/or replace the defective component before going any further.

Second, turn the power off, discharge the filter capacitors, and connect the base and emitter leads of power transistors *Q6* and *Q7*. Connect a milliammeter to a phone plug and insert it into *Bias Jack J2* to measure *Q6*'s collector current. Switch the amplifier back on. Adjust *Bias Control R10* for a reading of 20 mA. Finally, recheck the *Zero Adjustment* control setting.

An important point: be sure that your speaker system is capable of handling 70 watts per channel. Otherwise, you may end up with a puff of smoke and burnt-out voice coils.

Although the amplifier needn't be "babied," it should be installed where there is a reasonable amount of air circulation—this *doesn't* mean near a hot air duct. Conventional installation and interconnection techniques can be used as shown in Fig. 8.

You'll find a preamplifier of comparable quality to match the Brute-70 on page 47. —30—

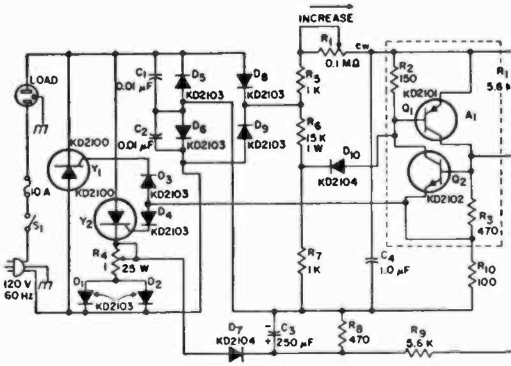
BINARY COUNTER

(*Continued from page* 122)

be fastened to the case with #6 hardware, or can be pop-riveted in place. Switches *S1* and *S2* are mounted with hardware provided. The lamps are held by ½"-o.d. rubber grommets mounted in the holes provided. If a dialplate is used, it can be secured to the cover with the mounting hardware for the push-button switches. A cross-section view of the assembled unit (Fig. 6) shows mounting details of major components. Rubber feet can be attached to the container base.

Operation. Insert the batteries and flip the power switch to *ON*. With each depression of the *COUNT* push button, the binary count is advanced by one. To demonstrate binary addition, clear the binary counter to 000 with the *CLEAR* push button, and press the *COUNT* button to enter your first number. If it's a 2, enter binary 010 by depressing the *COUNT* push button twice. Now enter your second number. If it's a 3, enter 011 by pressing the *COUNT* push button three times. The answer 101 should appear on the readout lamps. —30—

Build your own motor speed control with RCA experimenter Kits



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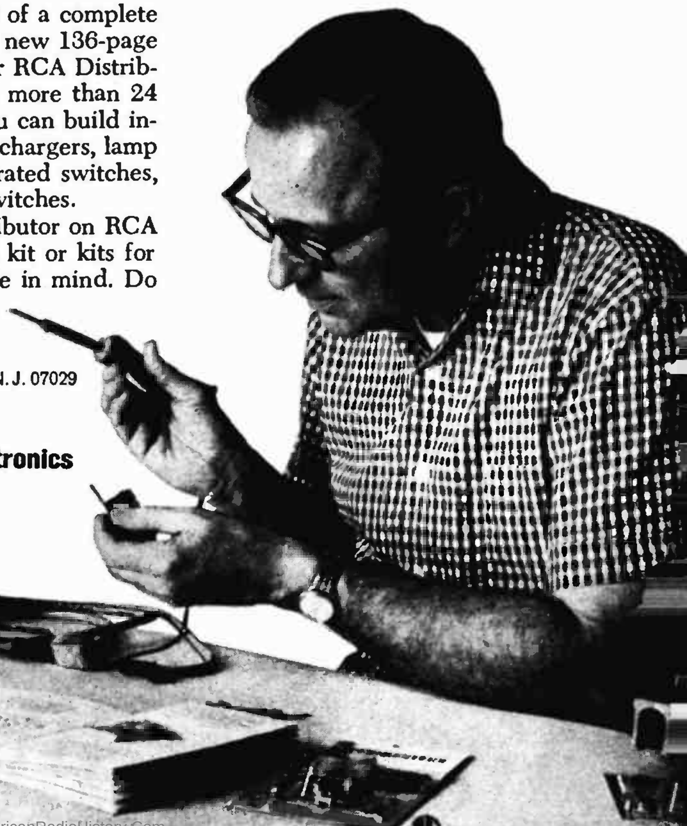


REMOTE CONTROL SYSTEM

(*Continued from page* 12)

immediately, adjust *L1* and *L2* until it does. Use a voltmeter to tune the units for a peak voltage indication across the relay winding. Center the slug in both coils before you start adjusting.

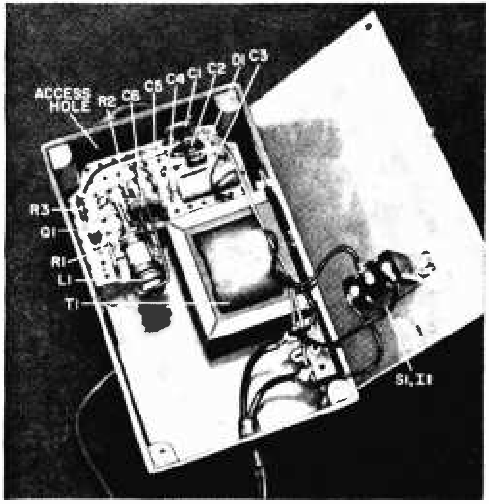


Fig. 4. Transmitter parts layout is not critical, but avoid excessive component lead length to prevent shorts between the a.c. and d.c. voltage sections.

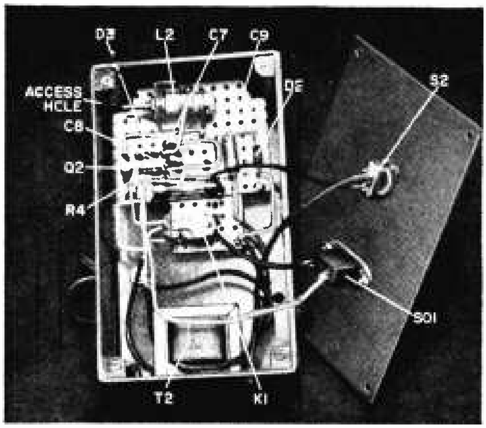


Fig. 5. Breadboard-type layout in receiver is easy to follow and greatly simplifies construction. However, almost any other type of chassis construction can be used. Drill access hole directly in line with tuning screw of coil L2 to tune the unit.

If you do not peak the adjustment with a voltmeter, you can put some distance between the transmitter and receiver and optimize the adjustment. The greater the distance, the more critical the tuning.

If you encounter a situation where the relay will not pull in, try connecting another 0.002-μF capacitor in series with *C7*. —30—

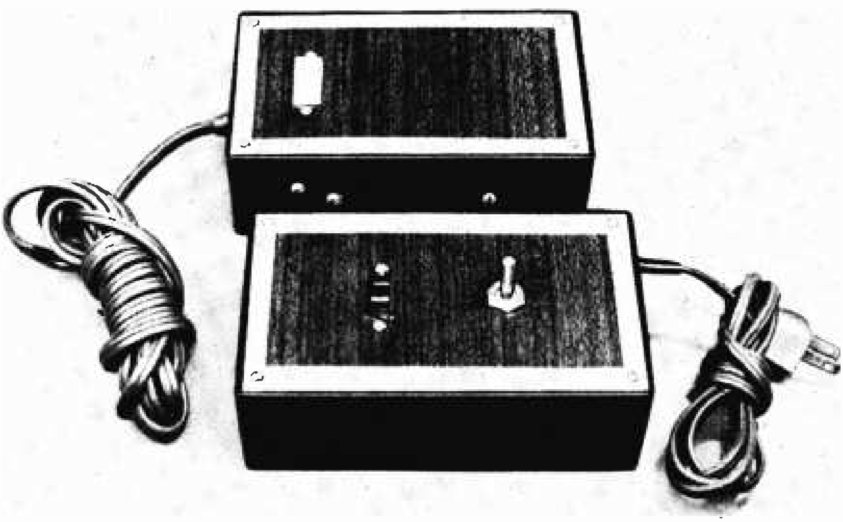


Fig. 6. Matching transmitter (top) and receiver units can add a distinctive touch to your room furnishings if you cover their lids with simulated wood or leather grain adhesive-backed vinyl. Leave about ½" of the metal cover showing or cover the entire lid, whichever blends with your room decor and suits your taste.

VOM RANGE SPLITTER

(*Continued from page* 115)

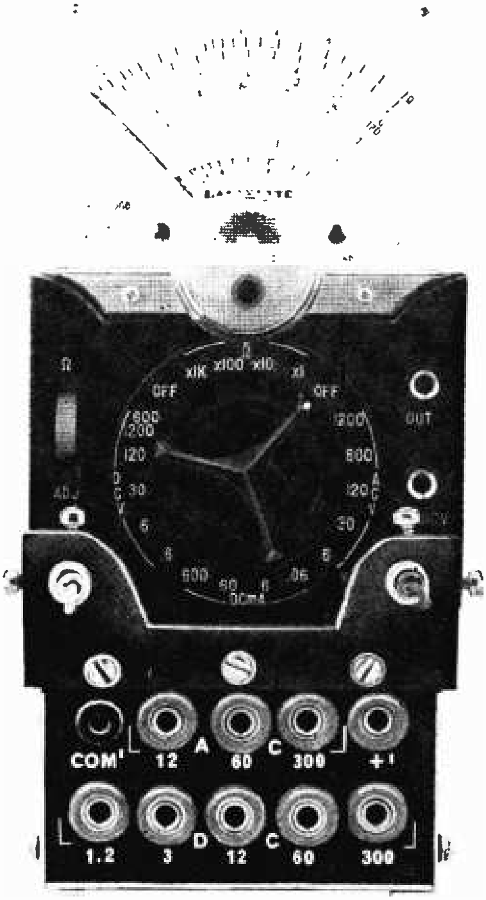


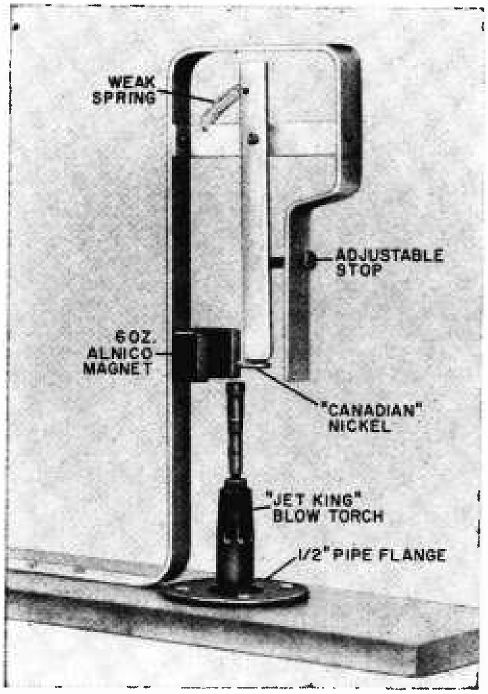
Fig. 5. The VRS adapter can be quickly plugged into the meter. It does not affect normal meter functions and increases number of voltage ranges.

To double the meter's range, say from 30 volts to 60 volts d.c., be sure to set the meter range selector switch to the correct position and plug the test leads into the correct jacks on the VRS as well as to observe proper polarity for d.c. measurements, thus preventing damage to the meter.

The VRS does not in any way permanently modify your VOM. It is an auxiliary device for adding in-between ranges when the occasion demands it, and you can use your meter in the regular way at any time. —30—

THERMOMAGNETIC MOTOR

(*Continued from page* 131)



You can build motor frame with Reynolds stock aluminum, wood board, and pipe flange in half an hour.

alnico magnet, purchased at the local hardware store for $1.25, served the purpose admirably.

Almost any magnetic material can be used for the magnetic rider. Iron is an obvious choice because of its availability (nails, paper clips, and a host of other common items). However, nickel is better since it has a much lower Curie temperature. But don't bother trying to use United States nickels—they are made of a non-magnetic nickel-copper alloy. However, Canadian nickels are quite magnetic and will work very well.

A limitless number of variations of the basic thermomagnetic motor can be devised. A few of Nikola Tesla's variations can be seen in his patent drawings. Tesla was granted two patents (numbers 396,121 and 428,057) for his invention of the thermomagnetic motor, copies of which can be obtained for 50 cents each from the Commissioner of Patents, Washington, D.C. -30-

CB "AUDIO LEVELER"

(*Continued from page* 58)

Testing and Adjustment. The Audio Leveler can be tested and adjusted with the aid of an oscilloscope, or by direct on-the-air transmissions.

If a scope is employed, it must be connected as in Fig. 7 (a demodulator probe could also be used in the test lead between transmitter and scope if one is available.) With the transmitter turned on, adjust potentiometer *R9* for maximum undistorted output on the oscilloscope while you talk into the microphone at a distance of from 6 to 12 inches. If the circuit has been properly adjusted, the signal level on the scope

The circuit board can be mounted externally, or put inside the transmitter cabinet. It is shown here installed in a Heathkit Model GW-14 transceiver. The input of the "Leveler" was designed to match a Turner 333 microphone. If you use another mike, it may be necessary to eliminate C2 to cut bass.

will show only a negligible increase when you talk into the mike from a closer distance.

The other test method is to have another CB'er monitor your transmissions while you slowly advance the setting on *R9*. When your monitor detects a deterioration of speech quality, back off slightly on the adjustment until the quality is restored. This is the proper setting. -30-

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ELECTRONIC magazine project **KITS.** TV, Radio, HiFi, Service **MANUALS,** $1. Technical Services Associates, Box 1167, Berkeley, Calif. 94701.

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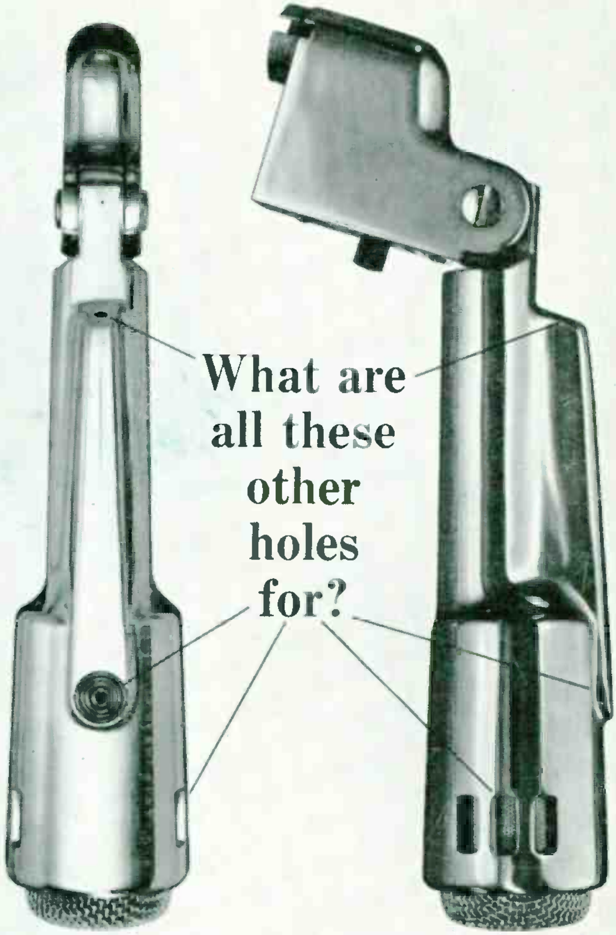
CIRCLE NO. 7 ON READER SERVICE CARD

If the Electro-Voice Model 664 picks up sound here...



What are all these other holes for?

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