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HANDBOOK

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More than 5 million two-way transmitters have skyrocketed the demand for service men and field, system, and R & D engineers. Topnotch licensed experts can earn \$12,000 a year or more. You can be your own boss, build your own company. And you don't need a college education to break in.

HOW WOULD YOU LIKE to earn \$5 to \$7 an hour... \$200 to \$300 a week ... \$10,000 to \$15,000 a year? One of your best chances today, especially if you don't have a college education, is in the field of two-way radio.

Two-way radio is booming. Today there are more than five million two-way transmitters for police cars, fire trucks, taxis, planes, etc. and Citizen's Band uses—and the number is growing at the rate of 80,000 new transmitters per month.

This wildfire boom presents a solid gold opportunity for trained two-way radio service experts. Most of them are earning \$5,000 to \$10,000 a year more than the average radio-TV repair man.

Why You'll Earn Top Pay

One reason is that the U.S. doesn't permit anyone to service two-way radio systems unless he is licensed by the FCC (Federal Communications Commission). And there aren't enough licensed experts to go around.

Another reason two-way radio men earn so much more than radio-TV service men is that they are needed more often and more desperately. A two-way radio user *must* keep those transmitters operating at all times, and *must* have them checked at regular intervals by licensed personnel to meet FCC requirements.

This means that the available li-

censed expert can "write his own ticket" when it comes to earnings. Some work by the hour and usually charge at least \$5.00 per hour, \$7.50 on evenings and Sundays, plus travel expenses. Others charge each customer a monthly retainer fee, such as \$20 a month for a base station and \$7.50 for each mobile station. A survey showed that one man can easily maintain at least 15 base stations and 85 mobiles. This would add up to at least \$12,000 a year.

How to Get Started

How do you break into the ranks of the big-money earners in two-way radio? This is probably the best way:

1. Without quitting your present job, learn enough about electronics fundamentals to pass the Government FCC License. Then get a job in a two-way radio service shop and "learn the ropes" of the business.

2. As soon as you've earned a reputation as an expert, there are several ways you can go. You can move out, and start signing up your own customers. You might become a franchised service representative of a big manufacturer and then start getting into two-way radio sales, where one sales contract might net you \$5,000. Or you may be invited to move up into a high-prestige salaried job with one of the same manufacturers.

The first step—mastering the fundamentals of Electronics in your spare time and getting your FCC License—can be easier than you think.

Cleveland Institute of Electronics has been successfully teaching Electronics by mail for over thirty years. Right at home, in your spare time, you learn Electronics step by step. Our AUTO-PROGRAMMED™ lessons and coaching by expert instructors make

everything clear and easy even for men who thought they were "poor learners." You'll learn not only the fundamentals that apply to all electronics design and servicing, but also the specific procedures for installing, troubleshooting, and maintaining two-way mobile equipment.

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How to get into one of today's hottest money-making fields—servicing 2-way radios!



He's flying high. Before he got his CIE training and FCC License, Ed Dulaney's only professional skill was as a commercial pilot engaged in crop dusting. Today he has his own two-way radio company, with seven full-time employees. "I am much better off financially, and really enjoy my work," he says. "I found my electronics lessons thorough and easy to understand. The CIE course was the best investment I ever made."



Business is booming. August Gibbenmeyer was in radio-TV repair work before studying with CIE. Now, he says, "we are in the marine and two-way radio business. Our trade has grown by leaps and bounds."

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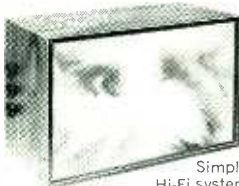
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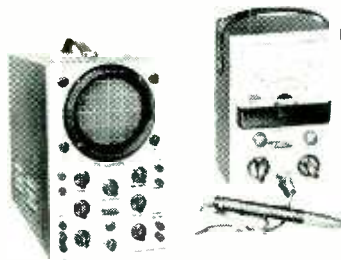
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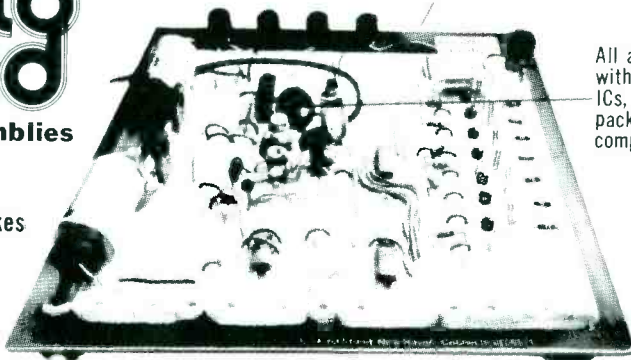
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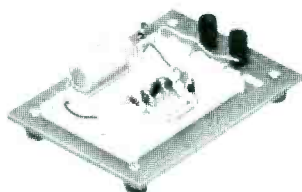
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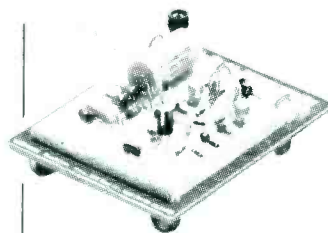
Proto Board 100. 10 IC capacity breadboard kit, includes all components, down to nuts, bolts, screws and instructions.

19⁹⁵



Proto Board 203. Built-in regulated short-proof 5V, 1-AMP power supply. 2 extra floating 5-way binding posts. 24-14 pin DIP capacity. 9 $\frac{3}{4}$ " long x 6 $\frac{1}{2}$ " wide x 2 $\frac{3}{4}$ " high. All metal construction.

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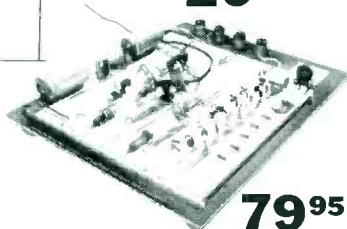
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CIRCLE NO. 1 ON READER SERVICE CARD

BUILD THE MONODIGICHRON

This unique electronic clock uses only a one-digit readout and displays hours and minutes in sequential form.

BY MICHAEL S. ROBBINS

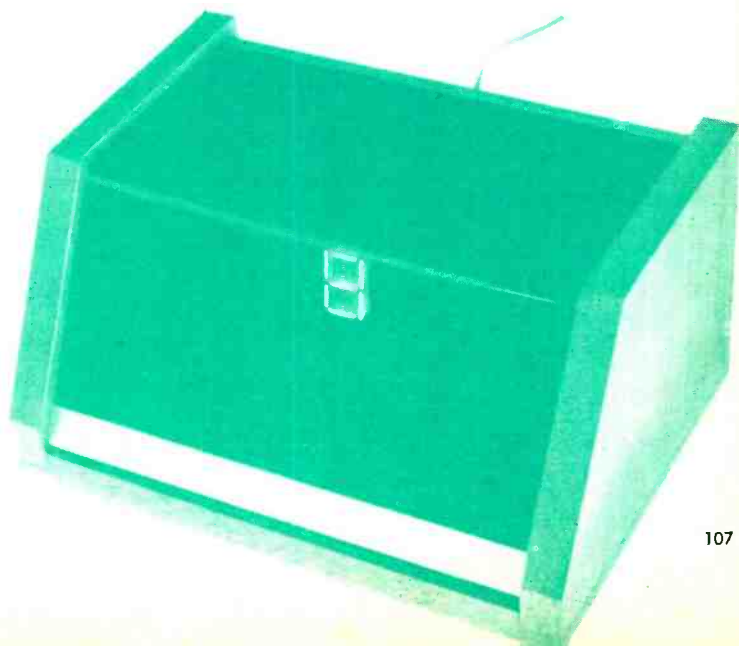
THE Monodigichron is a true electronic digital clock featuring sequential display of tens of hours, hours, tens of minutes and minutes on one seven-segment readout device. Instead of displaying all four digits continuously in a static presentation, the Monodigichron dynamically flashes the hours and minutes in sequence at a rate of about fifteen times per minute.

The circuit uses the latest LSI-MOS integrated circuit for positive synchronization to the 60-Hz power line frequency. Two pushbuttons (fast and slow) are provided for initial time setting.

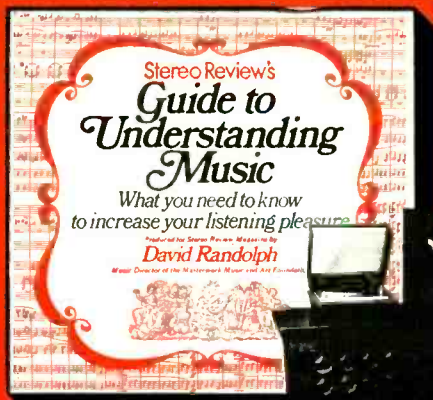
The large, bright, incandescent readout tube allows the Monodigichron to be read in total darkness as well as in brightly lit rooms. The display is all electronic and therefore completely silent. Because the readout is a bright filamentary type, any color filter may be used.

Power for the clock is supplied by a molded, plug-in transformer which is U. L. approved.

Circuit Design. A block diagram of the clock circuit is shown in Fig. 1, while the schematic is in Fig. 2. As in most ac digital clocks, the time base is the 60-Hz power-line frequency which is applied to a shaping circuit (*D10*, *D11*, *R9*, *R10*, and *C2*) for squaring and removal of transients. An array of flip-flops within *IC2* counts the 60-Hz input and provides one output pulse for every 60 input pulses (1 Hz). A binary coded decimal counter (BCD) totals the 1-Hz pulses and provides four output lines for display of the seconds count. (Though the seconds are not displayed in the clock described here, they are counted in the IC.) A fifth line provides one pulse every 10 seconds for the tens-of-seconds BCD count-



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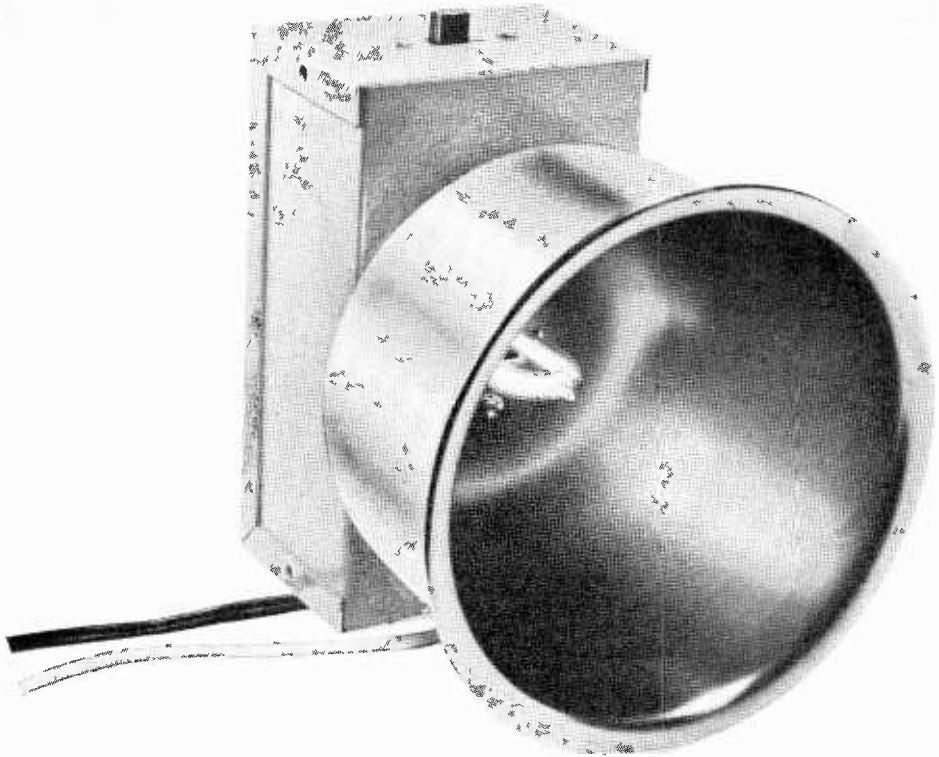
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CIRCLE NO. 9 ON READER SERVICE CARD



UNIVERSAL STROBE GOES PSYCHEDELIC

BY JAMES CUCCIA

- EXCITES DANCERS
- STOPS MOTION
- TAKES PICTURES
- TIMES ENGINES

EDITOR'S NOTE

Medical opinion concerning the use of strobe lighting in darkened rooms is "cautionary." Prolonged use may induce hallucinations or trigger undesired side-effects. It should not be used in the presence of anyone subject to epilepsy.

ONE OF THE MOST interesting of the new "turned on" type of lighting effects is strobe lighting. By using a strobe light system flashing at the proper rate in a semi-darkened room, a visual flicker effect similar to that found in old-time movies can be seen as people walk or dance in the light of the flash. Since the action seems to take place as a series of "still" frames, a very unreal atmosphere can be created.

The "Universal Psychedelic Strobe" described in this article will not only be the hit of your next party, but can also earn its keep by performing other, less glamorous duties. It will serve as an auto-



Fig. 2. Actual-size printed circuit board. You can make the board yourself or purchase it (see Parts List). If you make your own board, drill the holes as shown.

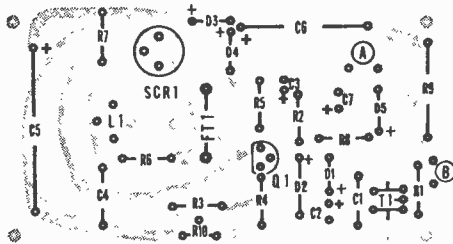
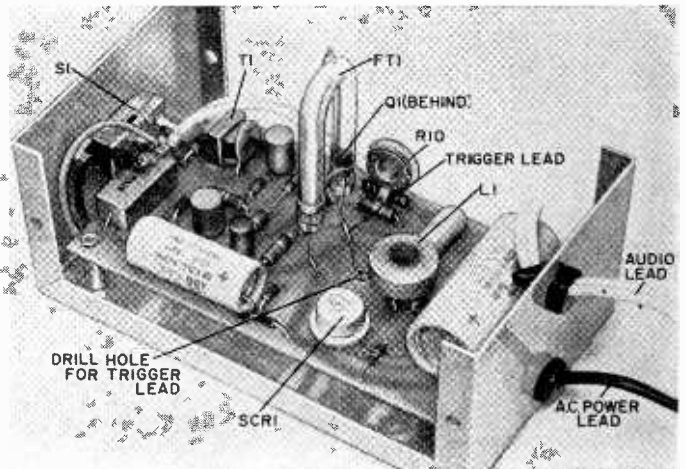


Fig. 3. Component mounting for the strobe. The terminals marked "B" are for the audio input, those marked "A" for power input. Some flash tubes will trigger more consistently if R6 is left out of the circuit. To do this, simply wire a jumper in place of R6. Simultaneously, it may be useful to drop R7 value to 100,000 ohms, or below.

Fig. 4. The finished strobe before the top cover and reflector are assembled. Note that a hole must be drilled in the PC board to accommodate the lamp trigger.



Be especially careful when installing the strobe tube as it is fragile and it cannot withstand mechanical shock. The flashtube is polarized. The end of the tube with the mesh attached to the wire inside the tube must be connected to the ground side of circuit.

HOW IT WORKS

The heart of the strobe is a low-cost xenon flashtube that can be operated from a 250- to 300-volt d.c. voltage source. This voltage is produced by a voltage doubler consisting of *D3*, *D4*, *C5*, and *C6*, with *R9* limiting the surge current flow. However, the flashtube will not fire until its trigger electrode is provided with a 3000-volt pulse, which is generated in a "flyback" type pulse generator consisting of auto transformer *L1* and *SCR1*.

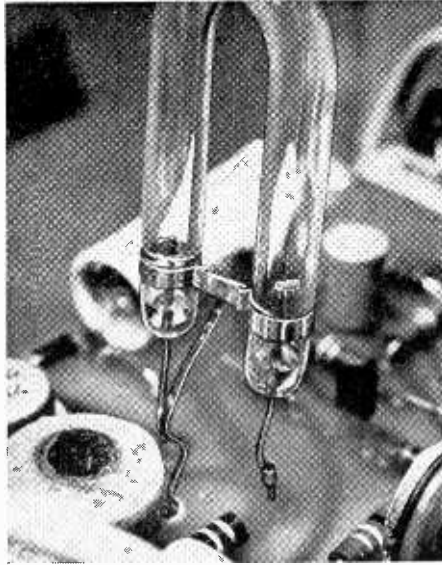
When the power is first turned on, the SCR is in its non-conducting state; thus *C4* is allowed to charge up to the power supply potential. If the gate of the SCR is furnished with a positive-going trigger pulse, the SCR goes almost instantaneously into conduction and allows *C4* to discharge through the lower end of inductor *L1*. The auto transformer action of *L1* produces a 3- to 4-kV pulse at its high-voltage end which triggers the flashtube on.

The SCR is triggered by unijunction transistor *Q1*. This UJT is connected as a conventional relaxation oscillator in which *C3* discharges through the UJT every time the voltage across *C3* exceeds the firing potential of the UJT. The rate of charge of *C3* is determined by potentiometer *R10* and series resistor *R3*. As *R10* is set to a higher voltage, capacitor *C3* reaches the required firing voltage faster, making the UJT oscillate at a faster rate. The positive-going pulses generated at the UJT *B1* lead put the SCR into conduction.

Once the SCR conducts, the voltage at its anode momentarily drops to zero, allowing the SCR to switch to its non-conducting state, and be ready for the next gate trigger pulse. Supply voltage for the UJT is obtained from a separate power source (consisting of diode *D5*, resistor *R8*, and filter capacitor *C7*) to prevent the sudden current surge produced by the flashtube from firing the transistor.

To make the flash rate follow a given audio level, transformer *T1* isolates the strobe from any external grounds (remember that it is a line-operated device), and couples the UJT circuit into an audio amplifier. The audio signal applied to *T1* is rectified by diodes *D1* and *D2*, and the resulting d.c. is applied through *R2* to the emitter of the UJT. Capacitor *C3* is also charged by a voltage generated by the input signal. If *R10* is set properly, every time that the d.c. on the emitter reaches the required firing voltage, the UJT triggers, producing a flash.

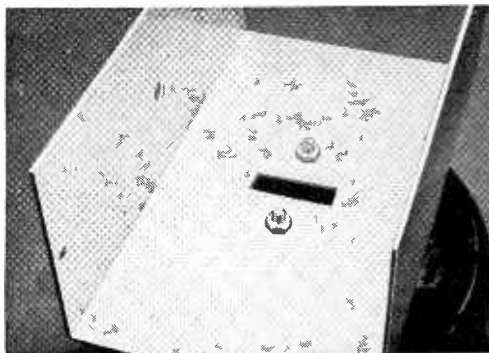
Cut a slot in both cover and reflector so that tube can easily slip through. Be careful also when installing cover or the tube, or its leads, may be damaged.



surface similar in size to that made in the enclosure cover. Bolt the reflector to the metal cover, carefully aligning the two slots. Now, still being very careful, mount the cover-reflector combination on the remainder of the enclosure.

Operation. Point the strobe reflector so that it will not flash directly into your eyes. Connect the power lead to a source of 117 volts a.c. and turn on *S1*. A slight rotation of *R10* should start the flash operating. The frequency of the flash is dependent on the setting of *R10*.

To make the strobe follow a musical beat, connect the audio leads in parallel
(Continued on page 20)





MOTOR SPEED CONTROLLER

By CHARLES M. LENNY

*VARIABLE SPEED
AT
FULL TORQUE*

You can win at slot-car racing, extend battery life of variable-speed toys, get more recording time on your battery-powered tape recorder, and be able to control the speed of a great variety of d.c. motor driven devices if you build this low-cost d.c. motor controller. When used as a slot-car speed control, you can keep the car at full speed until you hit the corners, then you can rapidly reduce speed to avoid spinning out—it is an axiom of slot-car racing that the highest controllable speed in the corners wins races. A built-in electronic brake makes sure that when power is removed from the car motor, the speed will reduce and the car will not hurtle through the corner and off the track.

When not used for slot-car racing, the

controller can be used with any battery driven toy that incorporates a speed control (usually a rheostat)—simply substitute the controller for the rheostat. By making this substitution, the power that formerly was wasted in heating the rheostat (I^2R losses) will be saved and battery life will be greatly lengthened.

Another application is to slow down the recording time of low-cost, battery-powered, portable tape recorders. Although the frequency response suffers and the motor pulsations can be heard on the tape, you can increase the available recording time by as much as three times that formerly obtained. Although music reproduction is far from ideal, speech frequencies are sufficient for recording speeches, interviews, etc.

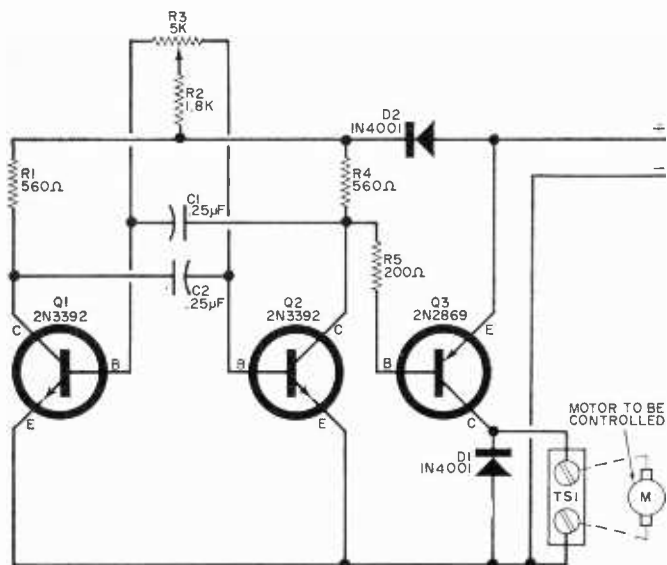


Fig. 1. The motor speed controller applies d.c. voltage to miniature motors in short pulses. The width of the applied pulse determines the speed of rotation of the motor armature. A wider pulse applies more voltage per unit of time and the speed is increased. A narrow pulse works in the opposite fashion—less voltage delivered to the motor.

PARTS LIST

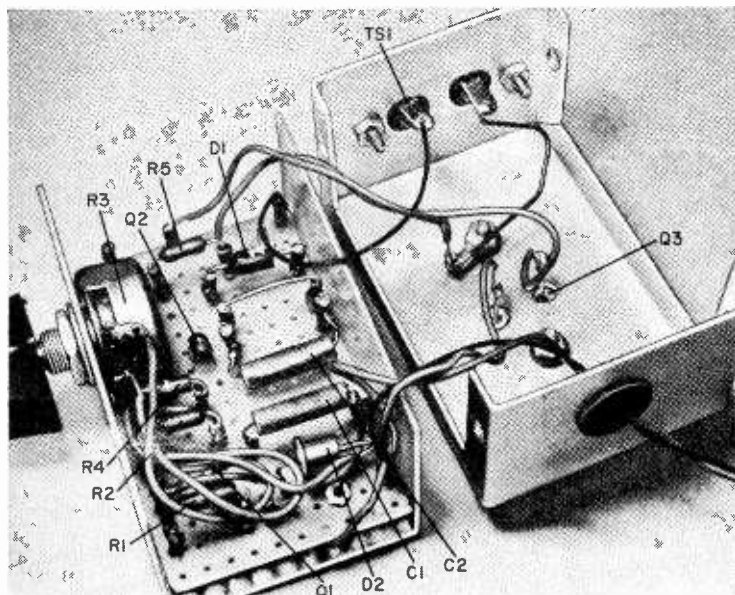
C1, C2—0.22- μ F tantalum electrolytic capacitor
D1, D2—1N4001 diode
R1, R4—560-ohm, $\frac{1}{2}$ -watt resistor
R2—1800-ohm, $\frac{1}{2}$ -watt resistor
R3—5000-ohm, 2-watt linear potentiometer
R5—200-ohm, $\frac{1}{2}$ -watt resistor

Q1, Q2—2N3392 transistor
Q3—2N2869 transistor
TS1—two-terminal strip

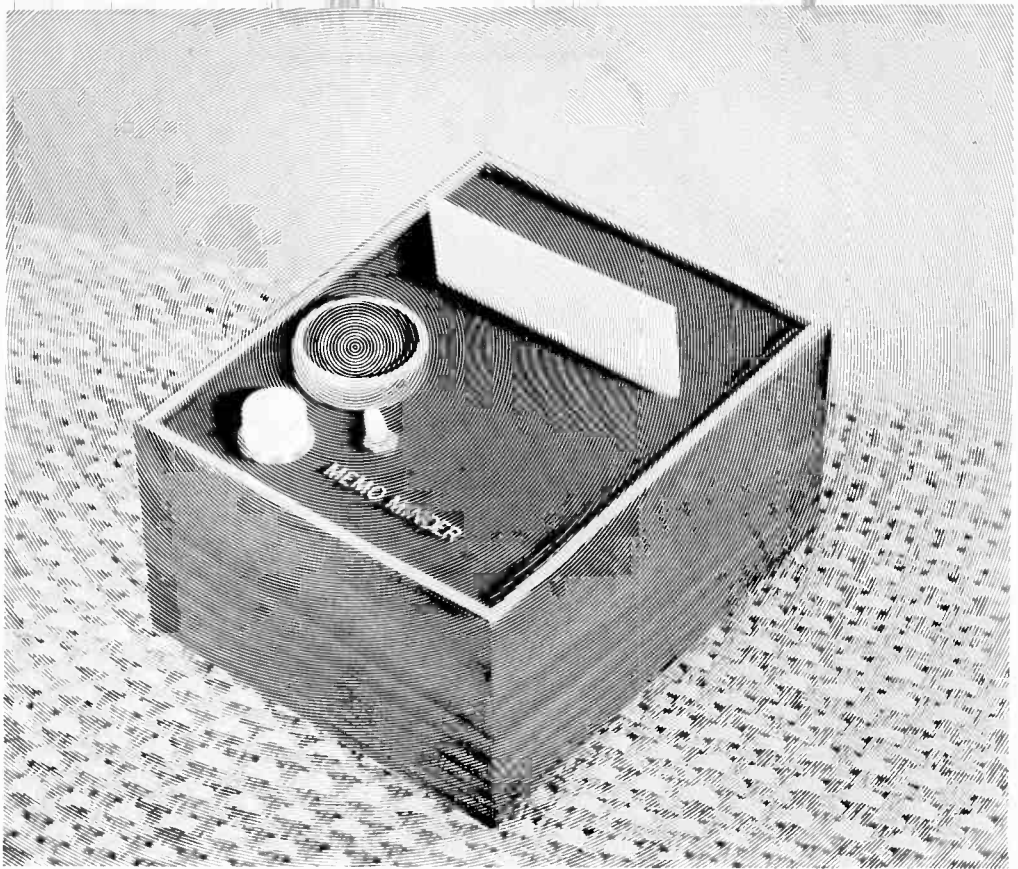
Misc.—Power transistor insulated mounting hardware and mica insulating sheet, silicone grease (optional), metal box, spacers (4), perf board, rubber grommet, wire, solder, etc.

Construction. The author elected to build up the schematic of Fig. 1 using perf-board construction as shown in Fig. 2. Parts layout is not critical, and almost any variation will be satisfactory. Note that power transistor *Q3* is not mounted

on the board. Cut a piece of perf board to a size that will easily fit into the metal case that you select. Stand the board off the case using a spacer at each of the four corners. Make sure that no part of
(Continued on page 153)



The author built his own speed controller in an ordinary aluminum metal box. The circuit is assembled on a perf-board.



BUILD YOUR OWN **MEMO MINDER**

URGENT NOTES AND TELEPHONE MESSAGES
MAKE THEMSELVES KNOWN

By **R. PERSING***

WHAT EXCUSE does your wife give when that important phone message—which arrived just after you left—goes unseen and unanswered? Was the message plainly visible, or hidden under some old newspapers? Did your wife forget to hang it on your tackboard or message clip? If you have this problem—and what family doesn't—the "Memo Minder" is for you!

To leave a short written message, simply write it on a 3" x 5" card and drop it into the slot of the Memo Minder. Automatically, the Memo Minder senses the presence of the message and a bright lamp starts flashing at a rate of about once-per-second. The lamp will keep flashing as long as the card is in the message slot, and only when the card is removed will the Memo Minder go back to sleep.

If you're not likely to see the flashing light, the recipient of the message can turn on a Sonalert alarm—its insistent

*RCA Laboratories, Princeton, N. J.

PARTS LIST

A1—Audible alarm such as Mallory Sonalert SC628A (optional)
C1—1000- μ F, 25-volt electrolytic capacitor
C2—100- μ F, 15-volt electrolytic capacitor
D1—1N3255 diode
I1—#50 lamp
I2—#44 lamp
Q1—Unijunction transistor (Texas Instruments T1S43)
R1—20-ohm, $\frac{1}{2}$ -watt resistor
R2—10,000-ohm, $\frac{1}{2}$ -watt resistor
R3—1500-ohm, $\frac{1}{2}$ -watt resistor (nominal value—see text)
R4—68-ohm, $\frac{1}{2}$ -watt resistor
R5—430-ohm, $\frac{1}{2}$ -watt resistor
R6—Photoresistor (Clairax CL505L photocell)
S1—S.p.s.t. switch (optional)
SCR1—2N3528 silicon-controlled rectifier (RCA)
T1—Power transformer; primary, 117 volts; secondary, 12 volts CT
I—3" x 4" x 5" metal box
Misc.—Line cord, $\frac{1}{2}$ " inside-diameter plastic tube, sockets for I1 and I2 (see text), material for paper guides, flat black paint, vector board, screws, glue, etc.

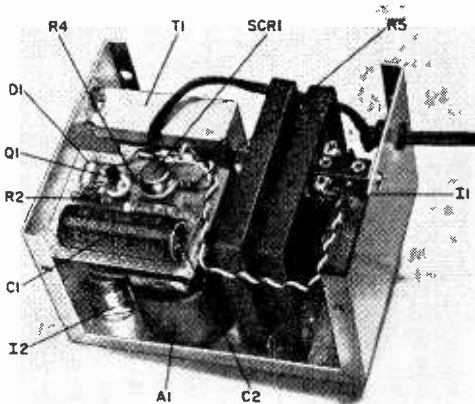


Fig. 3. The perforated circuit board is secured to the side of the chassis with a small L-bracket. Resistor R1 is mounted directly on bulb I1's socket.

when dark, its resistance is very high. When R6 is in the dark, as would be the case when a message card is in the Memo Minder, essentially it does not influence the circuit and the transistor oscillates normally. However, with no message in the Memo Minder, R6 is illuminated by I1, reducing its resistance, and the total base-1 to ground resistance, to a very low value. With the circuit in this state, R2 supplies just enough current to the emitter junction to prevent Q1 from returning to its reverse-biased emitter-base-1 state necessary for continued oscillation.

Resistor R3 in the base-2 leg of Q1

may require a slight alteration in value to compensate the circuit for the particular unijunction transistor and SCR used. This adjustment will be described later.

Lamp I1 is supplied with power through dropping resistor R1, which produces about 4 volts across the normally 7.5-volt bulb. Although the light output is reduced, it is still sufficient to operate R6, and bulb life is greatly extended.

Message indicator lamp I2 is connected in series with SCR1 across the 12-volt a.c. supply. To make the lamp glow, the SCR must be turned on. This is accomplished by supplying the SCR gate electrode with a positive-going pulse (with respect to its cathode) during the part of the a.c. sine wave when the SCR anode is supplied with a positive voltage. The gate is generated, as previously described, across R5.

Once the SCR is gated on, it will remain on until the a.c. waveform on its anode passes through zero (as occurs during each cycle of the power line sine wave). As the gate pulse is longer than the a.c. cycle, the SCR will turn on and off at a 60-Hz rate for the duration of the gate pulse, but this will have no noticeable effect on the bulb operation. When the gate pulse stops, the next time that the anode alternation passes through zero, the SCR automatically shuts itself off, and remains off until the gate pulse is re-introduced.

Construction. Begin construction by preparing two paper guides, which can be made from plastic, metal, or any other suitable material. The author used the cover from a plastic box for each of the guides, with the rim of each cover providing a convenient means for mounting. Although dimensions are not critical, those indicated in Fig. 2 should be adhered to as closely as possible. The plastic tube used to house photoresistor R6 is glued to one paper guide and tilted at an angle of approximately 15 degrees to minimize the effect of stray room light. The photoresistor is very sensitive and any light reflected onto it will cause the flasher to stop even when there is a piece of paper in the slot.

Once the guides are cut to size, holes drilled for bulb I1 and the tube, and provisions made for mounting them in the box, they should be painted with a

flat, black paint. Be sure to paint both the inside and outside of the tube.

When the glue and paint have dried, *R6* should be inserted in the end of the tube and held in place with a dab of glue. The paper guides should be temporarily mounted in the box and the socket for *I1* should be bent and oriented so that it will be in line with the tube housing *R6*. There should be enough space left in the box to mount the remainder of the components as shown in Fig. 3. The socket for *I2* must be an enclosed type so it will not interfere with the proper operation of the photoresistor.

The power supply consists of *T1*, which has a center tapped 12.6-volt secondary, rectifier *D1*, and filter capacitor *C1*.

The circuit can be built on a small piece of vector board or a printed circuit can be made. Sockets for *Q1* and *SCR1* are not absolutely essential but, if possible, should be used. Layout of the components is not at all critical but be sure to refer to the base diagram for *Q1* and *SCR1* when wiring the circuit.

Adjustment. It is advisable to temporarily insert a 5000- to 10,000-ohm potentiometer in place of *R3*. Turn on the power and adjust the potentiometer until proper operation of *I2* is obtained—when a piece of paper is put into the slot, bulb *I2* should flash about once a second. Improper operation would be indicated by *I2* staying on all of the time, or not flashing at all. When the piece of paper is removed, the light should flash once and then remain off.

While you're making this adjustment, be sure there isn't any bright light shining on the open box since this might adversely affect the proper operation of *R6*. Once the proper value of *R3* has been determined and an equivalent-valued fixed resistor has been wired into the circuit, the Memo Minder is complete. If desired, a Sonalert alarm (*A1*) and associated on-off switch *S1* can be included as shown in Fig. 1.

Plug in the Memo Minder, and when it wants you, it will let you know. —30—

READ

Popular Electronics

PSYCHEDELIC STROBE

(Continued from page 14)

with a loudspeaker voice coil, turn down the audio output, and adjust *R10* until the flash just stops firing. As the volume is turned up, the flash will start to follow the major beat of the music, producing one flash for each beat. When an audio amplifier is played at very loud volume, it may be necessary to bridge the audio output with a potentiometer to provide the strobe with enough signal to fire, but not enough to overload.

To use the strobe as an auto timing light, ground one of the audio leads to the engine and connect a 5-megohm resistor in series with the other one. Solder a small piece of insulated wire to the far end of the resistor, and wrap several turns around the number-one spark plug lead. Set *R10* until the flash just stops when the engine is not running. Now start the engine. Every time the number-one plug fires, it will cause the strobe to fire. If the strobe does not fire, it may be necessary to connect the far end of the resistor directly to the spark plug.

To use the strobe as a slave flash unit for your camera, connect one audio input to one side of the camera switch, and the other audio input to a 1½-volt flashlight cell in series with the other side of the camera switch. Set *R10* so that the strobe doesn't self-trigger. Every time the camera switch is operated the unit will flash. If the flash does not put out enough light for some photography purposes, the value of *C5* can be increased somewhat. This capacitance value should not be changed if the unit is being employed as a psychedelic strobe, as the higher light output will shorten the flashtube life.

To use the strobe as a mechanical motion stopper, *R10* can be adjusted until the motion being observed seems to be stopped. If major use of this mode of operation is desired, it is possible to remove *R10* from the circuit board and to replace it with a conventional potentiometer mounted on the metal enclosure as the speed control; the potentiometer shaft should have a pointer knob attached to it and a dial can be made and calibrated against known speeds. —30—



BY W. T. LEMEN

Build a Stopclock

ELECTRONIC TIMER
TURNS ON OR
TURNS OFF AT
ANY PRESET
INTERVAL FROM
ONE SECOND
TO TEN
MINUTES

“TIMING IN” or “timing out” makes no difference to the “Stopclock.” Easy to build, simple, and reliable, it is accurate enough for most photography, game, or other hobby purposes, turning lights or low-wattage appliances on or off, or for any other use where accurate timing between one second and 10 minutes is required.

Unlike most other electronic timers, this circuit (see Fig. 1) uses a transistor constant-current generator to charge the timing capacitor (*C1*). The rate is relatively linear over most of its charging curve. Since the rate of charge of the capacitor is independent of voltage, overall timing is not seriously affected by the normal variations in the 117-volt a.c. power line. Timing errors of less than 5% can be expected.

To increase the timing versatility, a second load outlet (*SO2*, shown connected by dotted lines in Fig. 1), can be tied to the unused contacts of the relay (*K1*) so that contact is made when the relay is energized.

Construction. The circuit, including the power supply, can be assembled on a 3½”

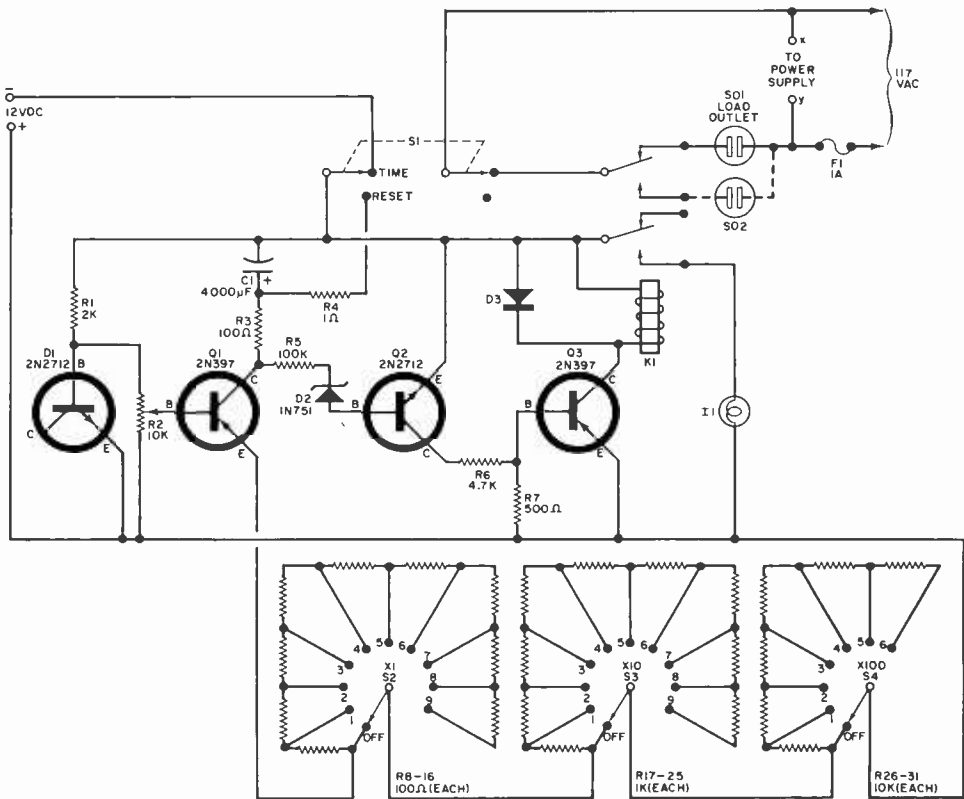
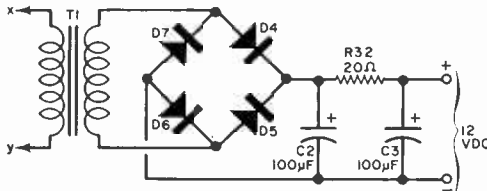


Fig. 1. The Stopclock circuit uses an R/C time base, but the charging current is at a constant rate. Details on circuit operation appear on page 47. Note optional connections to a second a.c. outlet (SO2) which is activated when the Stopclock is turned on and shuts off when the selected timing interval has been reached—just the reverse of the normal operation (SO1).



PARTS LIST

- C1*—4000- μ F, 15-volt electrolytic capacitor (Mallory 1540A, or similar)
C2, C3—100- μ F, 25-volt electrolytic capacitor (Sprague TE1211, or similar)
D1—2N2712 transistor (only base and emitter used)
D2—1N751 zener diode
D3-D7—750-mA, 200-volt rectifier diode
I1—14-volt indicator lamp, with mounting (preferably red window)
K1—D.p.d.t. relay, 12 volts, 80 mA (Potter & Brumfield KM11D, or similar)
Q1, Q3—2N397 transistor
Q2—2N2712 transistor
R1—2000-ohm, $\frac{1}{2}$ -watt resistor
R2—10,000-ohm potentiometer
R3—100-ohm, $\frac{1}{2}$ -watt resistor
R4—1-ohm, 1-watt resistor (value not critical)
R5—100,000-ohm, $\frac{1}{4}$ -watt resistor
R6—4700-ohm, $\frac{1}{4}$ -watt resistor
R7—500-ohm, $\frac{1}{4}$ -watt resistor
R8-R16—100-ohm, $\frac{1}{4}$ -watt resistor
R17-R25—1000-ohm, $\frac{1}{4}$ -watt resistor
R26-R31—10,000-ohm, $\frac{1}{4}$ -watt resistor
R32—20-ohm, 5-watt resistor
S1—D.p.d.t. toggle switch
S2, S3, S4—1-pole, 12-position, non-shorting rotary switch (Mallory 32112J, or similar)
SO1, SO2—Chassis-mounting a.c. socket (Cinch-Jones 2R2 or similar; SO2 is optional—see text)
T1—Filament transformer: primary, 117 volts; secondary, 12 volts (Stancor P-8391)
 Misc.—5 $\frac{1}{4}$ " x 3 $\frac{1}{2}$ " perforated circuit board; metal cabinet of suitable dimensions; a.c. line cord; hardware; dialplates (2 Mallory 389, 1 Mallory 386); solder, wire, etc.

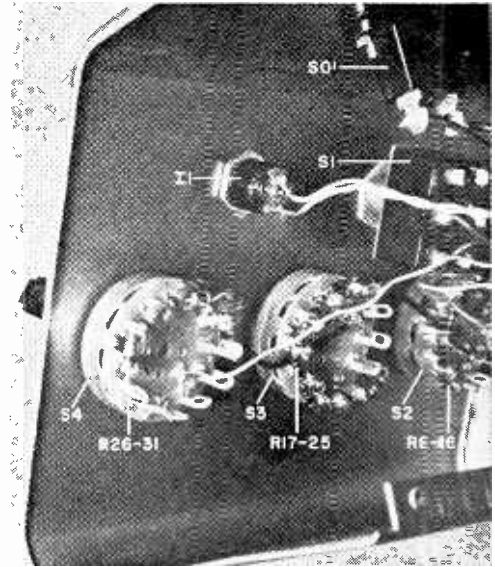
HOW IT WORKS

Constant-current transistor *Q1* has its base voltage controlled by the base-emitter junction of *D1* (actually a 2N2712 transistor without a collector connection). This voltage is applied to *Q1* via timer-calibrate potentiometer *R2*. The collector current of *Q1* is determined by the value of resistance placed in *Q1*'s emitter lead.

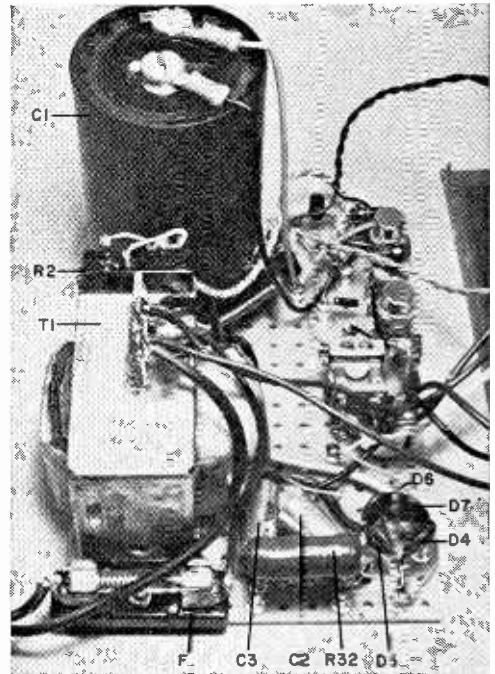
This resistance value is selected by *S2*, *S3*, and *S4*, and the circuit has been arranged so that each 100 ohms of resistance added to the emitter of *Q1* equals one second of time. A look at the schematic will show that each step of *S2* adds 100 ohms of resistance; therefore, it can set up to nine seconds. The values of *S3* are one decade larger; therefore, it can set from 10 to 90 seconds. Switch *S4*, still another decade higher, can set from 100 to 600 seconds. By combining switch settings, it becomes possible to insert from one to 699 seconds (11.65 minutes) into the timer. If, perchance, all three timing switches were to be set to their zero state, the current through *Q1* would become excessive, and it is for this reason that limiting resistor *R3* is added to the circuit.

When *Reset-Time* switch *S1* is in the *Reset* state, timing capacitor *C1* is completely discharged by *R4*, and the circuit to the load is opened. When *S1* is placed in the *Time* position, and a time has been selected via *S2*, *S3*, and/or *S4*, the load is supplied with voltage through contacts of *S1* and relay *K1*. Simultaneously, timing capacitor *C1* starts to charge.

As the voltage across *C1* exceeds the break-over point of zener diode *D2* (about 4.5 volts), current flows through *R5* and *D2*, causing transistor *Q2* to saturate. This transistor, in turn, turns on power transistor *Q3*, energizing the coil of relay *K1*. The relay closes, breaks the circuit to the external load, and turns on front-panel indicator lamp *I1* to show that the timing has been completed. Diode *D3*, across the *K1* coil, effectively suppresses the transient high-voltage spikes that are generated across the coil when the current suddenly starts and stops.



Timing resistors *R8* through *R31* are soldered to the terminals of rotary switches *S2*, *S3*, and *S4*. If you use 5% resistors, cut the wire leads short, but use a minimum amount of heat to make connections.



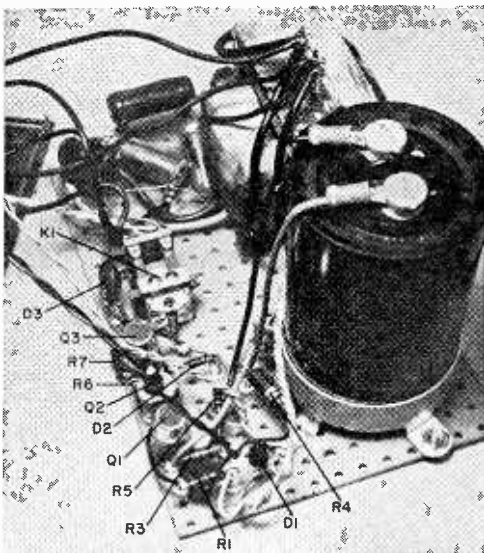
Any layout plan convenient to the builder can be used to duplicate construction of the Stopclock. The author used perforated phenolic board because the circuit was totally enclosed in a metal cabinet.

x 5¼" piece of perforated circuit board. Although the author used a sloping panel cabinet (as shown in photo at right), any other type of cabinet can be used. Mount the *Reset-Time* switch, *S1*, indicator lamp *I1*, and the three timing switches *S2*, *S3*, and *S4* on the front panel. The controlled outlet(s) is mounted on the top surface of the cabinet. No input power on/off switch is provided, because when the unit is not actually timing, power consumption is negligible.

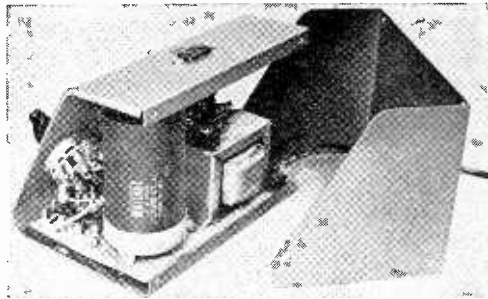
All resistors in the time-setting circuit are $\pm 10\%$, sorted for 1% tolerance between values. Precision ($\pm 1\%$) resistors can be used if price is not the main consideration.

No heat sinks are required for the semiconductors specified. However, if you attempt to build a timer of great precision, the transistors can be heat-sinked for better temperature stabilization.

Calibration. After completing the timer and inspecting it for correct wiring, plug it into a 117-volt a.c. power line. Adjust potentiometer *R2* to about center range and place the three timing switches in the zero position (one detent below 1).



Parts placement is not critical in circuits like the Stopclock. Point-to-point wiring using small terminals and transistor sockets proved convenient for the author. As mentioned in the caption to the photo above, the size of *C1* is larger than need be for this project. Use any metal enclosure to house your duplication of this unusual timer project.



The author managed to squeeze everything in a Bud sloping panel aluminum box (Type AC-1612). A phenolic board bearing most of the wiring is supported away from the metal bottom of the box with short insulating spacers. Size of the box used will be determined by the physical size of charging capacitor *C1*. A smaller and cheaper capacitor can be used at *C1*. Investigate the Sprague 36D or 39D series electrolytics stocked by some industrial parts suppliers.

When switch *S1* is placed in the *Time* position, the indicator lamp (*I1*) should come on instantly.

Leaving timing switches *X1* (*S2*) and *X100* (*S4*) in the zero position, set the *X10* (*S3*) switch to position 6 (60 seconds or one minute). Place *S1* in the *Time* position and adjust *R2* until the indicator lamp turns on at exactly one minute.

Most timing errors will occur in the time periods over five minutes. If more accuracy is desired, the 10,000-ohm resistors that make up the *X100* range will have to be independently adjusted as required.

Operation. Connect the "Stopclock" to a 117-volt a.c. source and place the *Reset-Time* switch in the *Reset* position. Connect the load to be controlled to the *Load* outlet socket, then set the *X1*, *X10*, *X100 Seconds* switches to the desired number of seconds. For example, to set up for 4 minutes, to set up for 4 minutes, put the *X100* switch at position 2 and the *X10* switch at position 4. For 7 minutes and 15 seconds, put the *X100* at position 4, the *X10* switch at position 3, and the *X1* switch at position 5 (total: 435 seconds).

If you wired your model to include a "time-out" provision, the timing function remains the same, but the a.c. output connections will work in reverse. Place the *Reset-Time* switch at *Time* and the "Stopclock" will automatically "time out" to the desired interval. -30-

BUILD...

SIMPLE-MINDED "MAGGIE"

...AN ELECTRIC MOTOR WITH A WARPED,
COIL-LESS ARMATURE

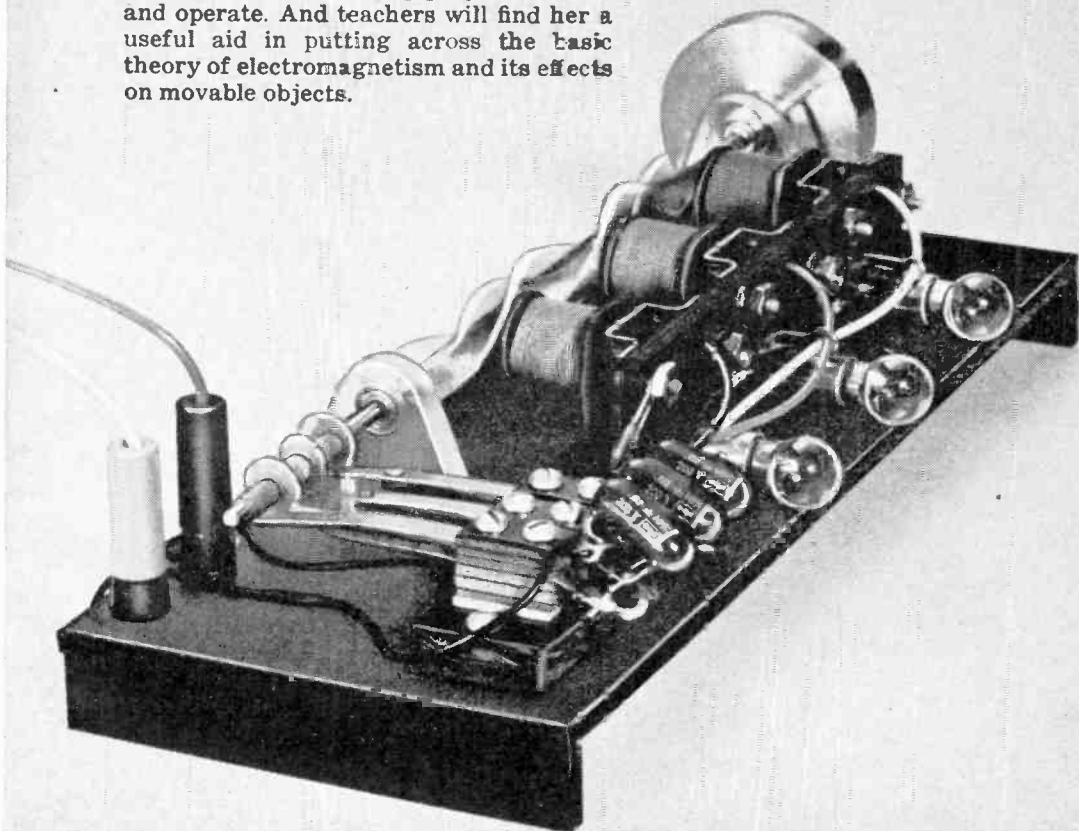
MAGGIE" IS A SIMPLETON. Her "brain" is made up of three ordinary electromagnets salvaged from a couple of door bells. For "brawn," she gets by with a twisted piece of soft, flat iron substituting for an armature.

A weird-looking contraption, *Maggie* "swears" she's a genuine, bona fide, homemade universal electric motor destined to be the "sweetheart" at your next Science Fair. For she can operate with either a.c. or d.c. power—no batteries, please—without the use of rectifiers or converters!

Students of science or electricity will find *Maggie* a rewarding project to build and operate. And teachers will find her a useful aid in putting across the basic theory of electromagnetism and its effects on movable objects.

*Science Fair
Winner*

By **DAVID GIERKE**



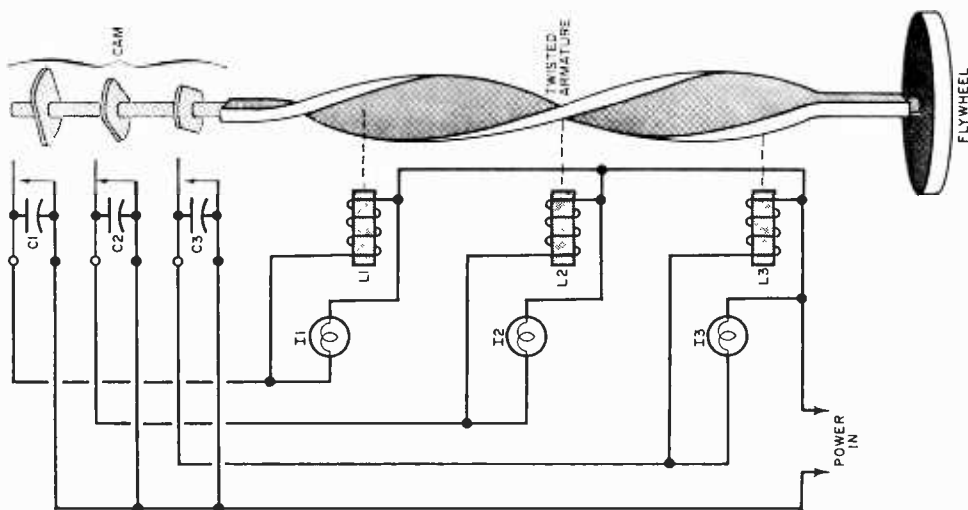


Fig. 1. Each of the cams on the twisted armature is related to a respective electromagnet to pulse the power at a precise time in order to generate maximum torque and speed while the armature is rotating.

How "Maggie" Works. The twisted armature motor operates on the basic principle of magnetic attraction. Three electromagnets (see Fig. 1) are employed in a series-aiding arrangement to provide the magnetomotive force required to drive the armature. The electromagnets are of the 6- to 12-volt variety supplied with ordinary house bell buzzers, and are aligned on a common plane.

In operation, the electromagnets are energized through a set of three commutator contacts which are alternately activated by the rotating cam fingers positioned on the armature drive shaft. To suppress arcing, capacitors *C1*, *C2*, and *C3* are bridged across respective pairs of contact terminals. Lamps *I1*, *I2*, and *I3*, each in parallel with a coil, add to the appearance of the project but are not essential to the operation of the motor. The armature, made from a flat piece of soft iron that is twisted 360 degrees, is mounted in close proximity to the poles of the electromagnets and perpendicular to them.

The electromagnets behave exactly like bar magnets with north and south poles at opposite ends. The magnetic flux traveling outside the core from the north to the south pole cuts across the armature, attracts the nearest edge of the arma-

PARTS LIST

- C1, C2, C3*—0.02- μ F, 200-volt ceramic capacitor
- I1, I2, I3*—General Electric #57 lamp, or similar
- 1— $1\frac{1}{8}$ "-diameter steel flywheel
- 1— $\frac{3}{8}$ "-wide x 6"-long strip of $\frac{1}{8}$ "-thick soft iron
- 1—12" x 12" sheet of $\frac{3}{16}$ "-thick plexiglass—see text
- 1—Motor armature—see text
- 2—Insulated banana plugs and jacks
- 3—Lamp sockets
- 3—6-12 volt electromagnets—see text
- 3—Sets of telephone relay contacts—see text
- 1— $\frac{1}{2}$ "-wide x 6"-long strip of $\frac{1}{16}$ "-thick sheet iron or heavy-gauge tin for brackets
- Misc.—Fiber discs (3), fiber spacers (3), wire, solder, #6 hardware, small ball bearings (2), power supply—6- or 12-volt filament transformer or d.c. or a.c. power supply

ture and causes it to rotate. The speed of rotation will be essentially proportional to the field strength of the electromagnets and the applied power.

To reduce friction and thereby increase efficiency and motor speed, the armature is mounted on ball bearings. A flywheel is also used to provide the necessary momentum to keep the armature rotating smoothly once it has started to turn.

Construction. The motor frame is built from $\frac{3}{16}$ "-thick plexiglass, although hardwood lumber can be used if plexiglass is not readily available. Dimensions for the

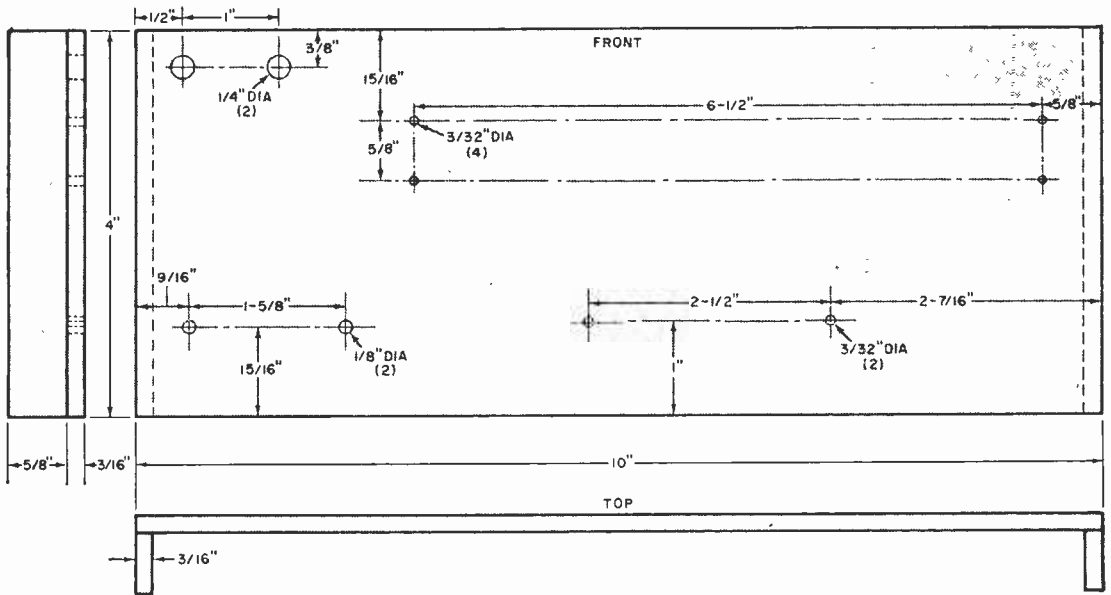


Fig. 2. The base and supports are fabricated from plexiglass and bonded together with epoxy or other type of strong plastic cement. Two pieces of plastic are used to build up the commutator support.

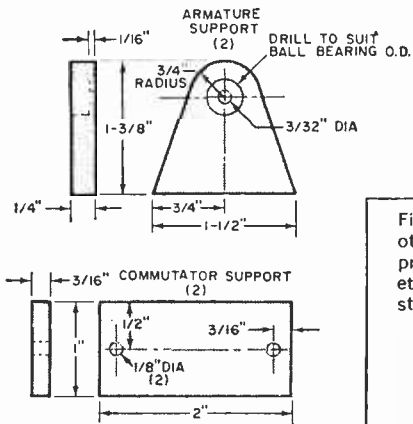
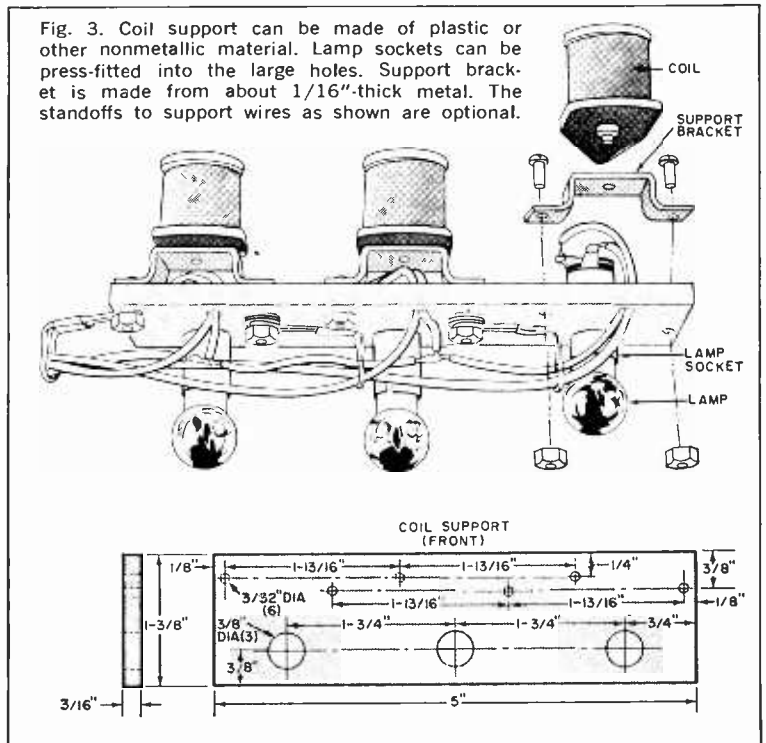


Fig. 3. Coil support can be made of plastic or other nonmetallic material. Lamp sockets can be press-fitted into the large holes. Support bracket is made from about 1/16" thick metal. The standoffs to support wires as shown are optional.



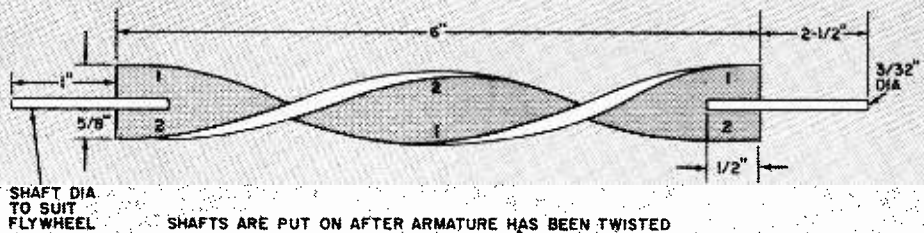


Fig. 4. The lengths of the shafts on each end of the soft iron armature should be long enough to accommodate the flywheel on one end (about 1"), and the cams and spacers on the other end (about 2 1/2").

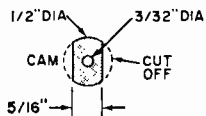


Fig. 5. Either plastic or fiber material can be used for the cams and spacers. The inner diameters of each must be small enough to require a tight press-fit to prevent slippage. Thickness of the cams is not critical.

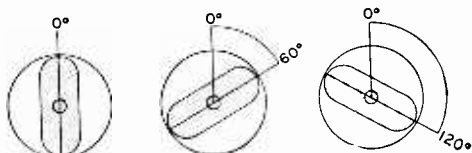
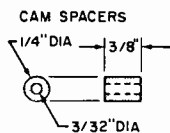
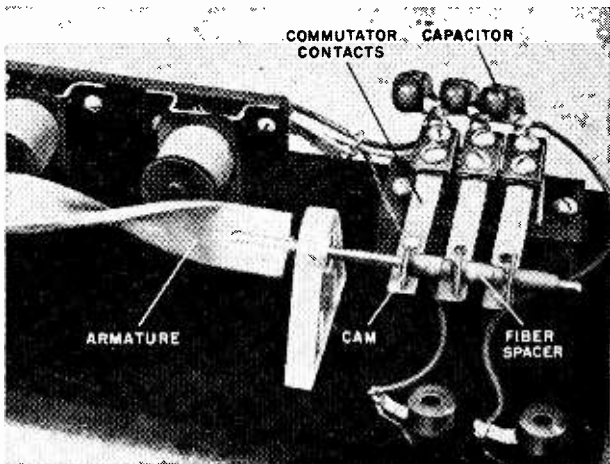


Fig. 6. Each cam should be oriented on the shaft as shown. The switches should close just as the portion of the armature's edge comes within range of the respective electromagnets. Irregularities in the twist of the armature can be compensated for by only minor adjustment of each of the cams.

base and supports are shown in Fig. 2. Any three similar iron core coils of suitable power and flux rating can serve as the electromagnets. However, the solenoids used with home-type bell buzzers are quite satisfactory for this application, and are relatively inexpensive. In addition, they are available at practically all hardware and electrical supply stores. Since you'll need three coils, you should get two standard buzzers—each is equipped with two coils.

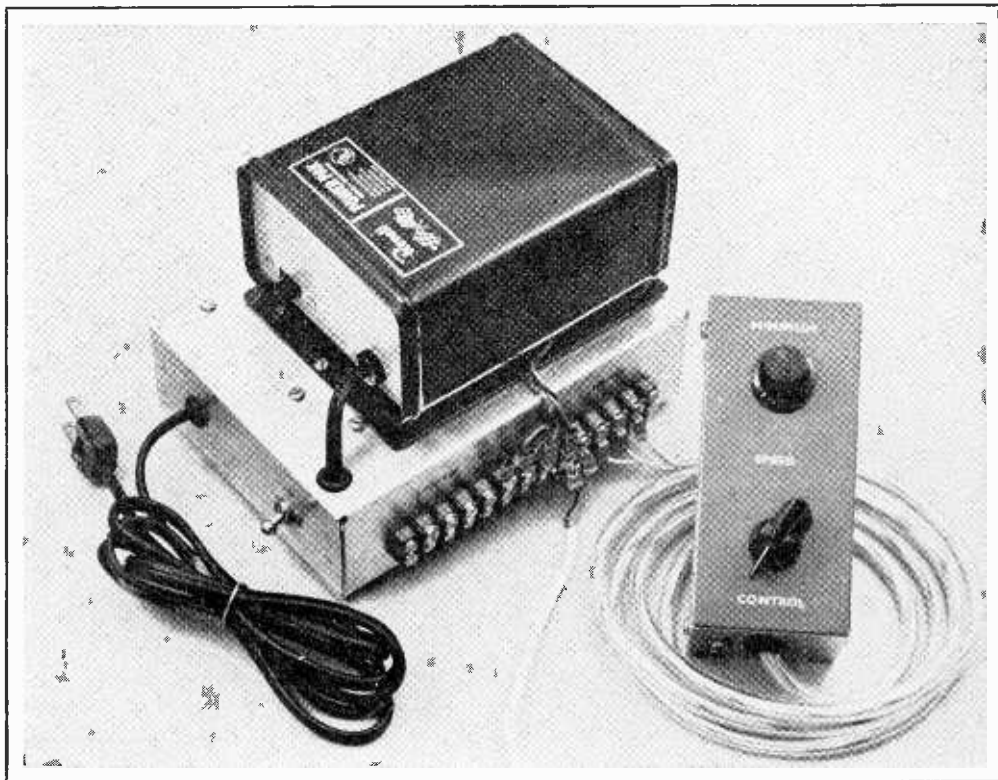
After each solenoid is removed from the buzzer, it is mounted on its metal support bracket (see Fig. 3) by simply pressing the core piece into the hole provided. Each coil bracket is then mounted on the plexiglass support along with the three lamp sockets.

Fig. 7. Space the cams along the shaft so that they activate their respective switches. Armature must be mounted slightly above the cores of the electromagnets in order to obtain maximum torque and eliminate the possibility of "locking" action.



The armature is fabricated from a 5/8"-wide x 6"-long strip of 1/8"-thick soft iron twisted as shown in Fig. 4; aluminum or other non-ferrous metal *cannot* be used. You can start with a strip about 2' long. Put one end in a vise and attach a long wrench on the other end. Twist the strip until you wind up with 1 complete revolution (360°) within a 6" length. Mark this piece off and use a hacksaw to cut away the unused portions. Cut a notch on each end as shown.

After the armature has been formed, it is fitted with a shaft at either end as shown. The shaft can be welded on or simply slipped into the notch and flattened to form a tight fit. Observe that the diameter of the shaft depends on the
(Continued on page 34)



Modern

Slot-Car Controller

ANY SPEED AT MAXIMUM TORQUE
WITH ELECTRONIC BRAKING AS A BONUS

BY BRIAN C. SNOW

IF YOU are a slot-car racing enthusiast, you probably have lost your patience with the conventional hand control. Although these hand controls *can* be mastered, they frequently cause more trouble than they are worth. If, however, you are both a slot-car and electronics enthusiast, you can build an electronic speed controller which will give you complete control over your slot car—at all times—at speeds ranging from a slow crawl to all-out.

Unlike rheostat control of motor speed which wastes power in heating the rheostat and loses motor torque, the pulse

method of power control used in this controller is very efficient and produces a wide range of slot-car motor speed control *with* optimum motor torque at all speeds. As a bonus, this circuit includes an efficient electronic brake.

The speed controller described in this article contains two electronic assemblies on the same PC board, so that one assembly controls two tracks independent of each other, with each track having its own hand controller. A common power supply handles both assemblies.

The controller is connected between your conventional track power supply

TWO CIRCUITS REQUIRED, ONE FOR EACH CAR TO BE CONTROLLED.

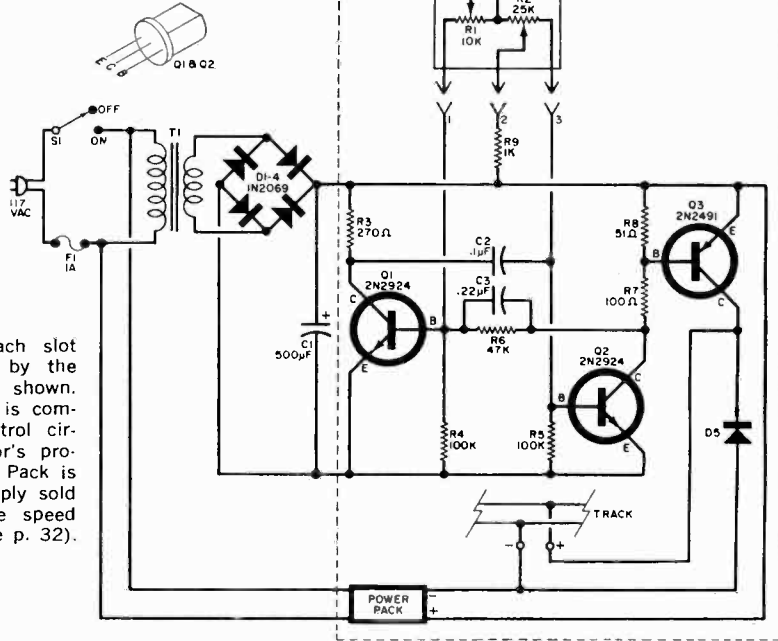
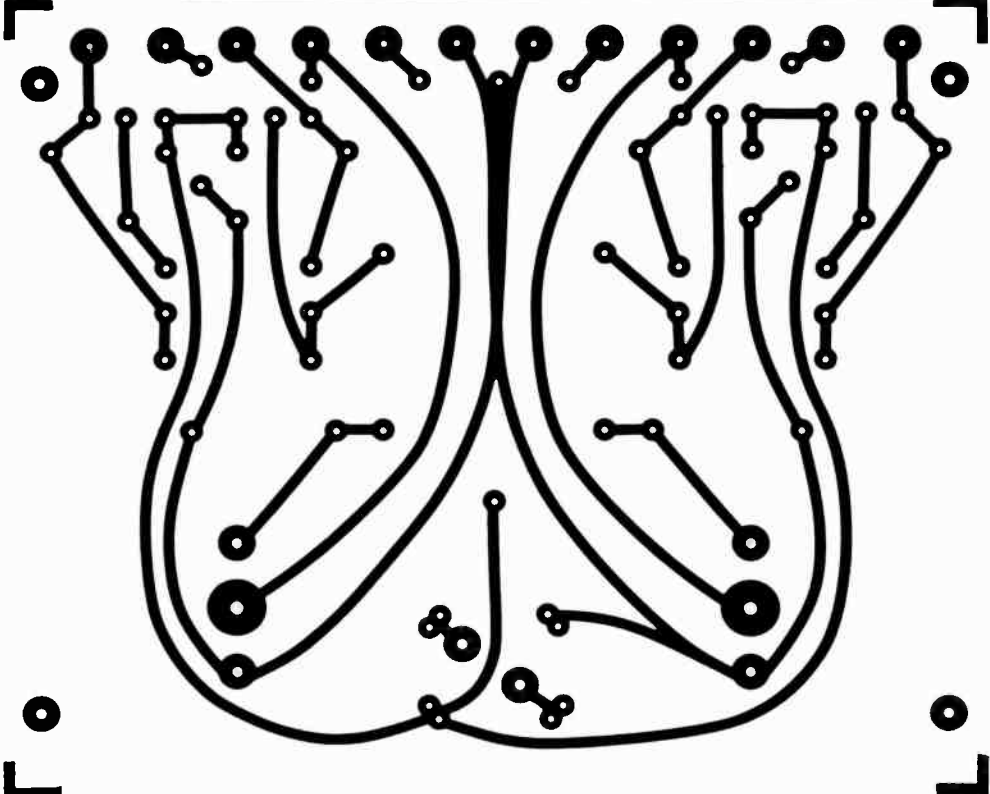


Fig. 1 (right). Each slot car is controlled by the 3-transistor circuit shown. The power supply is common to both control circuits in the author's prototype. The Power Pack is the usual d.c. supply sold for slot cars. The speed control is new (see p. 32).



PARTS LIST

- C1*—500- μ F, 25-volt electrolytic capacitor
C2—0.1- μ F capacitor (2 needed)
C3—0.22- μ F capacitor (2 needed)
D1, D2, D3, D4, D5—1N2069 diode (6 needed)
F1—1-ampere fuse with holder
Q1, Q2—2N2924 transistor (4 needed)
Q3—2N2491 transistor (2 needed)
R1—10,000-ohm linear taper potentiometer (2 needed)
R2—25,000-ohm linear taper potentiometer (2 needed)
R3—270-ohm, $\frac{1}{2}$ -watt resistor (2 needed)
R4, R5—100,000-ohm, $\frac{1}{2}$ -watt resistor (2 needed)
R6—47,000-ohm, $\frac{1}{2}$ -watt resistor (2 needed)
R7—100-ohm, 1-watt resistor (2 needed)
R8—51-ohm, $\frac{1}{2}$ -watt resistor (2 needed)
R9—1000-ohm, $\frac{1}{2}$ -watt resistor (2 needed)
S1—S.p.s.t. switch
T1—Power transformer: primary, 117 volts a.c.; secondary, 6.3 volts a.c., 0.6 ampere
 1—5" x 7" x 2" metal chassis
 2—5" x 2 $\frac{1}{4}$ " x 2 $\frac{1}{4}$ " metal boxes
 1—12-terminal barrier strip (Cinch-Jones 12-140-Y or similar)
 4—#6 x $\frac{1}{4}$ " x $\frac{1}{2}$ " standoffs
 Misc.—Solderless crimp terminals, $\frac{1}{4}$ "-i.d. rubber grommets, knobs, cable clamps, 6-32 screws, 10-32 nuts and washers to mount both Q3's, line cord, decals, wire, solder, etc.

The circuit board and heat sinks are available for \$3, and a complete kit for \$25, both postpaid, from Brian Snow, Box 228D, RR2, Russiaville, Ind. 46979.

HOW IT WORKS

The output of transformer *T1* is full-wave rectified by *D1* through *D4*, while capacitor *C1* acts as a filter. The remainder of the circuit is in duplicate, one for each track. Only one track system is discussed in the following paragraphs.

Transistors *Q1* and *Q2*, together with their associated components, make up a multivibrator whose oscillation rate is determined by the setting of potentiometers *R1* and *R2*. Variation in the setting of these potentiometers causes the multivibrator to oscillate from zero to a median of 400 Hz. The output of *Q2* is directly coupled to control transistor *Q3*, causing *Q3* to switch on and off in step with *Q2*.

The d.c. output of the power pack (usually supplied with the slot-car track as a means of powering the cars) has its negative lead connected directly to one track, and its positive lead connected to the other track through series transistor *Q3*. Therefore, the slot-car track will receive power only when *Q3* is turned on.

When the multivibrator is operating at a high repetition rate, the track is supplied with a series of narrow power pulses. When the multivibrator is operating at a slower rate, the track receives a series of wider power pulses. The inertia of the slot-car integrates these power pulses so that the narrow pulses represent a simulated throttle reduction (with high torque, however), while the wider pulses represent a simulated throttle opening.

Diode *D5* protects *Q3* and simultaneously acts as an electronic brake for the car being controlled. During the intervals when *Q3* is turned off, the track receives no voltage from the power pack. However, the car is still in motion and its motor acts as a voltage generator, feeding an undesired voltage into the track. It is possible for this voltage to reach a value capable of breaking down *Q3*. Diode *D5* acts as a short circuit to this voltage, removing the breakdown danger, while also acting as an electronic fast-acting brake.

and the track proper—no modification is required for most installations. This controller has been used with the Aurora HO and the Revell $\frac{1}{32}$ -scale slot-car sets.

When not used with slot cars, the speed controller can be employed to vary the r/min of any small d. c. motor requiring up to about 30 volts, but not drawing more than 4 amperes in its "worst-case" (usually stalled) condition.

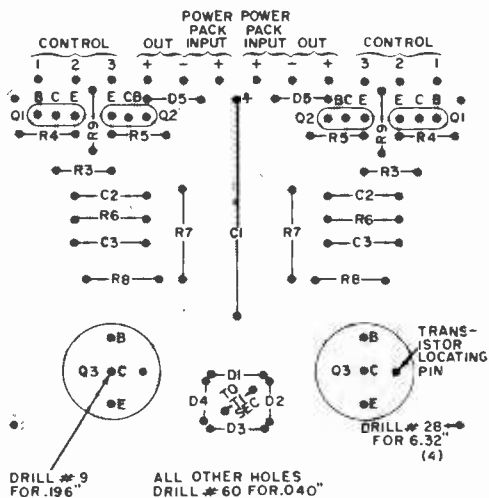
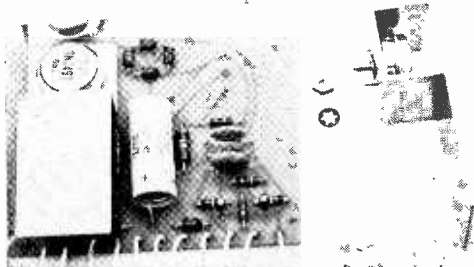


Fig. 3 (above). Component placement for circuit board. Note duplication of parts; one PC board controls two slot cars.

Fig. 2 (left). Actual-size layout of printed circuit board used by author.

Fig. 4 (right). Transistor *Q3* (and heat sink) were temporarily removed from the PC board to show mounting arrangement.



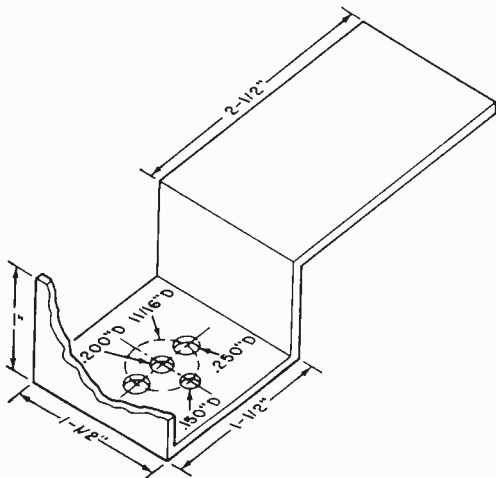


Fig. 5. Drilling and bending details for the heat sinks used at Q3. Cut from aluminum sheet stock.

Construction. The speed controller consists of three sections (see photo on page 29 and Fig. 1): the electronic switcher whose chassis also mounts the track power supply; and a pair of remote speed control units (one for each track) connected to the electronic switcher via lengths of three-conductor cables.

The electronic switcher uses a printed board, the actual-size layout for which is shown in Fig. 2. Figure 3 illustrates the parts layout. Heat sinks for the output transistors (both Q3's) are fabricated as shown in Fig. 5, and a completed PC board is shown in Fig. 4.

When assembling each Q3 and its heat sink, cut off the flat-lip portion of the emitter and base leads to allow the terminals to slip through the heat sink and into the PC board. A 10-32 washer be-

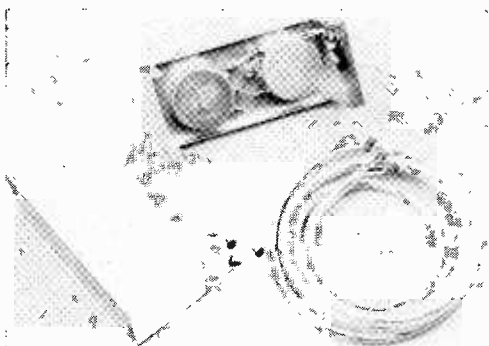


Fig. 6. Speed control is simply two potentiometers.

WHAT IS PULSE POWER?

The d.c. motor in the slot car requires a certain minimum current (from the track power supply) before it starts to rotate and drive the car. At this minimum current point, the motor is barely rotating and has very little torque ("guts"). It is only when the applied motor current exceeds this minimum that it starts to drive solidly.

Many conventional speed controllers use a hand-controlled rheostat (variable resistance) to control motor current—the less the resistance, the faster the motor runs. Unfortunately, at the low motor speeds, the current flow through the rheostat/motor combination is at borderline minimum, thus affecting motor speed, torque, and car handling. This is also the reason why rheostat-controlled cars always start with a "jerk." If the rheostat is released to cut power from the track, the car remains in motion and it coasts until friction brings it to a stop.

Unlike a rheostat controller, the pulse controller described in this article applies full power to the track in the form of short, full-power pulses only a few milliseconds in duration. The motor immediately starts up at full torque, but before it can overcome the slot-car inertia and get going at high speed, the power is shut off as the pulse comes to an end. However, the car does move. A few milliseconds later, another short pulse of power is applied, and the sequence is repeated.

As more and more power pulses are applied (via the speed control potentiometer), the mass of the slot car integrates these motor power spurts into a smooth flow of power, until the car is moving at a rate dependent on how wide the power pulses are and how often they occur. As the pulses become wider, and occur more often, the average motor power increases to the maximum of the track power supply capabilities.

tween the heat sink and the circuit board (on Q3's stud) provides the necessary clearance for the transistor's locating pin. The transistor and heat sink are then mounted to the circuit board.

Mount the printed board assembly within a chassis (5" x 7" x 2") as shown in the photo on page 34, along with transformer T1, fuse F1, power switch S1, and a 12-terminal barrier strip to provide the external connections called for in Fig. 3. Note that 12 holes (approximately 1/4"-diameter) must be drilled in the chassis so that the terminal pins of the barrier strip protrude into the chassis for wiring to their respective points. Use four 1/2" standoffs to separate the PC board from the chassis.

(Continued on page 34)

BUILD A STACKED-ANTENNA AM RADIO

TWO ANTENNAS
CAN BE
BETTER THAN ONE

By ART TRAUFFER

IT IS a well-known fact that you can increase a radio's sensitivity simply by using a better antenna. The technique of stacking two or more antennas in parallel is also well known. Since the ferrite loopstick has taken the place of outdoor antennas, particularly for local reception of AM broadcast programs, why not try stacking two loopsticks?

You can't just connect two loopstick antennas in parallel, however, because these antennas are also used to form the tunable tank circuit at the head end of the radio. When you connect two coils in

parallel, you decrease their total inductive reactance and shift the band of frequencies covered. But, with a little do-it-yourself activity, you can make them work for you. It is necessary only to double the inductive reactance of each antenna, so that the total reactance of the two when in parallel is the same as for the one that would ordinarily be used.

You can build a small two-loopstick radio in about an hour, and at a cost of less than \$5.00.

How It Works. The circuit shown here is that of a simple crystal type radio with one stage of amplification. Coils *L1* and *L2* act as the antennas, and connected across *C1*, they form a resonant circuit that can be tuned across the AM broadcast band.

When a signal is picked up by *L1* and *L2*, it is detected by *D1* and capacitively coupled to amplifier stage *Q1*. After amplification, the demodulated signal is fed to the headphones.

Power for the circuit is supplied by a 1/2- or 3-volt battery, *B1*. Resistor *R1* provides forward bias for *Q1*, and allows it to operate as a simple Class A amplifier.

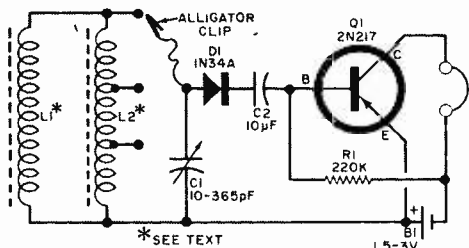
Construction. The best way to build this circuit is to breadboard it. Parts layout is not critical, except for *L1* and *L2* which must be mounted two or three inches apart and parallel to each other for best results.

The antennas, *L1* and *L2*, are wound on 7 1/2"-long by 0.33"-diameter ferrite rods using #24 enameled and cotton-covered wire. Wind 125 turns of wire evenly spaced along the length of the rods. Both coils must be wound in the same direction. As you wind *L2*, strip back the cotton and enamel insulation at several places along the rod and "break out" into small loops, to make the taps. Then use wax or coil dope to hold the wire in place.

No power switch is needed since all you have to do to break the circuit is unplug the headphones from the radio. However, if you decide to wire the headphones directly into the circuit, connect an s.p.s.t. switch in series with either connection to *B1*. Use the alligator clip to select the tap that gives you best reception.

PARTS LIST

B1—1.5- or 3.0-volt battery
C1—10- to-365 pF miniature tuning capacitor
C2—10-μF, 10-volt electrolytic capacitor
D1—1N34A diode
L1, L2—Antenna coils—see text
Q1—2N217 transistor
R1—220,000-ohm, 1/2-watt resistor
Misc.—Headphones, battery holder, hookup wire, etc.



Stacked ferrite core antennas (*L1* and *L2*) provide an AM radio with increased sensitivity to incoming signals. Since the antennas also form part of a tunable tank circuit, they must be specially wound.

SIMPLE-MINDED "MAGGIE"

(Continued from page 28)

i.d. of the ball bearings you select and the flywheel used. Therefore, get bearings that are compatible with the i.d. of the flywheel opening.

The bearings are pressure-fitted into the armature supports and then the armature shafts are pushed into the bearings. Now, screw down the armature supports and mount and secure the flywheel on one end of the shaft. Then pressure-fit fiber cams and spacers on the appropriate end of the shaft. Fabrication details for the cams and spacers are given in Fig. 5. Orient and position these parts on the shaft as shown in Figs. 6 and 7.

The switches used for the commutator are spring-contact types which can be salvaged from old telephone relays. The contact springs should have dimensions of $2\frac{1}{4}$ " in length and about $\frac{1}{4}$ " in width. Relays that have contacts as described can be obtained from most surplus electronics parts stores at low cost. Once the switches are mounted, wire a capacitor across each, and connect the electromagnets and lamps as shown in the schematic drawing (Fig. 1).

Operation. Because *Maggie* is an inefficient old "lady," she consumes a relatively large amount of power and cannot be run from ordinary dry batteries. However, you can use any one of a number of suitable low-voltage power supplies, including a 6- or 12-volt filament transformer, a Variac, or a low-voltage d.c. supply rated at about 20 amperes.

If the armature fails to turn over with at least 6 volts across the electromagnets, adjust the cam followers so that the spring contacts will make and break contact as the armature rotates.

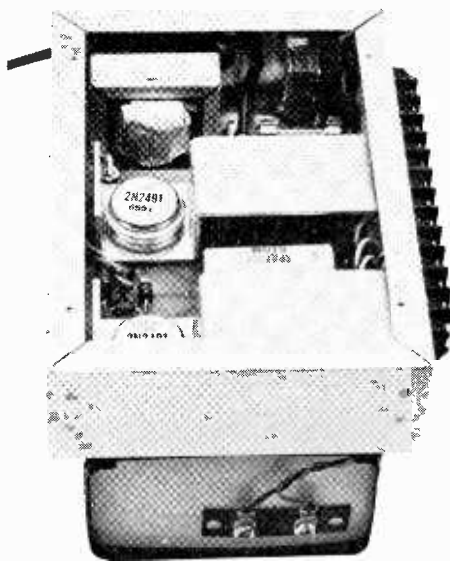
If you want the motor to run faster, adjust the position of the cams just as you would advance and retard a set of ignition points. Minor adjustments can make a big difference, and compensate for irregularities in the twist of the armature. You can also get more speed by increasing the operating voltage—but be sure not to exceed the power limits of the electromagnets. —50—

SLOT-CAR CONTROLLER

(Continued from page 32)

Each hand-control assembly (see Fig. 6) consists of *R1* and *R2* mounted within a $5" \times 2\frac{1}{4}" \times 2\frac{1}{4}"$ metal box with the two potentiometers wired as shown in Fig. 1.

Interconnecting Sections. Each hand-control assembly is interconnected to the main chassis via a convenient length of



In this underchassis view, PC board has been put in place and leads brought out to a 12-tag strip.

three-conductor cable, the far ends of which are terminated in solderless crimp lugs for attachment to the barrier strip. The leads should be color-coded (or otherwise identified), and the front surface of both hand controllers should be marked (with press-on lettering, or tape-writing) so that *R1* is labeled "Minimum" and *R2* is "Control." Both controls are further identified as "Speed" controls. (See photo on page 29.)

When attaching each hand-control assembly to the main chassis, make sure that the terminals are connected correctly. In each case, potentiometer *R1* is used to set the car's minimum speed while *R2* is adjusted for variable speed operation. —50—

CHAPTER

2

AUDIO STEREO HI-FI PROJECTS

In the last edition of the semi-annual **ELECTRONIC EXPERIMENTER'S HANDBOOK**, your editors predicted a rebirth of interest in building audio and hi-fi equipment. The six major construction projects in this chapter are a reaffirmation of that prediction. This chapter emphasizes the expanding interest in specialized and home-built hi-fi projects. Like many projects that were very popular in the days of vacuum tubes (really only 10 or 12 years ago), the Theremin has been converted to solid-state circuits. Possibly "converted" is not the proper word since, as with most hi-fi and audio projects, building for solid state involves wholly new designs and construction techniques. You have undoubtedly heard much about the world-renown Theremin—here is your chance to build your own and participate in making eerie sound effects, or even compose your own electronic music.

If the Theremin doesn't catch your fancy, how about the miniaturized reverb adapter for any hi-fi setup, the microphone mixer, the distortionless speech compressor, or if you like woodworking and building your own, the "Mighty-Mag" speaker system.

38	L'IL TIGER STEREO POWER AMPLIFIER.....	Daniel Meyer
43	MUSIC A LA THEREMIN.....	Louis E. Garner, Jr.
49	ADD "COMPLY" TO YOUR TAPE RECORDER.....	Charles Caringella, W6NJV
55	ELECTRONIC REVERB-B-B ADAPTER.....	Daniel Meyer
59	FET MIXER.....	Don M. Wherry, W6EUM
63	MIGHTY-MAG SPEAKER SYSTEM.....	David B. Weems
67	INSTANT NON-FAT SPEAKER ENCLOSURE.....	David B. Weems

NEW TRANSISTOR
DESIGN HAS 22
WATT MUSIC
POWER CAPABILITY



BUILD
Lil
Tiger
Stereo
Power
Amplifier

BY DANIEL MEYER

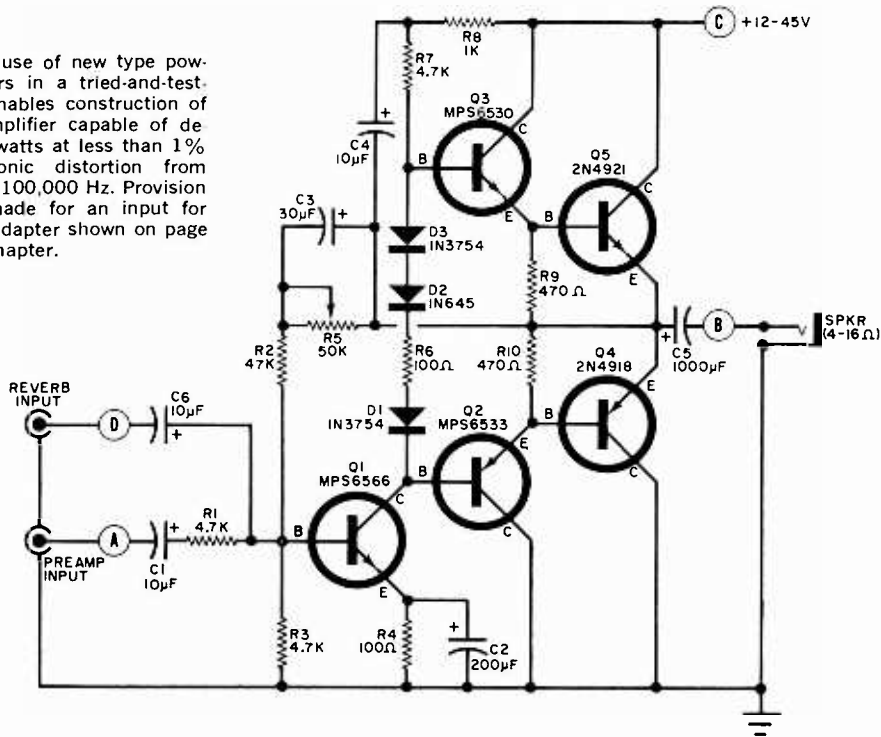
IF YOU would like to update your present audio system with a low-cost, superior-quality, cool-running, low-distortion transistor power amplifier—try the “L’il Tiger.” This small but versatile amplifier will put out a very clean 18 watts per channel r.m.s. with 8-ohm speakers, or a total of 36 watts for a stereo system.

Supply voltage can be anything from 12 to 45 volts, depending on the amount of output power you want, while the speaker can be rated anywhere from 3.2 to 16 ohms. The full electrical specifications given on page 42 clearly demonstrate the “L’il Tiger’s” capabilities.

The amplifier owes most of its outstanding characteristics to a new breed of transistors—uniquely designed plastic complementary silicon power transistors.

Circuit Development. Circuit designers realize that a complementary transistor output stage would be the most desirable arrangement in an audio power amplifier, but until recently, *pnp* power transistors complementary to existing *nnp* types either were not available, or were so expensive that they could not be considered practical. Attempts to design around this problem led to the quasi-complementary circuit (much as was used in the “Brute-70,” POPULAR ELECTRONICS, February, 1967). This type of circuit uses power transistors of the same polarity, with the result that one output transistor operates as a common emitter and the other as a common collector. The output impedances are not the same for positive and negative half cycles of the audio signal, but negative feedback produces a reasonably good amplifier.

Fig. 1. The use of new type power transistors in a tried-and-tested circuit enables construction of a power amplifier capable of delivering 22 watts at less than 1% total harmonic distortion from about 20 to 100,000 Hz. Provision has been made for an input for the reverb adapter shown on page 55 in this chapter.



Another solution to the problem has been to use one silicon and one germanium power transistor in the output stage. This combination can lead to thermal (heat) compensation problems, and the transistors are usually far from complementary in their characteristics. Again, lots of negative feedback can produce a pretty good amplifier, but feedback is used to correct for circuit nonlinearities, rather than the circuit being inherently linear with feedback used only to make it better.

The unusual construction of the Motorola transistors used in the "L'il Tiger" makes it possible to manufacture them at a reasonable cost while also making heat-sinking both simple and inexpensive. With the duty cycles found in speech and music, a simple heat sink is sufficient for operation at ambient temperatures of up to 120°F.

These transistors have excellent high frequency response. Unlike many previous power transistors, the new types will produce nearly full output up to at least 100 kHz. Since feedback is used only in one voltage amplifier of the "L'il Tiger" amplifier stage (see Fig. 1), the overall circuit is extremely stable

and needs no tricky amounts of high-frequency compensation.

A suitable 45-volt power supply for the "L'il Tiger" is presented in Fig. 2. Power output for various values of supply voltage and load impedance is given in Fig. 3, while Fig. 4 delineates the performance possible with a 45-volt power

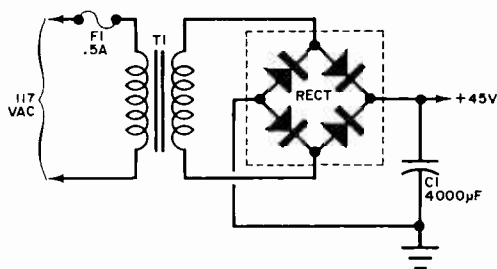


Fig. 2. Power supply for the "L'il Tiger" uses a conventional bridge rectifier and capacitor filter.

supply and an 8-ohm speaker. All of this performance can be had at a cost of around 50-cents-per-watt (less the cost of the power supply).

Construction. Figure 5 is an actual-size PC board foil layout, while Fig. 6 shows

HOW IT WORKS

The "Lil Tiger" circuit consists of a pair of compound emitter followers ($Q2$ - $Q4$, and $Q3$ - $Q5$), and a voltage amplifier ($Q1$). To prevent cross-over distortion in the Class B output and driver stages, the emitter followers are biased on slightly by a network consisting of $D1$, $D2$, $D3$, and resistor $R6$. This method of operation results in excellent thermal stability under almost any load and temperature conditions.

The audio signal on the output line (to terminal B on the PC board) is also coupled to the junction of $R7$ and $R8$ via capacitor $C4$. This coupling causes the instantaneous voltage at the junction of the two resistors to follow any variation in output voltage. The immediate result is that the voltage across $R7$, which is the collector load resistor of $Q1$, remains constant and does not drop to zero when a large, positive half-cycle signal is applied to the amplifier. The end result is the reduction of distortion by the emitter followers with decreasing supply voltage.

Voltage amplifier ($Q1$) is a common-emitter stage having a small amount of emitter resistance ($R4$) to compensate for variations in the transistors used. The bias point for $Q1$ is stabilized by d.c. feedback from the output through $R5$ and $R2$. Capacitor $C3$ passes the audio signal around $R5$, thus producing a.c. feedback which is not affected by any setting of $R5$. Potentiometer $R5$ sets the bias for the output stages. To prevent the driving source (preamplifier, etc.) from affecting the feedback loop, resistor $R1$ is introduced between the signal input and the base of $Q1$.

Output from the amplifier is taken via capacitor $C5$, whose value determines the low-frequency 3-dB point, which is about 20 Hz. The high-frequency cutoff (3-dB point) is determined by the transistors and feedback circuit. High-end cutoff is about 100 kHz.

the parts location and connection points to the printed board. The leads of the power transistors must be bent as shown in Fig. 7 so that each transistor mounting hole is aligned with the mounting hole on the printed board.

Figure 7 also shows the method of installing the heat sink and diode mounting clip to each power transistor. When the transistors are installed, the leads of $Q4$ face $C5$, while the leads of $Q5$ face toward $Q3$. Figure 8 shows $Q4$ positioned and ready for heat sink and diode clip mounting.

The cup-type #4-40 lock washer shown in Fig. 7 must be used to prevent cracking the power transistor case when it gets warm and expands. Silicone grease must be used between each transistor and its heat sink. Diode $D1$ is connected to the clip mounted on the $Q4$ heat sink, while diode $D3$ is clipped to the $Q5$ heat sink.

If you are planning to use the amplifier with 12- to 18-volt power supplies,

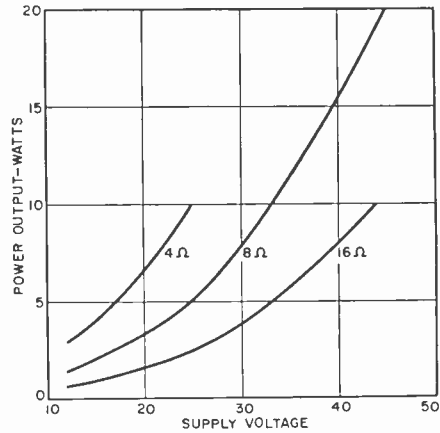


Fig. 3. If you know supply voltage and speaker impedance, amplifier power output can be determined.

AMPLIFIER PARTS LIST

- $C1$, $C6$ —10- μ F, 15-volt electrolytic capacitor
- $C2$ —200- μ F, 6-volt electrolytic capacitor
- $C3$ —30- μ F, 6-volt electrolytic capacitor
- $C4$ —10- μ F, 25-volt electrolytic capacitor
- $C5$ —1000- μ F, 25-volt electrolytic capacitor
- $D1$, $D3$ —1N3754 diode
- $D2$ —1N645 silicon bias diode, or similar
- $Q1$ —Motorola MPS 6566 transistor
- $Q2$ —Motorola MPS 6533 transistor
- $Q3$ —Motorola MPS 6530 transistor
- $Q4$ —2N4918 transistor
- $Q5$ —2N4921 transistor
- $R1$, $R3$, $R7$ —4700-ohm, $\frac{1}{2}$ -watt resistor
- $R2$ —47,000-ohm, $\frac{1}{2}$ -watt resistor—see text
- $R4$, $R6$ —100-ohm, $\frac{1}{2}$ -watt resistor—see text for $R6$
- $R5$ —50,000-ohm, $\frac{1}{4}$ -watt trimmer potentiometer (CTS X-201, or similar)
- $R8$ —1000-ohm, $\frac{1}{2}$ -watt resistor
- $R9$, $R10$ —470-ohm, $\frac{1}{2}$ -watt resistor
- ?—Staver V1-1 heat sinks
- 2—Diode mounting clips (RCA SA2100, or similar)
- 1—Printed circuit board*

*An etched and drilled circuit board is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, for \$2.25 postpaid; specify #140 when ordering. A complete set of parts, including the circuit board, is available for \$10 postpaid; specify #CA-140 when ordering.

POWER SUPPLY PARTS LIST

- $C1$ —4000- μ F, 50-volt electrolytic capacitor
- $F1$ —0.5-ampere fuse
- RECT—100-PIV bridge rectifier (Varo VS-248, or similar)
- $T1$ —Power transformer: primary, 117 volts; secondary, 34 volts, 1.5 ampere (Southwest Technical Products T34P15, or similar)

A kit consisting of the above parts plus chassis and hardware (for stereo version) is available from Southwest Technical Products Corp. for \$15; specify #P-140 when ordering.

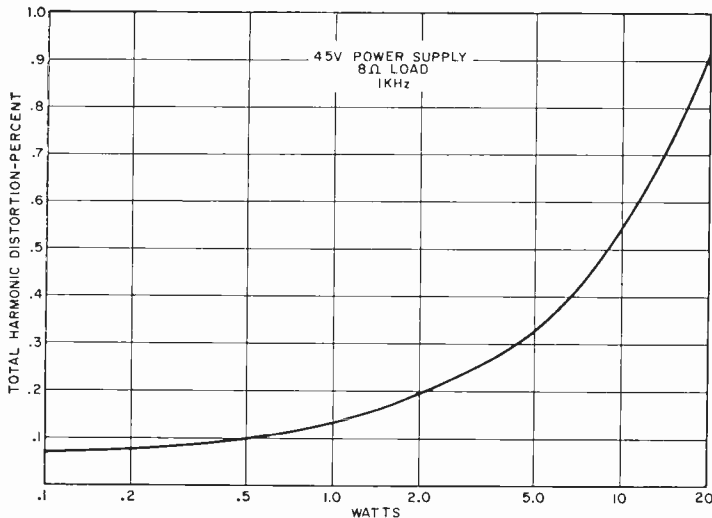


Fig. 4. Performance that can be expected from the "L'il Tiger" amplifier when using an 8-ohm speaker and a 45-volt power supply. Total harmonic distortion hits 1% at about 22 watts output.

Fig. 5. Actual-size photo of amplifier printed circuit board can be copied or the board can be purchased etched and drilled (see note in Parts List).



the value of $R2$ should be changed to 22,000 ohms. You will note that the schematic and PC board show an extra input terminal marked "Reverb Input." This input has been provided to make possible the use of the reverb adapter as detailed on page 55 of this issue. The extra input can also be used as a mixer input by adding a 4700-ohm resistor in series with capacitor $C6$ —for public address work, for example, where a microphone and phonograph are both fed into the same amplifier.

Testing and Use. The only adjustment that should be necessary is setting $R5$

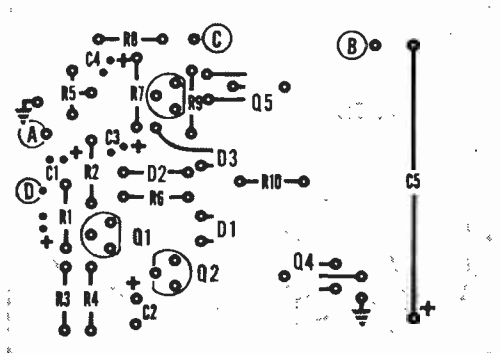


Fig. 6. Component layout on the reverse side of the circuit board. The unidentified transistor is Q3.

SPECIFICATIONS

Power Output	18 watts r.m.s., 22 watts IHFM per channel into an 8.0-ohm load with 45-volt power supply
Distortion	Less than 1% total harmonic up to full rated output
Frequency Response	3 dB down at 20 and 100,000 Hz
Input Impedance	Approximately 5000 ohms
Output Impedance	Approximately 0.1 ohm (damping factor of 80 with 8-ohm load)
Hum and Noise	More than 80 dB below 1 watt
Sensitivity	1.5-volt input for 20-watt output
Supply Voltage	12 to 45 volts d.c.

to a point that puts half of the power supply voltage across each of the output transistors. When balancing the supply voltage, measure the voltage from ground to the emitter of Q5.

The idle current of the amplifier should be between 5 and 10 milliamperes. If other than a 40- to 45-volt supply voltage is used, the value of R6 should be increased slightly to bring the idle current into this range. The amount of resistance needed can be found by inserting a milliammeter in series with the power supply voltage source and using a 500-ohm potentiometer in the circuit in place of R6.

(Continued on page 68)

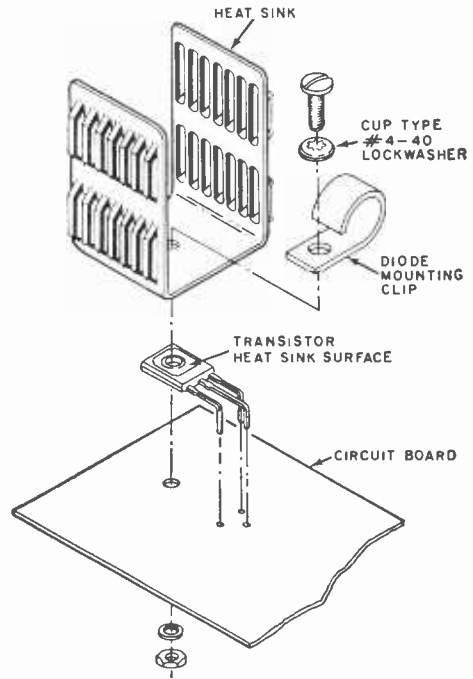


Fig. 7. Method of installing each power transistor, heat sink, and diode mounting clamp. The cup-shaped lock washer is necessary to prevent cracking the power transistor when it gets hot after long use.

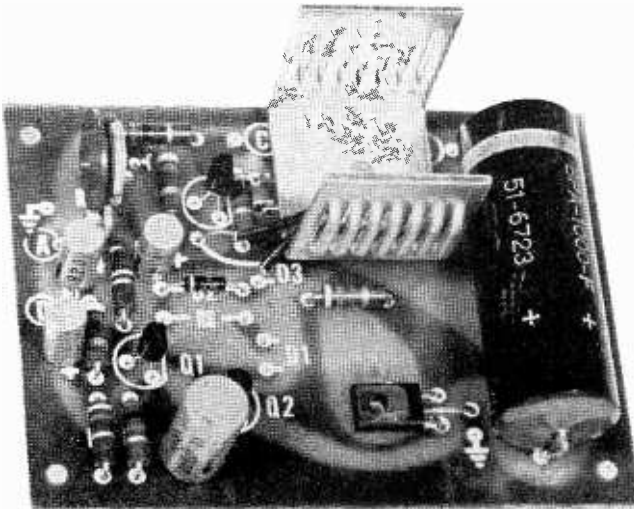
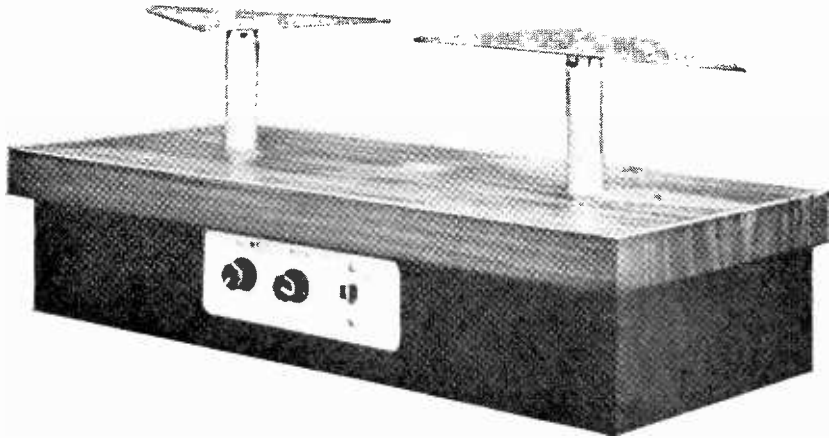


Fig. 8. This is the way the PC board should look after you install one power transistor/heat-sink/diode-clamp combination. The other power transistor is mounted and awaiting its remaining parts.

For that different sound...

Music à la *Theremin*



BY LOUIS E. GARNER, JR.

THE FIRST TRUE ALL-ELECTRONIC MUSICAL INSTRUMENT—BROUGHT UP TO DATE USING BIPOLAR TRANSISTORS AND FET'S

FOR ABOUT THE PRICE of an inexpensive guitar, plus a few hours assembly time, you can own and enjoy what is perhaps one of the most versatile of all musical instruments: the unique and amazing theremin. Named after its Russian-born inventor, Leon Theremin, its frequency range exceeds that of all other instruments, including theater pipe organs, while its dynamic range is limited only by the power capabilities of the amplifier and speaker system with which it is used. Above all, it is a *true* electronic instrument, not just an "electronic version" of a familiar string, reed, or percussion instrument. Its tone is unlike that of any conventional instrument.

A musician playing a theremin seems almost like a magician, for he can play a musical selection without actually touching the instrument itself! As he moves his hands back and forth near two metal plates, he seems to "conjure up" individual notes at any desired volume; he can "slide" from one musical note to another with ease, can produce tremolo and vi-

brato effects at will, and can even sound notes which fall outside the standard musical scale. He can play tunes or melodies, produce unusual sound effects, or can accompany a singer or another instrument—all by means of simple hand movements.*

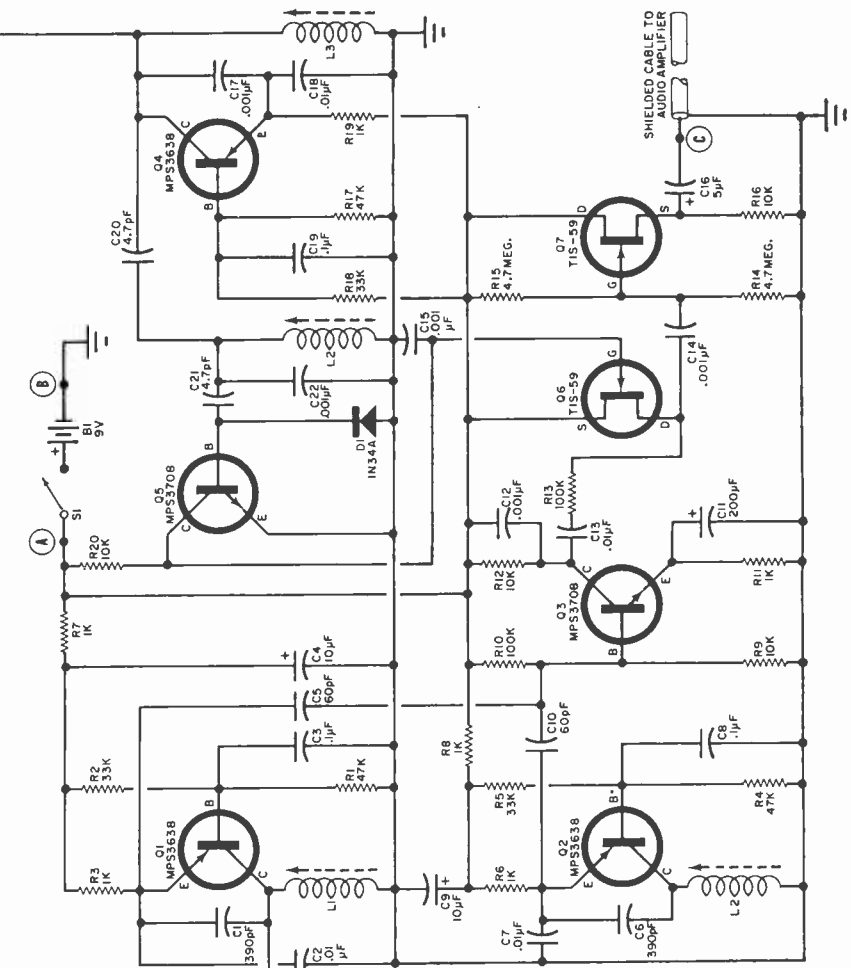
The theremin is ideal for amateur as well as professional musicians and can be used for "fun" sound effects as well as for serious music. It makes a wonderful addition to the home recreation room, and can be used equally well by rock 'n' roll groups or larger bands. Theatrical groups find it just the thing for producing eerie and spine-tingling background effects to accompany mystery or horror plays, and for the budding scientist or engineer, it is an excellent Science Fair project.

**Nearly everyone who has ever watched television or attended a motion picture has heard music and background effects produced by a theremin, yet relatively few could recognize the instrument, and fewer still have had the chance to own or play one. With its astounding tonal and dynamic ranges, it has been used to produce background music and special effects in scores of science-fiction, fantasy, horror, and mystery shows.*

VOLUME

PITCH

Fig. 1. A FET (Q6) acts as a voltage-variable resistor to control level of output signal. Use of a FET as output stage (Q7) prevents loading of mixer (Q3).



PARTS LIST

- B1—9-volt battery
- C1, C6—390-pF polystyrene capacitor
- C2, C7—0.01- μ F polystyrene capacitor
- C3, C8, C19—0.1- μ F disc ceramic capacitor
- C4, C9—10- μ F, 15-volt electrolytic capacitor
- C5, C10—60-pF polystyrene capacitor
- C11—200- μ F, 15-volt electrolytic capacitor
- C12, C14, C15—0.001- μ F disc ceramic capacitor
- C13—0.01- μ F disc ceramic capacitor
- C16—5- μ F, 15-volt electrolytic capacitor
- C17, C22—0.001- μ F polystyrene capacitor
- C18—0.01- μ F polystyrene capacitor
- C20, C21—4.7-pF polystyrene capacitor
- D1—1N34A diode
- L1, L2, L3, L4—50-300 μ H adjustable coil
- Q1, Q2, Q4—MPS3638 transistor (Motorola)
- Q3, Q5—MPS3708 transistor (Motorola)
- Q6, Q7—TIS-59 n-channel FET transistor (Texas Instruments)
- R1, R4, R17—47,000 ohms
- R2, R5, R18—33,000 ohms
- R3, R6, R7, R8, R11, R19—1000 ohms
- R9, R12, R16, R20—10,000 ohms
- R10, R13—100,000 ohms
- R14, R15—4.7 megohms
- Misc.—Etched circuit board, large circuit board antenna pipe and mounting hardware—see text, wooden cabinet or case approximately 18" x 6" x 4", battery mounting clip, shielded audio cable, two small knobs, spacers, hookup wire, solder, etc.

The following are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216: etched and drilled PC board, \$2.50; complete set of electronic components, including PC board, \$16.50; wooden cabinet and set of antennas, \$6.00.



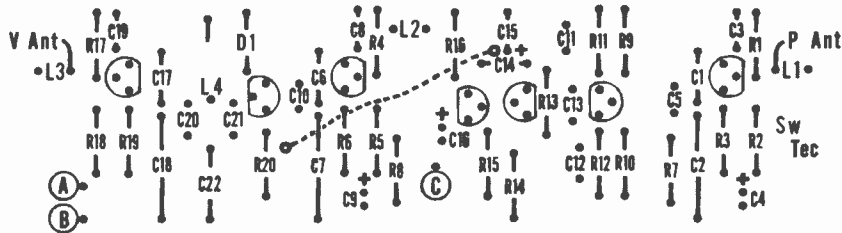
(A)

The typical theremin has two r.f. oscillators, one having a fixed, the other a variable, frequency, with their output signals combined in a mixer/amplifier stage. At "tune-up," the oscillators are preset to "zero beat" at the same frequency. The frequency of the variable oscillator is controlled by an external tuning capacity—the "antenna"—which is a "whip" or simple metallic plate.

As the musician's hand is moved near this antenna, the variable oscillator shifts frequency and a beat note is set up between the two oscillators. The pitch is proportional to the difference in frequency between the two oscillators. This beat note, amplified, is the theremin's output signal. The more advanced theremin designs—such as the version presented here—use a third oscillator to control output volume, and two antennas. This theremin also uses a unique FET volume control and a FET output stage. See Fig. 1.

Construction. Except for the two control antennas, power switch *S1*, and battery *B1*, all components are assembled on a printed circuit board as shown full-size in Fig. 2(a); the parts are assembled as shown in Fig. 2(b). An insulated jumper is required between *C15* and *R20* as shown in Fig. 2(b) and Fig. 3. Mount the PC board in a suitable cabinet with four spacers (see Fig. 3), making sure that suitable holes are drilled in the cabinet or through a dialplate to accept the tuning-slug screws of *L2* and *L4*. Coils *L1* and *L3* are mounted on small L-brackets; initially, these brackets should be adjusted so that *L1* is at right angles to *L2* and *L3* at right angles to *L4*. Switch

Fig. 2. Actual-size printed circuit board etching guide is shown at (A); dashed line in component layout guide (B) indicates insulated jumper wire.



(B)

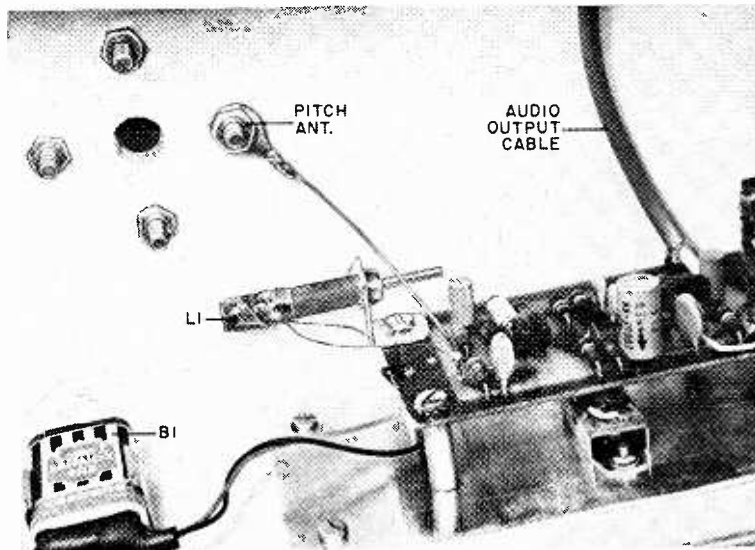


Fig. 3. Coils L1 and L3 should be mounted on L-brackets. Positions of these coils can be altered to change harmonic content (see "Tuning" instructions in text). Photo at far right demonstrates how insulated jumper wire between C15 and R20 should be routed.

S1 is also mounted on the cabinet or dialplate in the area of the L2 and L4 slug screws, while the battery is secured to the cabinet wall.

Ordinary copper-clad circuit board can be used to make up the pitch and volume control antennas. Although the author's units are equilateral triangles approximately 9" on a side—almost any other design will do—shape is not critical. If desired, the upper surface of the antennas may be covered with a plastic material.

The antennas are mechanically mounted on an electrically conducting support. The ones used by the author, (see Fig. 4) were six-inch lengths of $\frac{3}{4}$ " aluminum pipe with appropriate mounting flanges. The antennas were attached to the pipe with conduit plug buttons soldered to the bottom of each antenna. The flanges of the buttons should make a good friction fit to the pipe. A solder lug for connection to the PC board is placed under one of the pipe support mounting screws as shown in Fig. 3.

Connect the negative lead of the battery to terminal B on the PC board; then connect the positive battery lead, via S1, to terminal A. The center lead of the audio output coaxial cable is connected to terminal C on the PC board, while the associated braid is soldered to the ground foil. Connect the volume control lead and one lead from L3 to the proper hole

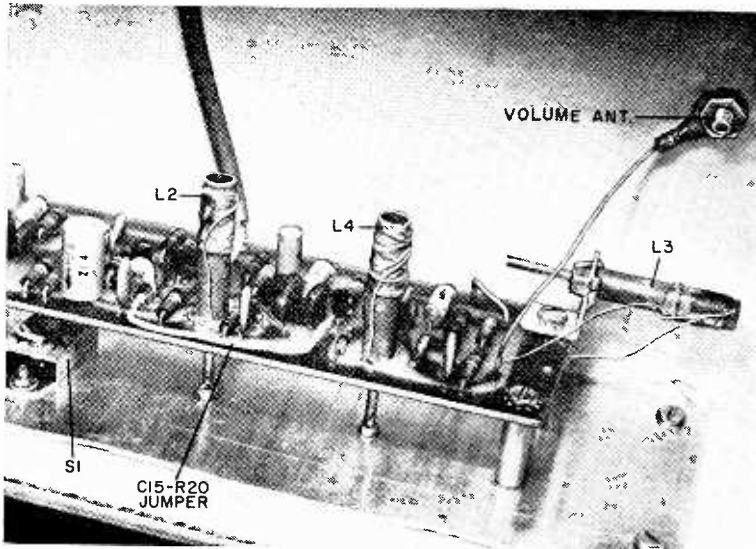
HOW IT WORKS

Transistors Q1 and Q2 are the variable and fixed "pitch" oscillators respectively, while Q4 serves as the "volume" oscillator. Essentially similar circuits are used in all three oscillators, so only one (Q1) will be described here. Base bias is established by resistor voltage divider R1 and R2, with the former bypassed for r.f. by C3. Resistor R3 serves as the emitter (output) load. The basic operating frequency is determined by the tuned circuit of L1 and combination of C1 and C2.

In the case of Q1 and Q4, their tuned circuits are also connected to external "antennas." When these antennas are "loaded" due to body capacitance (the presence of a hand near the antenna), this "load" is reflected to the tuned circuits as a capacitive change which, in turn, alters the frequency of oscillation. Because Q2's circuit uses no "antenna," its frequency remains constant at all times.

In operation, Q1's r.f. output signal is coupled to mixer/amplifier Q3 via coupling capacitor C5—while Q2's signal is coupled to Q3 via C10. If these two oscillators (Q1 and Q2) are at the same frequency, then there will be no resultant "beat" present at the collector of Q3. However, since Q1's frequency is determined by how close the operator's hand is to the "pitch" antenna, the resultant beat frequency will vary as the distance between the hand and antenna varies. Because the mixing action of Q3 produces both r.f. and audio beats, capacitor C12 is used to bypass the r.f. components and prevent them from appearing at the collector of Q3. The resultant audio beat is passed, via the volume control circuit, to the FET output stage, Q7.

Oscillator Q4 (the "volume" oscillator), like "pitch" oscillator Q1, has its frequency of oscillation determined by the amount of hand capacitance near its "antenna." The r.f. signal at the collector is coupled via C20 to another tuned



circuit consisting of *L4* and *C22*. The r.f. signal across this second tuned circuit is rectified by diode *D1* and applied to the base of d.c. amplifier *Q5*. Thus, the d.c. voltage level present at the collector of *Q5* is a function of the amount of r.f. present on *L4-C22*. This level is at its maximum when the *L4-C22* tuned circuit is at the same frequency as the *Q4* collector tuned circuit.

In practice, however, the frequency of *Q4*'s tuned circuit is made to be slightly higher than the *L4-C22* frequency. As a result, very little d.c. signal is passed to the base of *Q5*. This means that the voltage at the collector of *Q5* is at a maximum. If the frequency of *Q4*'s tuned circuit is reduced, when a hand is placed near the "volume" antenna, the base current applied to *Q5* increases, causing the collector voltage to drop.

The unique volume control consists of FET *Q6*, connected in shunt with the audio signal flow. The audio signal at the collector of *Q3* passes through d.c. blocking capacitor *C13* and is also isolated (for d.c.) from *Q7* by *C14*. Resistor *R13* and FET *Q6* are arranged as a voltage divider. If the gate voltage of *Q6* is highly positive, then the FET acts as a low resistance between *R13* and ground, greatly reducing the signal level allowed to pass to *Q7*. As the gate of *Q6* goes less positive, the effective resistance of *Q6* increases and the level of audio signal to *Q7* increases.

The voltage at the collector of d.c. amplifier *Q5* is connected to the gate of *Q6*. As this voltage level is determined by the frequency of *Q4*, the operator can readily adjust the output volume by changing his hand capacitance to the "volume" antenna. The variable-pitch, variable-volume audio signal is coupled to an external audio amplifier via FET *Q7*. A FET is used for *Q7* because its very high input impedance (a couple of megohms) will not affect operation of FET *Q6*. If desired, the source resistor of *Q7* (*R16*) can be changed to a similar-valued potentiometer.

on the PC board (see Fig. 3), then connect the pitch control lead and one lead of *L1* together and solder to the hole on the PC board. The other ends of both coils are soldered to the ground foil of the PC board.

Tuning. Although the theremin is used with an external audio amplifier and speaker, no special test equipment is needed for the tuning adjustments. The procedure is as follows.

(1) Temporarily short *Q6*'s gate and source electrodes together, using either a short clip lead, or a short length of hookup wire, tack-soldered in place.

(2) Preset the coil (*L1*, *L2*, *L3* and *L4*) cores to their mid-position.

(3) Connect the theremin's output cable to the input jack of an audio amplifier (with speaker)—a guitar amplifier is ideal. Turn the amplifier on, volume up to nearly full.

(4) Turn the theremin on by closing *S1* and adjust *L2*'s slug (keep hands or other parts of the body away from the pitch antenna) until a low frequency growling audio tone signal is heard from the speaker.

(5) Turn the theremin off and remove the short from *Q6*.

(6) Turn the theremin back on and adjust *L4*'s slug until a point is found where the growl is heard from the speaker. Then adjust *L3*'s stud until the sound

is reduced to near zero. This setting, although somewhat critical, will be stable once obtained.

(7) Finally, adjust $L2$'s slug until the growl becomes lower and lower in pitch, finally disappearing as "zero beat" is reached.

With the coils properly adjusted, no output signal will be obtained unless the operator's hands are moved near the *pitch* and *volume* control plates *simultaneously*. As the operator approaches the *pitch* control plate, a low-frequency note should be heard, increasing in pitch as the hand moves nearer and, finally, going higher and higher and beyond audibility as the hand almost touches the plate. As the operator puts his hand near the *volume* control, a low-level signal should be heard, increasing in amplitude until maximum volume is attained just before the plate is touched.

After the initial adjustments, $L2$ and $L4$ can be readjusted from time to time (using the front panel knobs) as needed to correct for minor frequency drift. In any case, a preliminary check of adjustment is always desirable whenever the theremin is to be used for a performance.

One further adjustment is optional. Coil $L1$'s positioning with respect to $L2$ will determine, to some extent, the shape of the output waveform and, hence, its harmonic content. The mounting bracket supporting $L1$ can be adjusted to reduce the mutual coil orientation to less than 90° if a greater harmonic content is desired. However, as the angle is reduced,

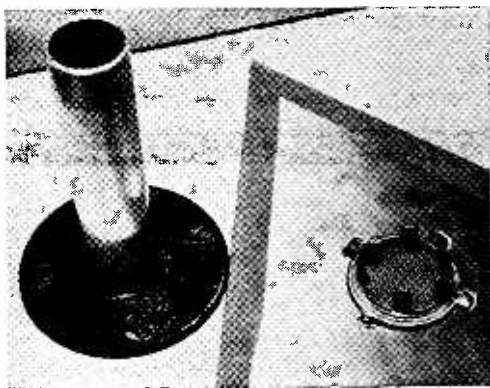


Fig. 4. Plug buttons soldered to metal plates that serve as antennas provide electrical coupling and mechanical support between antennas and pipes.

low-frequency notes may tend to become pulse-like in character.

Installation. A guitar or instrument amplifier is an ideal companion unit for the theremin; either one allows bass or treble boost, as desired, and fuzz (distortion) or reverberation.

If the theremin is used in conjunction with a power amplifier which does not have a built-in gain (or volume) control, a "volume level" control should be added to its basic circuit to prevent accidental overdrive. This can be accomplished quite easily by replacing source load resistor $R16$ (Fig. 1) with a 10,000-ohm potentiometer.

Operation. The results obtained depend more on the ability of the operator than on built-in limitations within the unit itself. A good "ear" for music is a must, of course, but, in addition, a moderate amount of skill is required, particularly in finger or hand dexterity and movement. For a start, here are the basic "playing" techniques.

To sound an individual note, first move the "pitch" control hand to the proper position near the *pitch* antenna (as determined by practice) to sound the desired pitch. Next, move the "volume" control hand *quickly* to the proper position near the *volume* antenna to sound the note at the desired level, then away after the proper interval to sound an eighth, quarter, half or full note.

To sustain a note, hold both hands in position. The note volume may be increased slowly by moving the "volume control" hand *slowly* nearer the *volume* antenna, reduced by moving it away.

To "slide" from one note to another, hold the "volume hand" fixed in position and move the "pitch hand" nearer (or away from) the *pitch* antenna plate.

To produce a vibrato effect, hold the "volume hand" fixed in position and shake—or tremble—the "pitch hand" at the desired rate.

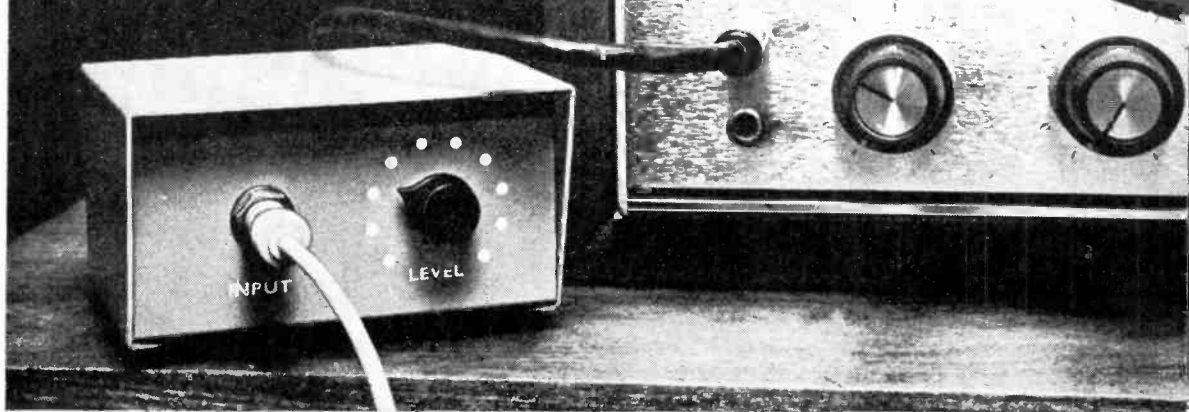
To create a tremolo effect, hold the "pitch hand" fixed in position and vibrate—or tremble—the "volume control" hand.

Tremolo and vibrato effects can be produced by simultaneously rapidly moving both hands back and forth.

Practice is important!

—50—

Add "COMPLY" to your Tape Recorder



DISTORTIONLESS SPEECH COMPRESSOR IS INVALUABLE AID

BY CHARLES CARINGELLA, W6NJV

YOU CAN simply forget to look at the recording level indicator on your tape recorder when you build and use *COMPLY*—for Control Of Microphone Peak Loudness Yield. Once *COMPLY* has been set up and adjusted, it will maintain the proper recording level automatically without further attention. It will hold the recording gain constant without introducing noise or distortion, no matter how close or far away you are from the microphone. You just set *COMPLY* once—then forget about it!

Easy to build, the automatic recorder control (*COMPLY*) is inserted directly in the line between the microphone and the tape recorder input, with no need to dig into the recorder circuitry. The 32-dB "compression" range of *COMPLY* also makes it ideal for several other ap-

plications. You can use it in the microphone line of a ham or CB transmitter for more modulation "punch." You can also use it ahead of a public address amplifier to maintain a constant output level regardless of variations in input level, and to minimize annoying feedback.

The completed unit can be housed in a modern-looking aluminum enclosure measuring only 3" deep by 4¼" wide by 2⅝" high. An internal 9-volt battery provides the power; however, provision can be made for connection to an external battery or power supply. The wiring diagram is shown in Fig. 1, while the curve in Fig. 2 illustrates the performance of the unit.

As total power consumption is only 2.5 milliamperes at 9 volts d.c., an ordinary transistor radio battery will power

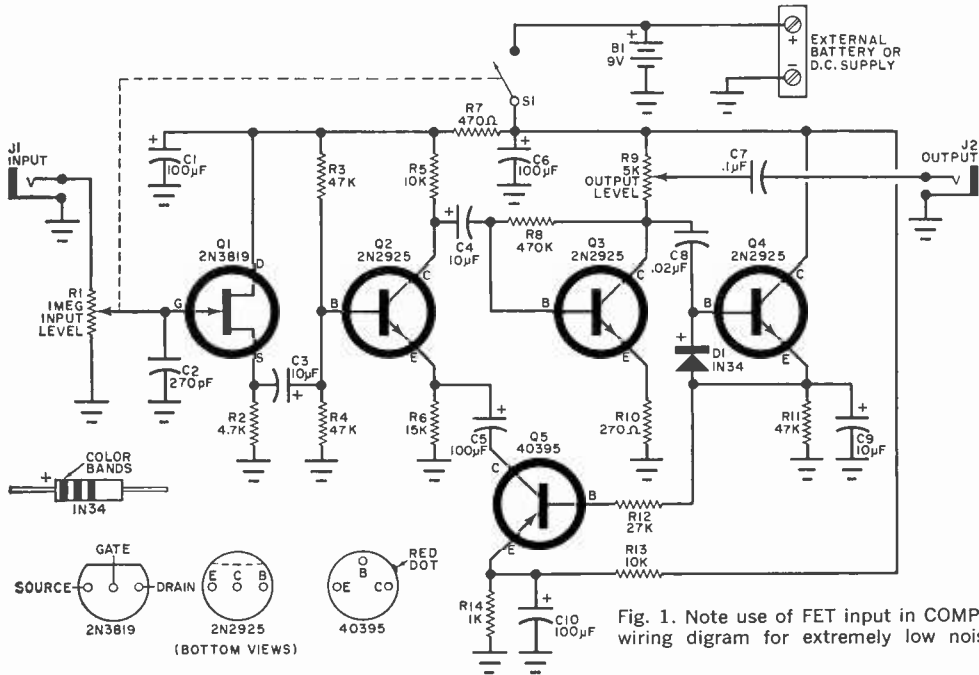


Fig. 1. Note use of FET input in COMPLY wiring diagram for extremely low noise.

PARTS LIST

- B1—9-volt battery
 C1, C5, C6, C10—100- μ F, 15-volt electrolytic capacitor
 C2—270-pF ceramic capacitor
 C3, C4, C9—10- μ F, 15-volt electrolytic capacitor
 C7—0.1- μ F ceramic capacitor
 C8—0.02- μ F ceramic capacitor
 D1—1N34 germanium diode or similar
 J1, J2—Standard open-circuit phone jack
 Q1—2N3819 n-channel field-effect transistor (Texas Instruments)
 Q2, Q3, Q4—2N2925 silicon npn transistor (General Electric)
 Q5—40395 germanium pnp transistor (RCA)
 R1—1-megohm, linear taper potentiometer with s.p.s.t. switch S1
 R2—4700 ohms
 R3, R4, R11—47,000 ohms
 R5, R13—10,000 ohms
 R6—15,000 ohms

All resistors
 1/2 watt carbon

- R7—470 ohms
 R8—470,000 ohms
 R9—5000-ohm linear taper potentiometer (screw-driver adj.)
 R10—270 ohms
 R12—27,000 ohms
 R14—1000 ohms
 S1—S.p.s.t. switch (part of R1)
 1—2" x 3" printed circuit board*
 1—3" x 4 1/4" x 2 3/8" aluminum cabinet (LMB 342 or similar)
 Misc.—Knob, battery holder, 1/8" spacers, terminal strip, battery clip, rubber feet, screws, hookup wire, solder, etc.

*Etched and drilled printed circuit board is available for \$2.50 postpaid from Caringella Electronics, Inc., P.O. Box 327, Upland, Calif. 91786; a complete kit of parts (including circuit board, pre-punched cabinet, all components, hardware, wire and solder, but less battery) for \$18.50 postpaid. California residents should add 5% sales tax to all orders.

HOW IT WORKS

Five low-cost transistors are employed in the COMPLY circuit. The input stage, Q1, is a 2N3819 n-channel silicon FET used as a "source follower," which is analogous to a cathode follower in vacuum-type circuitry. Utilizing the FET in the first stage provides high input impedance—about 1 megohm. Most important is the fact that input noise is practically nonexistent. The input "level" control is potentiometer R1.

Transistors Q2 and Q3 are npn silicon units operated as amplifiers to boost the low-level microphone signals. The output signal is obtained from the collector circuit of Q3, where R9 is the collector load and output "level" control. Part of the output signal is fed to diode D1 through capacitor C8. Diode D1 rectifies this signal and the resulting d.c. voltage is amplified by Q4,

another npn silicon transistor. The output of the Q4 stage is used to control Q5.

A general-purpose germanium pnp transistor, Q5 is operated at a low level in its linear resistance region and acts as a current-sensitive variable resistor. This "variable resistance" is in series with the emitter bypass capacitor, C5, of transistor Q2. Thus, the gain of Q2 changes as the resistance of Q5 changes. The circuit arrangement can be thought of as a form of negative feedback. As the input signal goes up, the gain of the amplifier goes down.

For input signals between 0.1 and 1.0 millivolt, the circuit operates as a straightforward amplifier with a voltage gain of approximately 200. Compression takes place in the range of 1.0 to 40 millivolts of input signal. Frequency response is "flat" from 10 Hz to well over 20 kHz, both in the linear region of amplification and the region of compression.

COMPLY for many months. If the control is connected to an external a.c.-operated power supply, it must be well filtered to avoid the introduction of hum into the tape recorder.

Construction. Most of the circuit components can be mounted on a 2" x 3" printed circuit board. The etched copper-foil side is shown (actual size) in Fig. 3, while Fig. 4 shows the reverse side on which the components are mounted.

Carefully observe the "flat" side of transistors *Q1*, *Q2*, *Q3*, and *Q4* when mounting them in place. Space each transistor about 1/4" away from the circuit board, and make sure each one is oriented properly before soldering it to the board. A heat sink should be used on each transistor lead (as well as on the diode leads) while soldering to prevent heat damage. Mount diode *D1* vertically on the board, and observe the polarity of the diode when it is mounted.

All of the capacitors should be flush-mounted against the circuit board. Observe the polarity of the electrolytic capacitors when installing them. Capacitor *C7* is the only one *not* mounted on the circuit board. All of the resistors are mounted vertically on the board; make sure that one end of each resistor is flush against the board.

A close-up view of the completed circuit board, prior to mounting in the cabinet, is shown in Fig. 5. The connecting leads should be long enough to reach the controls and jacks. Follow the drawing in Fig. 6 to make the holes in the cabinet.

Mount the input and output "level" controls, *R1* and *R9*, in the positions indicated in Fig. 7. Capacitor *C7* is soldered directly between *R9* and *J2*. An inside view of the completed unit is shown in Fig. 8. Mount the circuit board with 4-40 hardware and use 1/8" spacers between the board and the cabinet. Make sure the resistors on the board near control *R1* do not short out to the control's metal case.

Standard open-circuit phone jacks are used for both the microphone input to *COMPLY* and for the output connection. It will be necessary to fabricate a "patch" cable using shielded wire to connect the output of the control to the input of the tape recorder. There are a variety of pre-fabricated cables available at most radio supply stores and hi-fi shops.

Many tape recorder microphones are equipped with standard phone plugs on their cables. If your microphone is not equipped with a standard phone plug, it will be necessary to change the existing plug or get a suitable adapter.

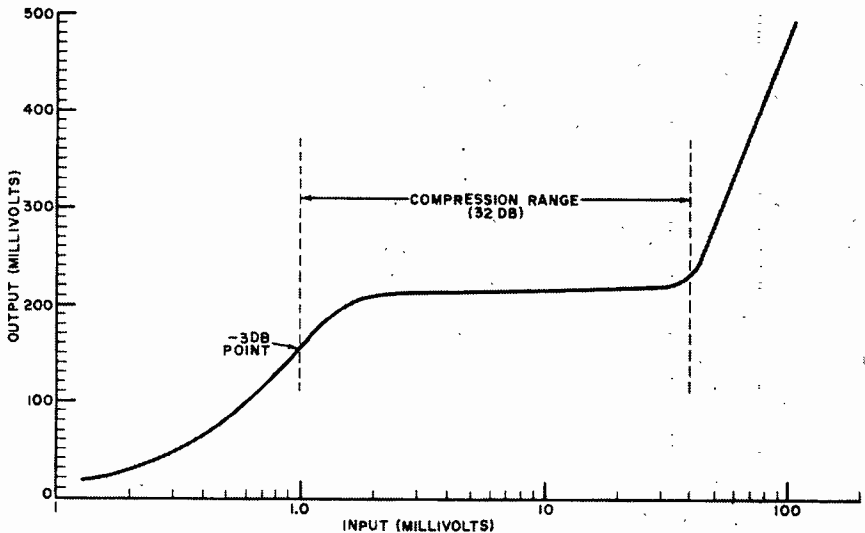


Fig. 2. The output voltage of your *COMPLY* unit should remain essentially flat for input variations from the microphone of between 1 and 40 millivolts, equal to 32 dB compression.

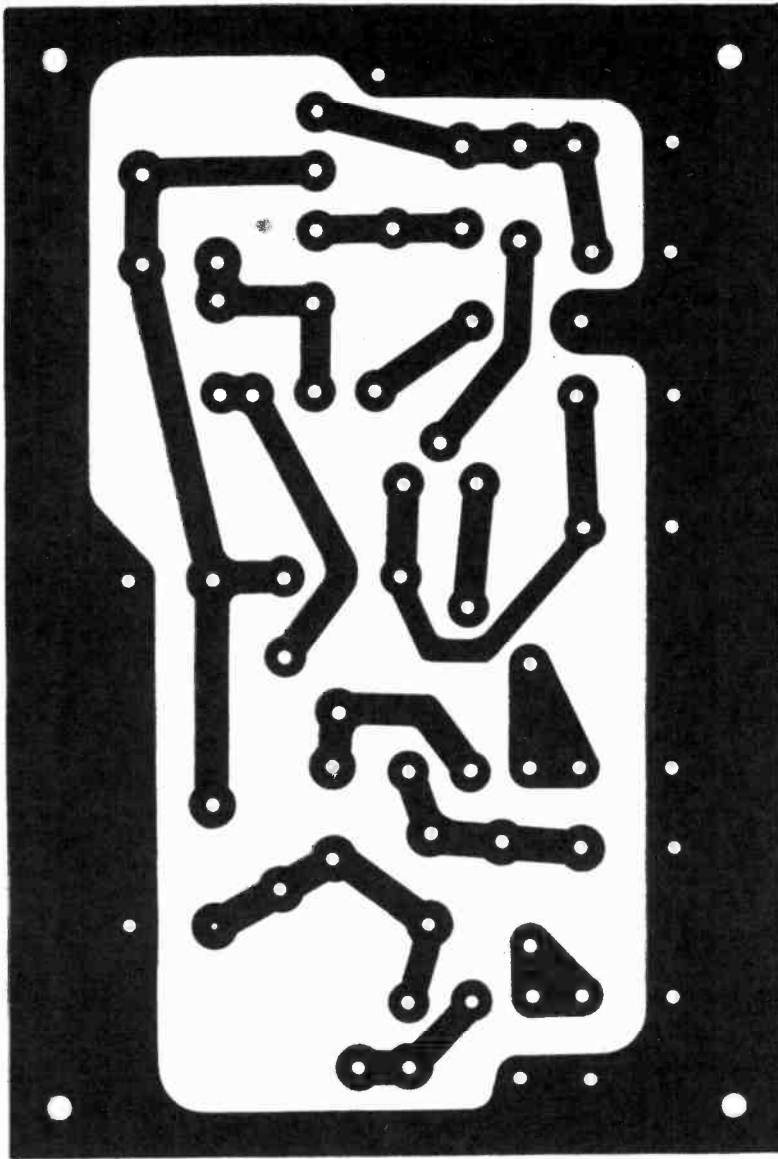


Fig. 3. Construction of COMPLY is greatly simplified through use of a printed circuit board. You can make your own board if you follow this twice-size board pattern. An etched and drilled board is available to readers at a very low cost.

Operation. The *COMPLY* unit is easy to set up and operate. First, connect the microphone directly to the tape recorder. Speak into the microphone at close range and adjust the gain control on the tape recorder for the proper recording level. When this has been done, unplug the microphone from the tape recorder and plug it into your *COMPLY* unit. Connect *COMPLY*'s output to the input of the tape recorder with the "patch" cable.

Set the *COMPLY* input level control up

about $\frac{1}{4}$ of the way from the fully off position. While speaking into the microphone at close range, set the output level control (*R9*) for the recording level on the tape recorder determined above.

Now back away from the microphone and set the input level control (*R1*) on *COMPLY* for the desired microphone sensitivity. If the input level is set for optimum pickup at about 2½-3 feet from the microphone, a speaker cannot "blast" the microphone even if he gets within 6

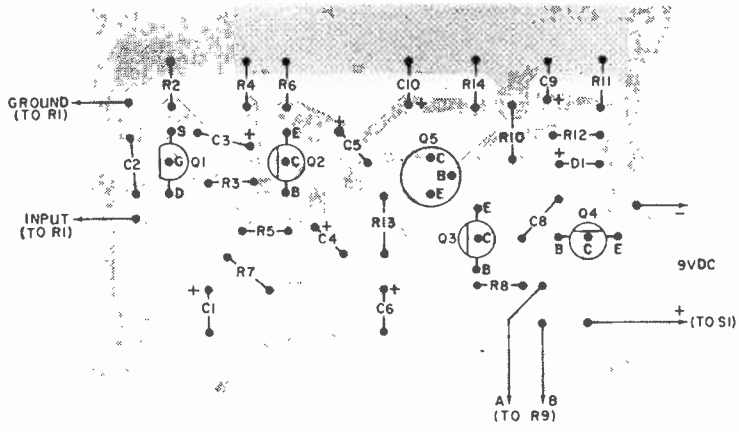


Fig. 4. Flip the printed circuit board over, and mount the necessary resistors, capacitors, and transistors according to placement shown. Be careful to observe polarity.

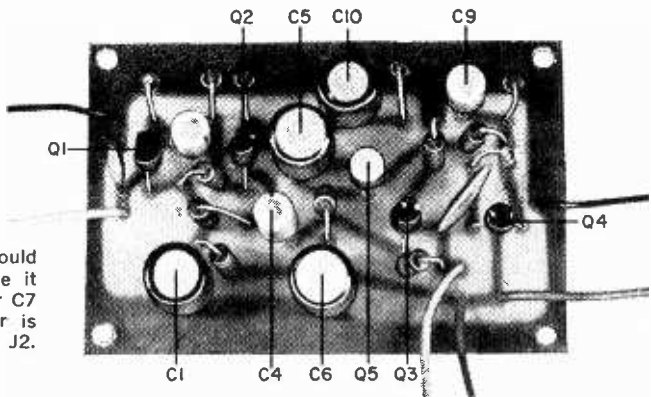


Fig. 5. The printed circuit board should look something like this just before it is mounted in the cabinet. Capacitor C7 is not on the board—this capacitor is connected directly between R9 and J2.

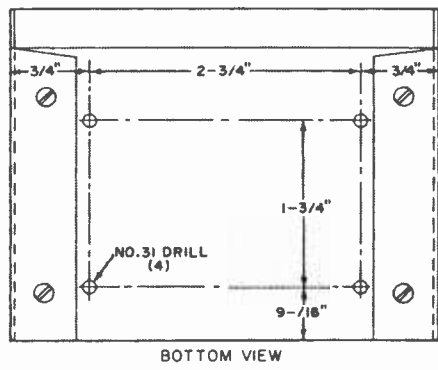
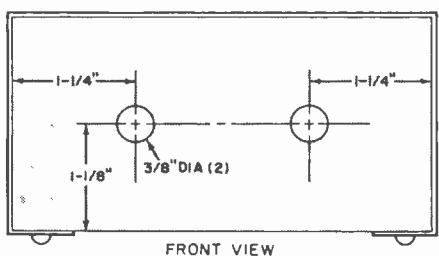
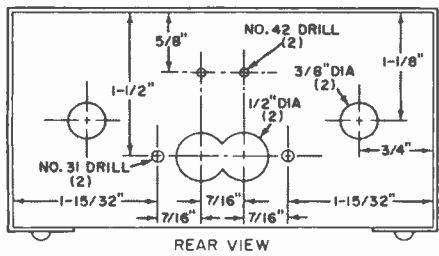


Fig. 6. If you obtain the LMB box used by the author, these rear, front and bottom view drawings will guide you in drilling necessary control holes.

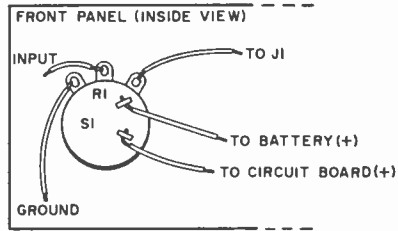
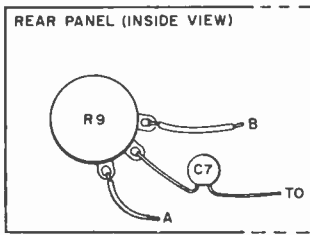


Fig. 7. Before mounting the COMPLY printed circuit board, attach the two controls, R1 and R9, to the front and rear panels, respectively. Capacitor C7 is then soldered in place from R9 to J2.

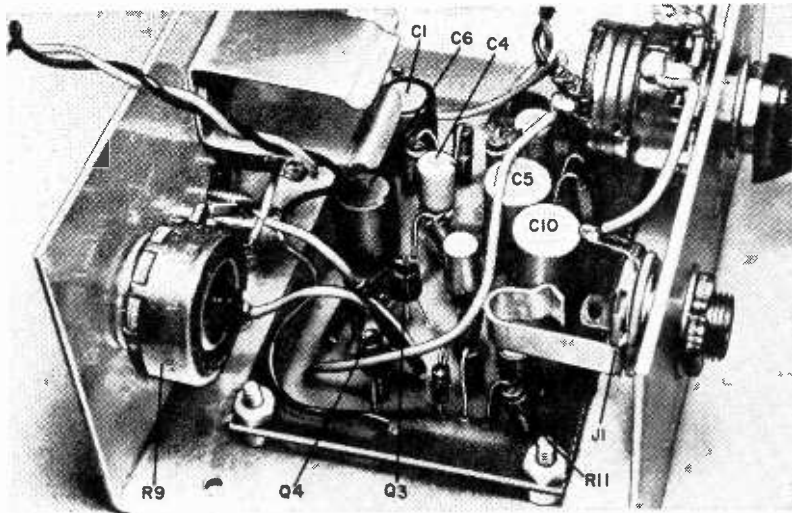
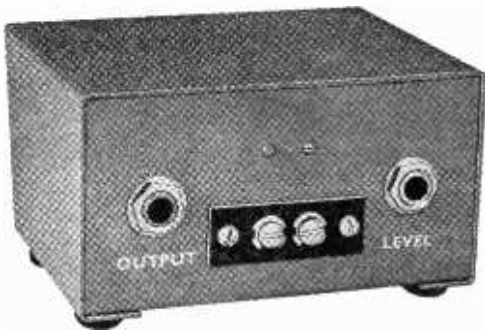


Fig. 8. The PC board is a snug fit in the recommended LMB box. If instructions detailed in text are followed, however, you should not encounter any problems. The battery is mounted in a holder.

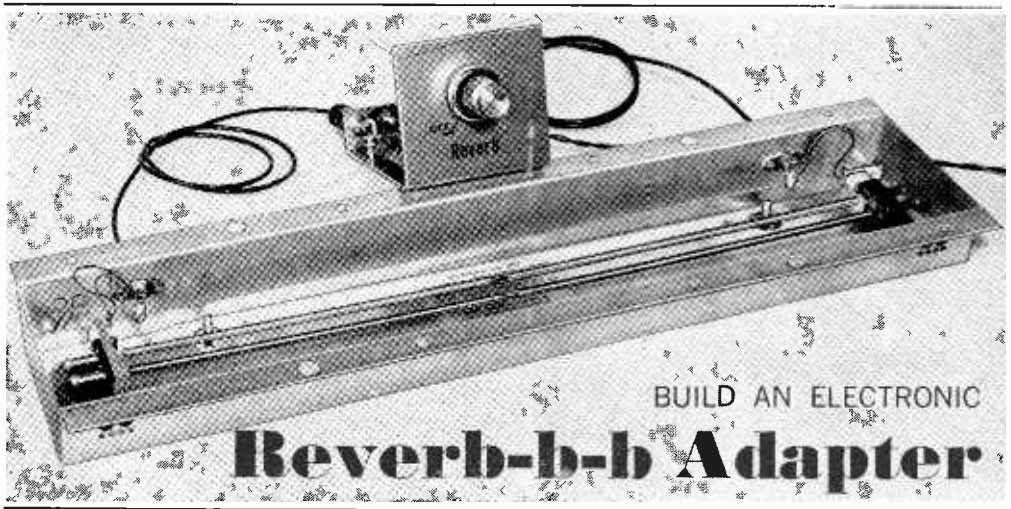


Rear view of COMPLY unit shows terminal strip for connection to external 9-volt power source. A screwdriver-adjusted pot is used for level setting.

inches of it. Unlike speech compressors used in some ham or CB rigs, *COMPLY* will not distort the sound by clipping off voice peaks to increase the modulation percentage level.

Your *COMPLY* unit should prove to be of tremendous value in making tape recordings at parties or informal gatherings where there is a mix of voice and music. Recording of press conferences is also greatly facilitated by *COMPLY*. After you have used it a while, you won't want to be without this handy recorder control.

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HOW HOW WOULD WOULD YOU YOU LIKE LIKE
TO TO INCORPORATE INCORPORATE A A CONTROLLABLE
CONTROLLABLE ECHO ECHO IN IN YOUR
YOUR AUDIO AUDIO SYSTEM SYSTEM ? ?

BY DANIEL MEYER

THE ADDITION of electronically generated reverberation to any audio system adds a new dimension to the reproduction of music. By adjustment of the amplitude and decay time of reverb (really an echo), speech, guitar music, or even simple recorded sounds can be made to seem as though you were hearing them in a huge concert hall. When electronic reverb is used with electronic musical instruments, the artist can create a variety of new sounds—ranging from a simple echo to a playing-in-a-barrel effect*.

Most low-cost reverb units can be purchased over the counter at various electronics supply houses. However, you cannot simply connect one between the signal source and the amplifier and expect it to work. The reverb unit must have a driver and an output amplifier, in addition to a resistive mixing circuit needed to combine the straight-through and the reverb sound. The complete re-

verb adapter described in this article contains all of these electronic elements and is designed to be connected between a conventional preamplifier and power amplifier, either vacuum-tube or transistor types. It is particularly useful with the "Brute-70" (Winter '68 EXPERIMENTER'S HANDBOOK) or the "L'il Tiger" (page 38) power amplifiers.

Construction. Putting the reverb adapter (Fig. 1) together is simplified by using the printed-circuit board shown actual size in Fig. 2. Install the components on the PC board in accordance with Fig. 3. The usual PC board construction techniques should be observed—all parts should be mounted close to the board; use rosin-core solder, do not overheat when soldering, and do not form solder bridges across the foil sections. Clip all component leads close to the solder.

The adapter can be mounted on a small metal chassis as shown in Fig. 4. Four small standoffs (approximately 1/4") and associated hardware secure the PC board to the base of the chassis, potentiometer R13 is mounted on the front panel,

**Don't confuse reverb and tremolo and Leslie effects. Reverb is an echo, tremolo an amplitude variation, and Leslie a warble—as though the sound were changing point source of direction.*

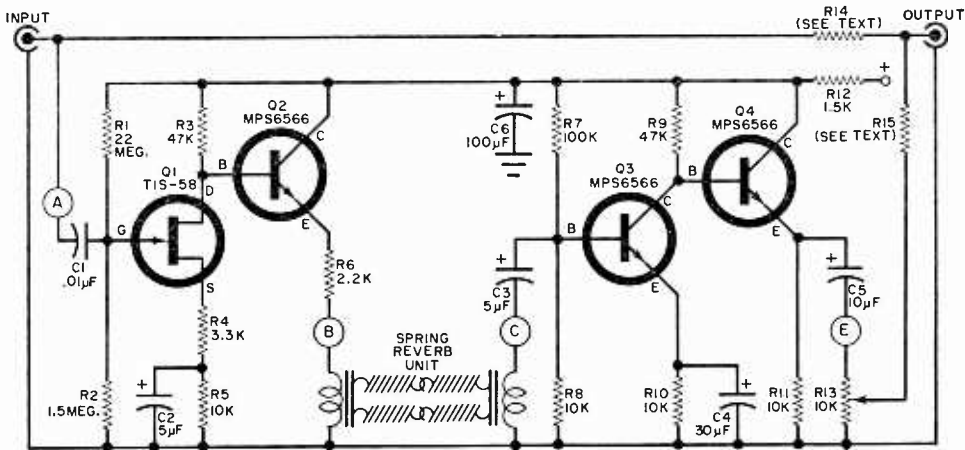


Fig. 1. The reverb adapter is connected in parallel with the input audio signal. Amount of echo to be added is determined by the setting of potentiometer R13.

PARTS LIST

C1—0.01- μ F capacitor
 C2, C3—5- μ F, 15-volt capacitor
 C4—30- μ F, 6-volt capacitor
 C5—10- μ F, 25-volt capacitor
 C6—100- μ F, 50-volt capacitor
 Q1—Texas Instruments TIS-58 field effect transistor
 Q2, Q3, Q4—Motorola MPS-6566 transistor
 R1—22 megohms
 R2—1.5 megohms
 R3, R9—47,000 ohms
 R4—3300 ohms
 R5, R8, R10, R11—10,000 ohms
 R6—2200 ohms
 R7—100,000 ohms
 R12—1500 ohms—see text

All resistors
 1/2 watt, \pm 10%

R13—10,000-ohm linear potentiometer
 R14, R15—See text
 1—Spring reverberation unit (Gibbs IV-C, Hammond Organ)
 1—Printed circuit board*
 Misc.—Phono jacks (4), single-hole mounting type; chassis—see text; wire, solder, spacers, bolts, nuts, etc.

*A kit of the circuit board, chassis, and electronic parts used in the driver amplifier is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas, 78216, for \$8.75 postpaid (#CA-139); the IV-C reverberation unit for \$10 plus 2 lb. postage; the circuit board alone for \$2 postpaid.

HOW IT WORKS

The heart of the reverb adapter is the spring reverberation unit: the electromechanical device that produces the delay and echo effects. Basically, it consists of a pair of contrawound springs (it could be only one spring) suspended between a pair of transducers. When the input transducer is supplied with an audio current, it causes the springs to twist in step. The twisting motion travels down the springs and excites the output transducer, generating an output voltage. Two simultaneous actions occur—there is a slight time delay of the signal in traversing the springs (approximately 25 milliseconds); and because of coupling inefficiencies, some of the signal “bounces” back and forth from transducer to transducer a couple of times, producing an “echo.” As each mechanical reflection produces a weaker and weaker signal in the output transducer, multiple weakening of acoustic signals in a “live” room is simulated.

Because the typical loss in the spring reverb system is about 40 dB, an input amplifier (Q1) is used. This stage employs a FET to produce a high input impedance (about 1 megohm), which allows the reverb adapter to be used with almost any type of input equipment without loading problems. An emitter follower (Q2) matches the input amplifier to the approximately 2000-ohm input impedance of the spring unit.

The electrical output of the spring unit is coupled to amplifier Q3, which raises the signal level back to the same level as was applied at the adapter input. Emitter follower Q4 isolates Q3 from any loading effects introduced by the external audio power amplifier. Potentiometer R13 acts as the “reverb level” control and is used to set the desired amount of reverberation. The input audio signal is directly coupled to the output via R14, while the reverb is introduced through R15.

while the four phono jacks are mounted along the rear apron. Connect short pieces of insulated wire between points A, B, C, and E of the PC board and their respective phono jacks (see Fig. 1).

The value of resistors R14 and R15 will depend on what type of audio system

the reverb adapter is to be used with. With vacuum-tube equipment, these two resistors should be between 47,000 and 100,000 ohms, with the exact value determined by test. Start with 47,000-ohm units, and remember that some signal loss will be encountered through the use

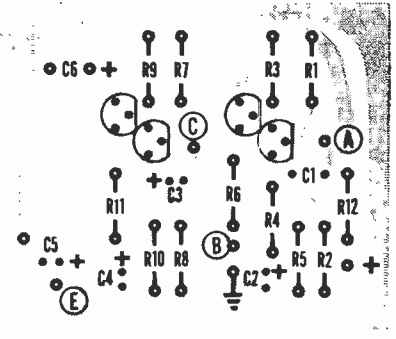
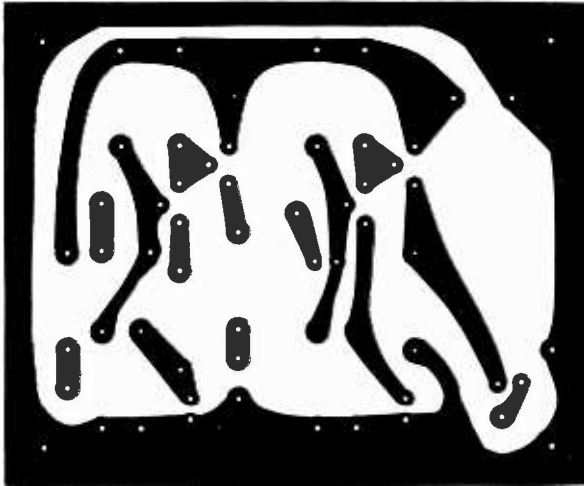


Fig. 2 (left). Actual-size printed board.

Fig. 3 (above). Component installation. Resistors *R14* and *R15*, with potentiometer *R13*, are installed on the chassis.

of these two resistors. With transistor audio equipment, resistors *R14* and *R15* will be in the range from 1000 to 4700 ohms, again with the best value determined by experimentation. A good compromise is 2200 ohms.

On transistor amplifiers, such as the "Brute 70" and "L'il Tiger," the reverb adapter can be added without a loss in gain by utilizing the present input resistor as one of the mixing resistors (*R14*). Figure 5 shows how this is done. Simply,

R14 in the reverb adapter is omitted and the input resistor of the amplifier is used in its place. In this case, the value of *R15* should be about the same as the input resistor of the amplifier. The value would be about 82,000 ohms with the "Brute 70" and about 4700 ohms with the "L'il Tiger." The "L'il Tiger" was designed with an extra input jack just for this purpose.

Power for the reverb adapter can be obtained from the power supply of

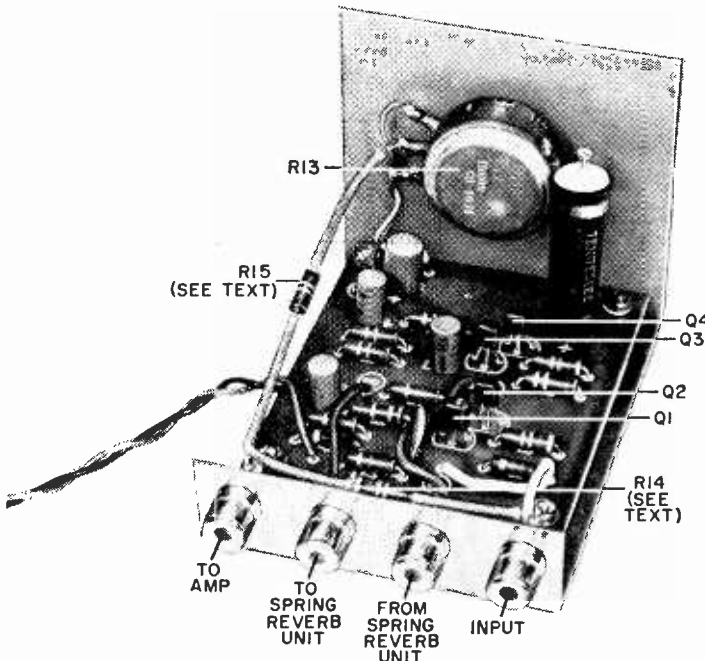


Fig. 4. The finished board can be mounted on a metal chassis with the external connections completed as shown here. Short spacers isolate board from chassis.

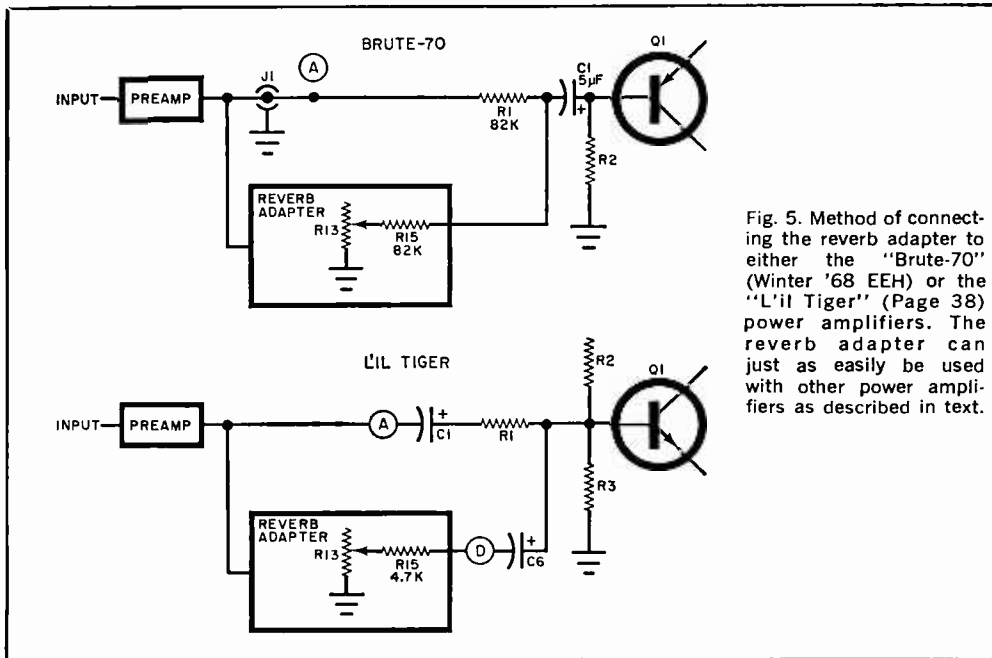


Fig. 5. Method of connecting the reverb adapter to either the "Brute-70" (Winter '68 EEH) or the "L'il Tiger" (Page 38) power amplifiers. The reverb adapter can just as easily be used with other power amplifiers as described in text.

either the "Brute 70" or "L'il Tiger." The value of $R12$ shown in Fig. 1 is correct for use with power supplies between 40 and 50 volts. For higher voltage sources, such as are found in vacuum-tube equipment, the value of $R12$ will have to be increased to a value that delivers the approximately 30 volts required by the reverb adapter, as shown in Fig. 6.

Installation and Use. On instrument amplifiers, the reverb adapter can be connected either between the instrument and its amplifier, or it can be inserted into the circuit between the preamplifier and the power amplifier stages. If you do not want to "go into" the amplifier, the first approach is the safest—but possibly not the best—as there is a possibility of hum pickup at these low-level stages.

The reverb spring unit is shock-mounted, but the long springs make it sensitive to any undue bouncing, which will produce a "boing"-like sound. Also, the magnetic pickups on the output end of the springs are sensitive to stray magnetic fields and will easily pick up any induction hum from an unshielded—or partially shielded—power transformer in the vicinity. Therefore, always mount the spring unit as far from power transformers as possible, and protect it from

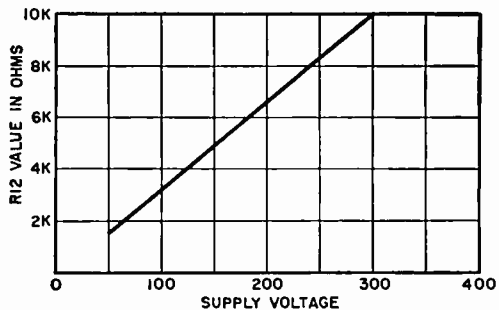
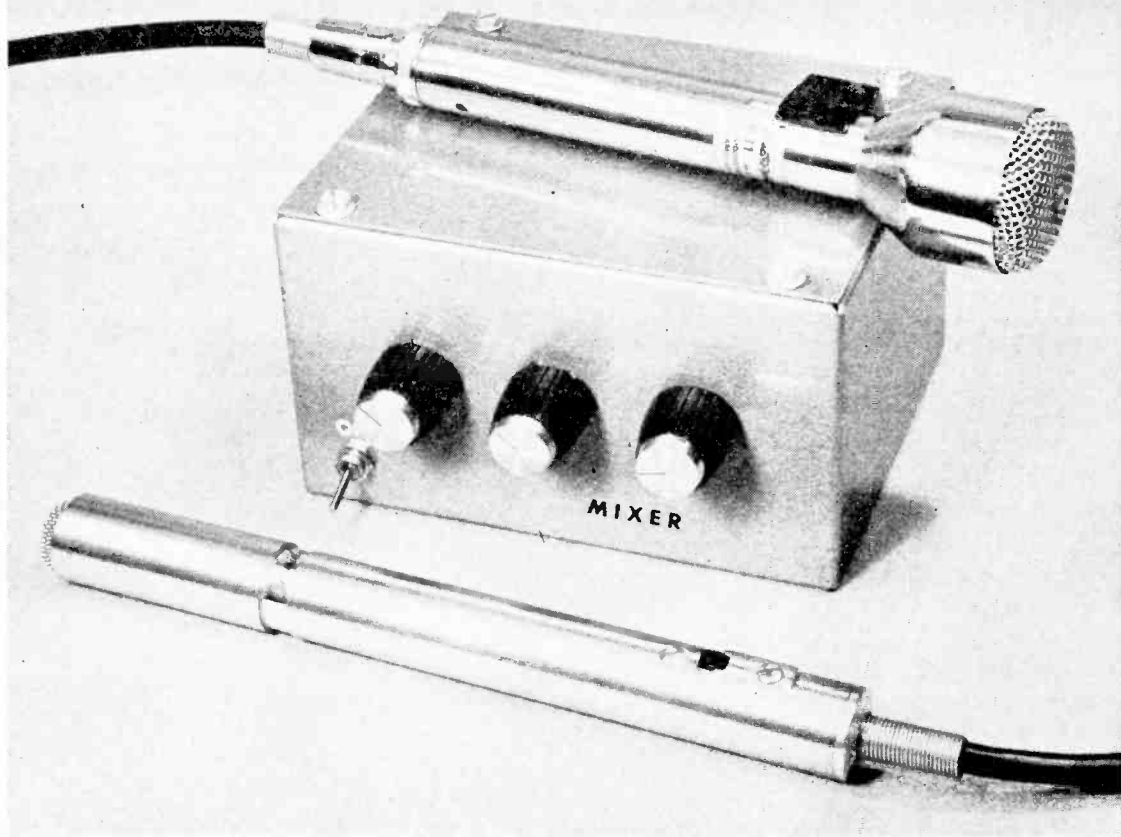


Fig. 6. To determine value of $R12$ at high voltages, draw a vertical line from the voltage to the reference line, then go horizontally to locate the value.

any mechanical shocks. In some cases, it may be necessary to wrap the reverb spring unit in fiberglass, or build a cover over it, to prevent acoustic feedback from a nearby speaker.

To obtain reverberation, rotate potentiometer $R13$ for the desired amount. When full reverb is used, it may have a "barrel" effect on voices. Some compromise will have to be made, as the best "sound" with music generally causes more echo on voice than most people like. And remember that too much reverberation can be disturbing, unless you are trying for novelty rather than realism. —50—



Build a FET Mixer

LOW-COST FETs MAKE PERFECT 3-CHANNEL MIXER

BY DON M. WHERRY, W6EUM

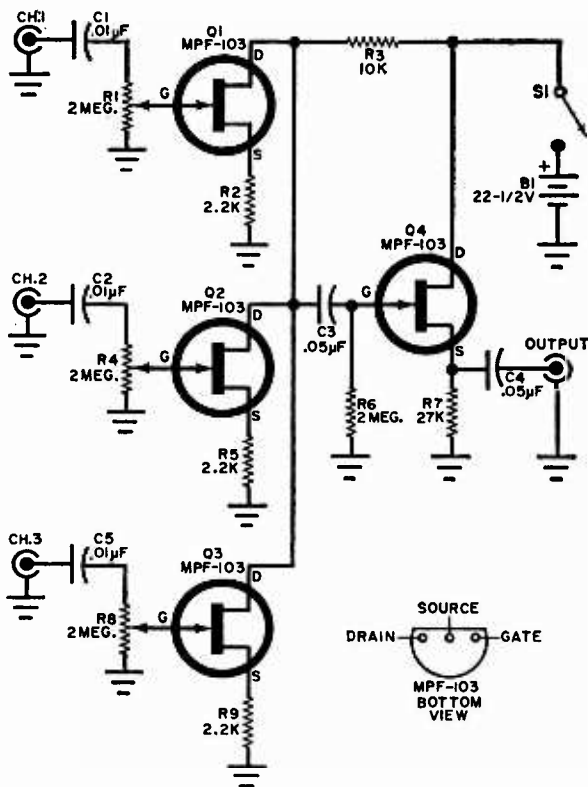
HAVE YOU EVER asked yourself, "Isn't there some easy way of mixing two or three microphones?" Would you like to mix several program sources, or just simply combine voice and music so that the result is "professional" sound? Yes, there are microphone mixers you can buy, but why go to that expense when in two evenings of work you can build your own.

The little *FET Mixer* shown in Fig. 1 will do the work of a microphone mixer selling for \$50. It has three separate inputs, each isolated from the output FET source-follower stage by a low-cost FET. The output of the *FET Mixer* is a

fairly low impedance—suitable for use with most tape recorders and hi-fi amplifiers. Battery-operated, the mixer is free of a.c. hum and is of sufficiently small size to be portable as well as sturdy and trouble-free.

Why So "Fancy"? There are many ways of mixing two or more audio signals. At least one commercially available microphone mixer uses the circuit shown in Fig. 2. Obviously, this circuit has no gain, and the advantage of being able to mix is offset by the higher volume control settings (more noise possible) in the tape recorder. This mixer also is plagued

Fig. 1. Not shown in this diagram are three 25- μ F capacitors that can be wired in parallel with resistors R2, R5, and R9. If these capacitors are installed, they will make a slight increase in the gain of the mixer. However, in most applications, the extra capacitors are unnecessary. If a 15-volt battery is used at B1, the value of resistor R3 should be decreased to about 6800 ohms, which will result in a 3 dB loss of overall gain.



PARTS LIST

- B1—22½-volt battery
- C1, C2, C5—0.01- μ F capacitor
- C3, C4—0.05- μ F capacitor
- Q1, Q2, Q3, Q4—Motorola MPF-103 junction field effect transistor
- R1, R4, R8—2-megohm linear potentiometer (IRC Q13-139)
- R2, R5, R9—2200-ohm, ½-watt resistor
- R3—10,000-ohm, ½-watt resistor
- R6—2-megohm, ½-watt resistor
- R7—27,000-ohm, ¼-watt resistor
- S1—S.p.s.t. miniature toggle switch
- Misc.—Phono jacks (4), cabinet, printed circuit board, spacers, knobs (3), solder, nuts, bolts, etc.

by annoying interaction between inputs.

Another commercially available mixer uses a single transistor (similar to the circuit surrounding Q4 in Fig. 1) to provide gain, but since the input connections are the same as in the simplified version (Fig. 2), there is still the chance of microphone interaction and feedback.

The *FET Mixer* provides isolation and gain. With a 22½-volt battery, the gain is about 8 dB. Frequency response is virtually flat from about 20 to 40,000 hertz. Interaction between channels is not measurable and, using the transistors indicated in the Parts List, the noise generated by the mixer is well below -64 dB for 1-volt output.

Construction. The author built his *FET Mixer* using a printed circuit board. This board is detailed in Fig. 3, actual size. No provision has been made to make the board available to readers, since the project is simple enough to permit PC board experimentation. Also, if you don't feel capable of working up your own PC

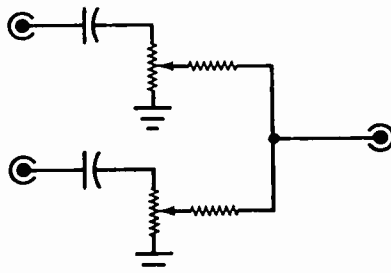


Fig. 2. Buy a cheap mixer and the circuit will look like this one. Isolation between the channels is poor, and you're bound to lose half the signal.

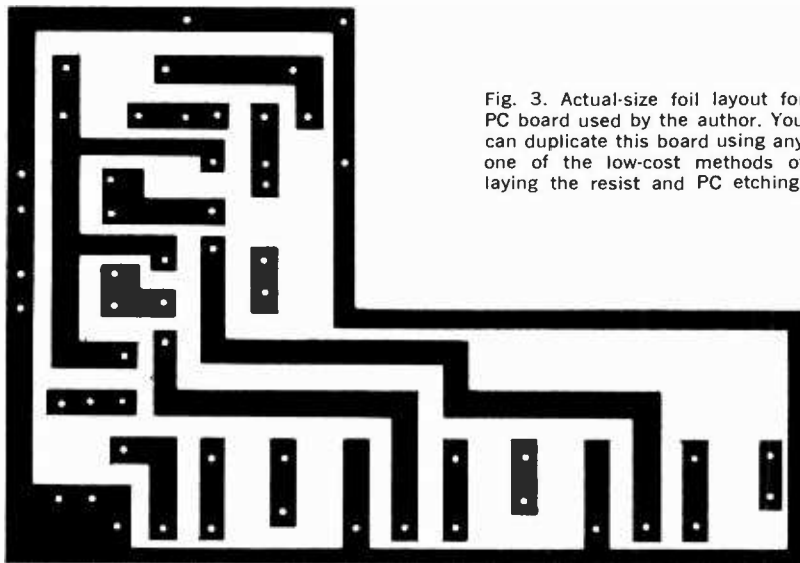


Fig. 3. Actual-size foil layout for PC board used by the author. You can duplicate this board using any one of the low-cost methods of laying the resist and PC etching.

board, the *FET Mixer* can be assembled on a perforated board (with flea clips), or even terminal strips.

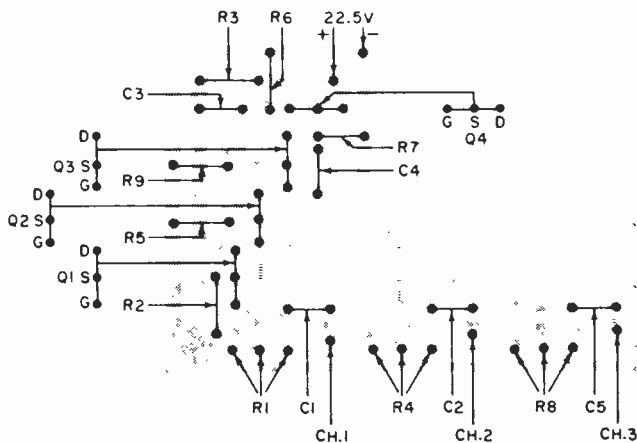
If you try to duplicate the author's construction, note that the board is actually mounted on and held in place by the three gain controls. Be sure to use the type of control called out in the Parts List. These controls have lug terminals and are specially desirable for mounting PC boards.

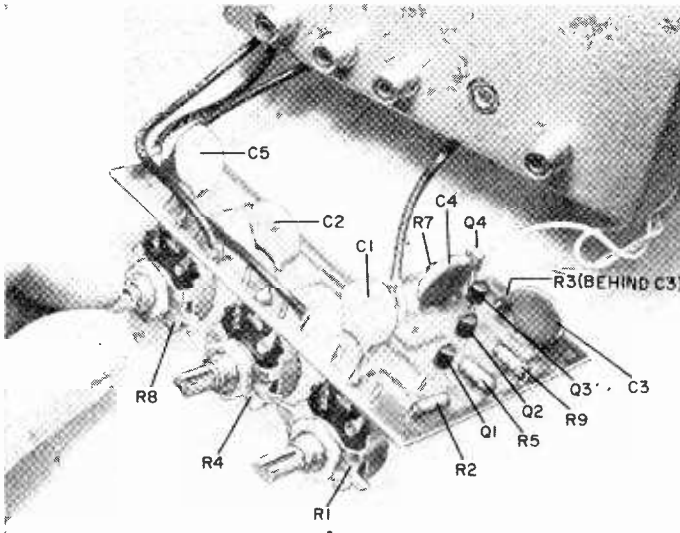
You should be able to mount all of the *FET Mixer* circuit, plus battery, in a

small aluminum box. The author mounted the unit in a locally made box measuring 5" x 3½" x 3". A separate on-off switch (*S1*) is employed, although one of the channel input controls could be backed with a switchplate. Use simple decal markings on the face of *FET Mixer* box, or knobs that are marked so that the controls can be approximately reset with ease. Most of your work will be done with the controls set between readings equivalent to 10 and 2 o'clock.

You could build a simple 117-volt a.c.

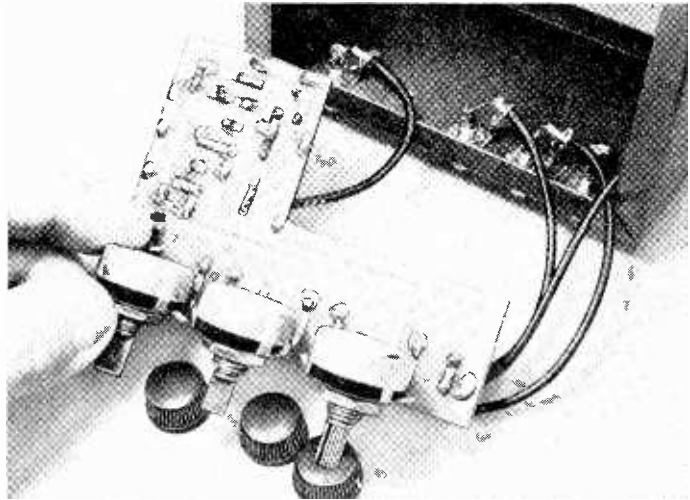
NOTE: This drawing shows the location of the components when you look up through the PC board—not down on the board as is frequently the case with other PC boards shown in this magazine. The extra holes near R2, R5, and R9 are for the three capacitors mentioned in the caption for Fig. 1. These capacitors are not usually required, since the mixer has an 8 dB gain without them.





Top view of mixer shows location of some of the components. Potentiometers are soldered in place right onto the printed circuit board. Enlarge the holes for soldering to the lugs of the potentiometers. Hole in back of metal box is for a clamp to secure the battery in place. Carefully observe lead orientations of transistors.

This is how the mixer looks when you turn the board over. Coax cables to the jacks are cut a little long and soldered in place. Since the board is held by the potentiometer lugs, holes for the shafts are drilled last in the box panel.



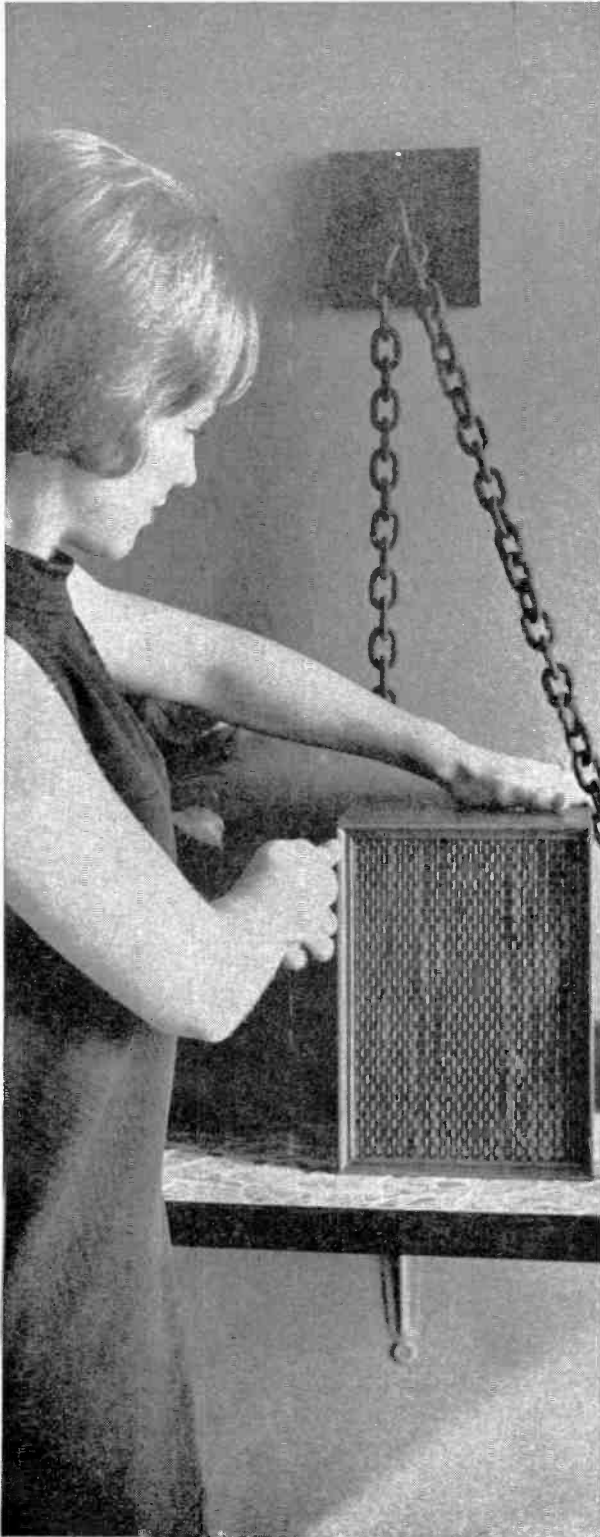
power supply to operate the *FET Mixer*, but you might encounter a.c. hum problems, and you would be adding an extra unnecessary a.c. cable.

Using the Mixer. Practice using the *FET Mixer* before making a valuable recording. Normally the microphone input control on your tape recorder should be set to its usual position. Connect the mixer output to the tape recorder and set all three channel input controls to zero.

Bring up the level of one channel to give you a normal recording level as

seen on the built-in indicator of your tape recorder. Note the dial reading and return this control to zero and bring up the level of the second input. Return this control to zero and repeat the process if you are using a third input. If only two inputs are used, leave the level of the third input at zero at all times.

Now bring up both mixer levels to their noted positions. Generally speaking, you should not find it necessary to back off on the tape record input level—even though it may appear that twice the input should require a drastic input level reduction.



Mighty- Mag Speaker System

BUILD YOUR OWN
ULTRA-COMPACT HI-FI
SPEAKER ENCLOSURE

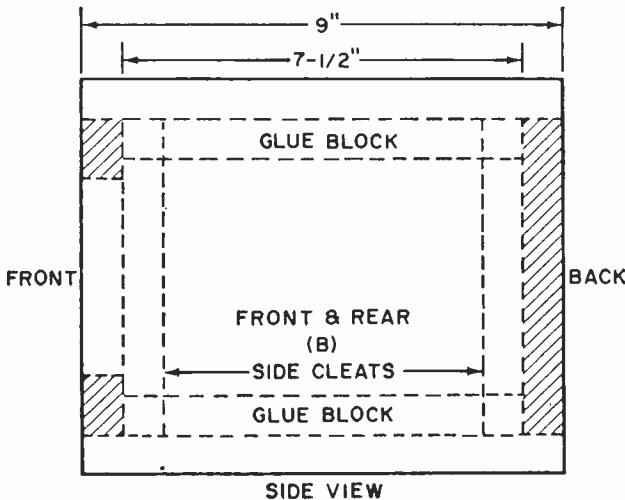
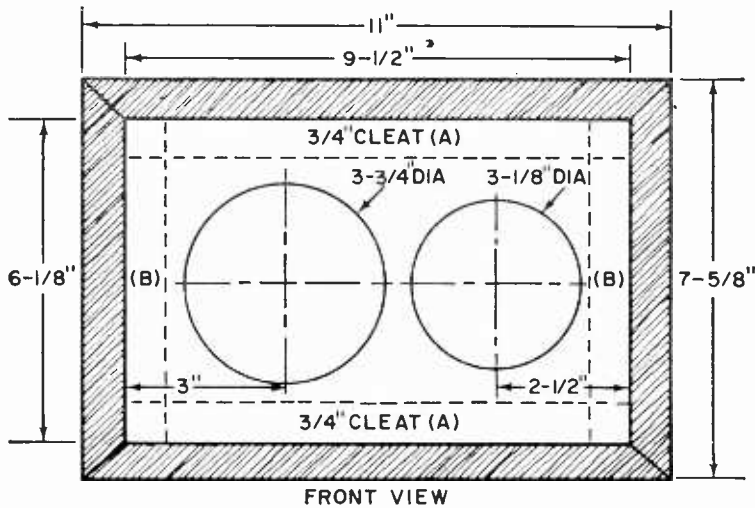
BY DAVID B. WEEMS

WHEN the *Maximus I** broke the sound barrier for shoe-box size hi-fi speaker systems about three years ago, it had two strikes against it from the start. Common sense insisted that it was just too small and the price of \$59.50 too high. Yet, thousands of apartment dwellers who valued compactness as well as good sound invested in the *Maximus I*.

What was really unique about the *Maximus I* was the woofer. Unlike the woofers of some small sealed speaker systems, this one—built by Goodmans of England—was strictly first class in quality of material and design. Various **EXPERIMENTER'S HANDBOOK** readers have asked if there were an equally good woofer that could be purchased as a separate component. Now, for the first time, the original woofer with its 3½-lb magnet structure and fundamental resonance below 45 Hz is available, and you can use it to build a small hi-fi speaker system comparable in performance to the original *Maximus I* at less than half its cost.

In order to achieve the goal of high performance at low cost, a lower cost tweeter has been substituted, the same

*Trade name, UTC Sound Division.



Details for assembling the enclosure are shown above. The small-diameter woofer and tweeter are only available from McGee Radio, 1901 McGee St., Kansas City, Mo. 64108. When you order, mention that you saw this story in this EXPERIMENTER'S HANDBOOK.

BILL OF MATERIALS

- 1—Maximus 4" woofer (McGee Radio Co. Stock No. 4WF MAX-1, \$14.95)
- 1—Tweeter (McGee Radio Co. Stock No. TS-6070, \$3.95)
- 2—9" x 11" lengths of 3/4" plywood for enclosure walls, beveled 45° at each end
- 2—9" x 7 5/8" lengths of 3/4" plywood for enclosure walls, beveled 45° at each end
- 2—6 1/8" x 9 1/2" lengths of 3/4" plywood for front and back
- 4—8" lengths of 3/4" x 3/4" pine for "A" cleats
- 4—6 1/8" lengths of 3/4" x 3/4" pine for "B" cleats
- 4—6" lengths of 3/4" x 3/4" pine for corner glue blocks
- 4—3/16" x 1 1/4" flathead bolts (for woofer mounting)
- 4—3/4" x #8 panhead screws (for tweeter mounting)
- 20—1 1/4" x #8 flathead wood screws (for front and back mounting)
- Misc.—Trim, grille cloth, glue

one used for the Cinderella speaker systems.* This tweeter, which has always seemed a good value, now has a fiberglass lining behind the cone to improve response smoothness, and using it results in another economy; the tweeter's built-in high-pass filter, a 5- μ F capacitor, eliminates the need for a more expensive crossover network.

Construction. It is not practical to try to equal the compactness of the *Maximus I* system unless you are a skilled metal worker; the front baffle in the factory unit was made of a special alloy only slightly more than $\frac{1}{16}$ -inch in thickness. Plywood for even a small enclosure should have a minimum thickness of $\frac{1}{2}$ -inch. Full $\frac{3}{4}$ -inch material was selected here, partly to avoid vibration, but mainly because it is more widely available with hardwood veneer. This thickness also allows a special method of construction in which the beveled corners

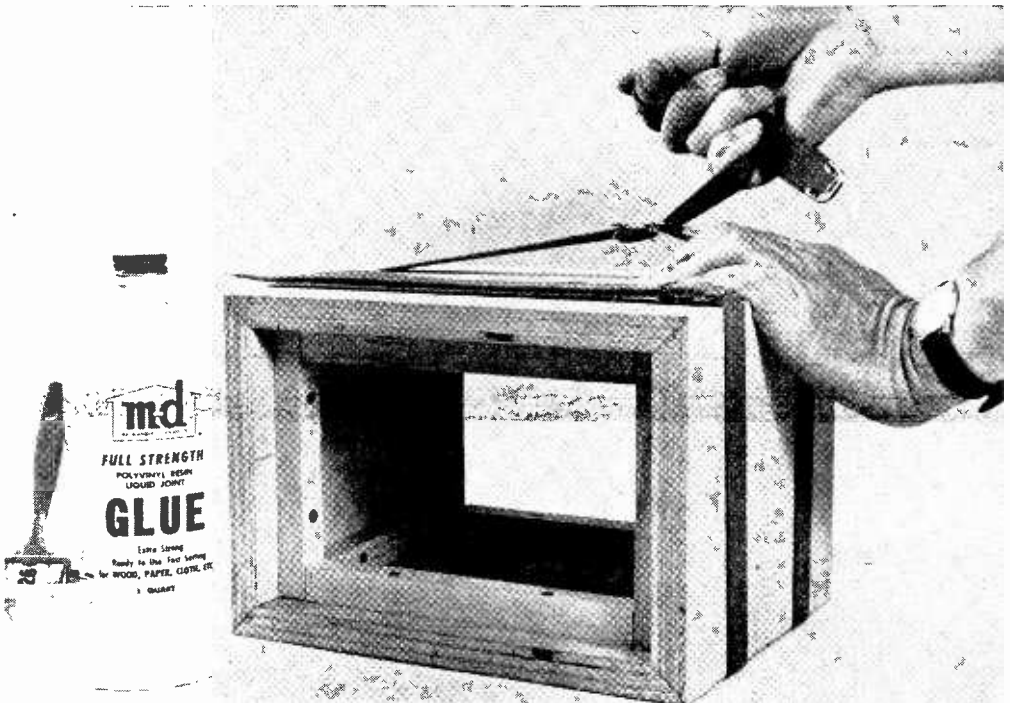
provide enough surface area contact between the parts to be held by wood glue alone.

First, cut out the parts. Then install the front and back cleats, positioned $\frac{3}{4}$ -inch away from the edges of the sides, top, and bottom to leave space for the front and back panels. These $\frac{3}{4}$ " x $\frac{3}{4}$ " cleats can be mounted with screws and glue or, if C-clamps are used, with nails and glue. The kind of nails that are stocked by building supply houses for use with dry wall house interior construction are just long enough to hold without penetrating the sides.

Corner glue blocks (6" long) can now be inserted from cleat to cleat at the interior corners of each of the smaller sides. The enclosure parts should be set on edge on a table top at several stages of their preparation to check their fit. After the glue has set on the cleats and blocks, the basic enclosure can be assembled by coating each joining surface with wood glue, setting the sides together, and applying pressure while the glue

*Build the "Cinderella," ELECTRONIC EXPERIMENTER'S HANDBOOK, 1966 Fall Edition.

After the cleats have been mounted, the sides, top, and bottom of the enclosure are glued and forced together. Apply equal pressure using a canvas strap.



sets. One of the most convenient methods of applying pressure is to use two 48-inch canvas straps. When tightened, the straps force the sides into position for a perfect fit.

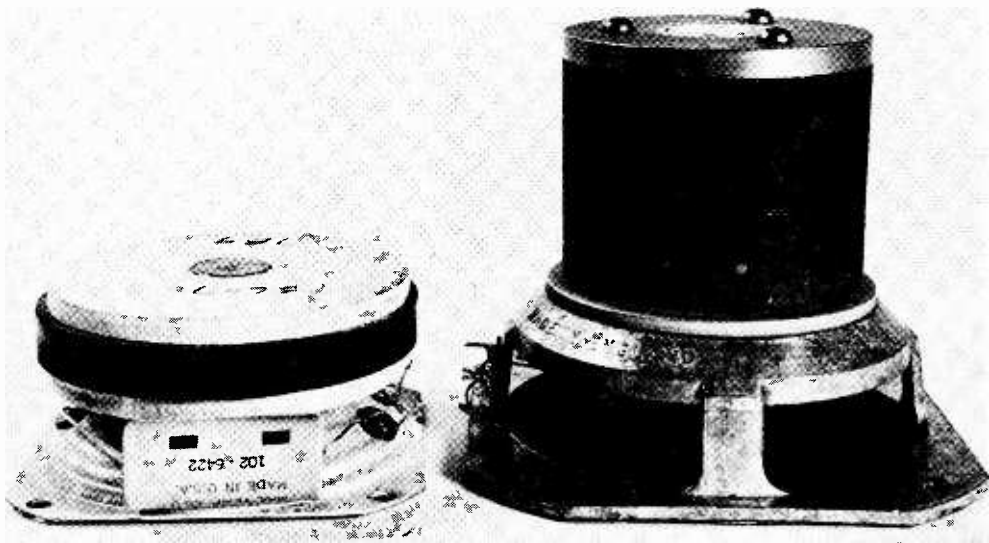
Next, the board cut for the front baffle should be set in place and an outline of the front cleats marked on it. The outline shows the space allowed for the speakers. Set the speakers in position and mark the location of the woofer mounting bolts. When these holes are drilled, diagonal lines between opposite holes will precisely locate the center of the woofer opening, which should approximate the point shown on the scale drawing. The tweeter cutout is less critical.

After the cutouts are made and the woofer bolts inserted, the panel should be painted flat black. Then the panel can be mounted with plenty of glue and 10 screws, three along each long edge of the piece and two at each end.

Finishing Touches. The plywood sides can now be sanded and finished, and grille cloth can be attached with tacks or, if used sparingly, contact cement. Any suitable trim will cover the raw edges of the plywood; the author used pre-finished picture frame molding. The frame was assembled and glued to the enclosure with contact cement, leaving no nail holes to fill.

Now install the speakers, using the bolts for the woofer, panhead screws for the tweeter. The speakers should be wired in phase, in this case a matter of connecting the left post on the woofer to the left post of the tweeter. The wires should be brought out the back of the cabinet without introducing an air leak. One method is to drill two small holes and screw tight-fitting bolts through the holes, after slipping the bolts through solder lugs to receive the speaker leads.

The interior of the cabinet is filled with acoustical felt, cotton batting, or



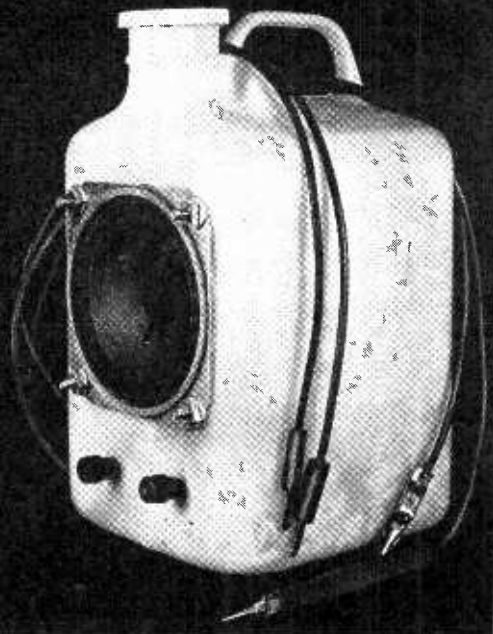
Massive magnet size of both tweeter (left) and woofer are apparent in this photo. Although low cost, these speakers are of modern design and capable of very good sound.

fiberglass. And, finally, the back can be installed; a gasket of thin cork, felt, or caulking compound around the rear cleats is desirable to eliminate air leaks.

Was it an extravagance for Goodmans to put a 3½-lb magnet structure on a 4-inch woofer? When you hear the smoothness of this little system, you'll know why they did it.

-30-

Instant Non-Fat Speaker Enclosure



TEST SPEAKER FINDS A NEW HOME

IF NECESSITY is the mother of invention, ingenuity must be the father, or so the saying goes. Recently I needed two identical speaker enclosures and the only systems available were too large or too heavy. Rather than assemble enclosures from plywood scraps, I settled for two empty white plastic milk containers! I converted them into enclosures in just about an hour.

But you don't need plastic milk containers to build the "Instant Non-Fat Enclosure." Any cube-shaped, one-gallon jug—preferably with a large carrying handle, for portability—will do. If you buy milk or liquid detergents in bulk, the jug is a bonus; otherwise, you can pick one up at a hardware store for about 25 to 50 cents.

Any replacement-type 3.5- to 8-ohm impedance speaker up to 5" in diameter (or 4" x 6" oval) can be used. The speaker should be mounted on the outside of the jug, so the mounting hole must be just large enough to accommodate all but the flat mounting rim of the speaker basket

—see the illustration on the next page. (For a typical 4"-diameter speaker, this hole will be about 3 $\frac{3}{4}$ " in diameter.)

Locate the speaker mounting hole so that when it is cut there will be enough room to mount a pair of banana jacks or 5-way binding posts along the bottom of the jug. After cutting the hole, temporarily set the speaker in place, and mark off the mounting screw holes. Remove the speaker, and punch or drill an $\frac{1}{8}$ " hole at each mark. Then screw a $\frac{3}{16}$ " x 1" binding-head machine screw (or regular machine screw and a lock-washer) into each hole. Use a short-handled screwdriver and orient the screws so that their heads are on the inside of the jug.

Solder a 12"-long piece of insulated stranded hookup wire to each of two chassis-mounting-type solder lugs. Then drill appropriate size holes and mount the banana jacks or binding posts in place, setting one of the solder lugs under each nut inside the jug before tightening the nuts.

To obtain the most acceptable sound from the "Instant Non-Fat Enclosure," the walls of the plastic jug must be made less flexible. This can be done by gluing two or three tongue depressors to the jug's side and rear interior walls. One

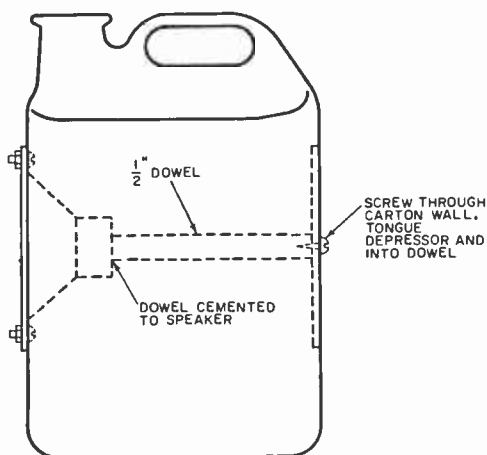
L'IL TIGER

(Continued from page 42)

tongue depressor should be oriented on the rear wall so that a wood screw can be driven through it and into the wood dowel as shown in drawing above. When the glue sets, apply a heavy coat of floor-tile adhesive to all interior surfaces except the cap.

Set the jug aside and allow the adhesive to set. Meanwhile, determine the distance between the speaker magnet support and rear wall of the jug when the speaker is mounted in place. Cut a $\frac{1}{2}$ " x $\frac{1}{2}$ " piece of wood to this length, and glue one end of this wood dowel to the rear of the magnet support.

Solder the hookup wires coming from the banana jacks or binding posts to the voice coil lugs on the speaker. When the

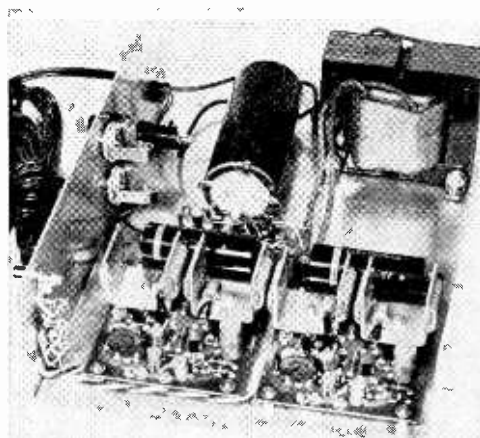


Dowel is cemented to speaker and screwed to rear wall of jug to insure maximum enclosure rigidity.

adhesive on the jug walls and the glue holding the wood dowel to the speaker magnet support set, fill the jug with shredded cotton batting or kapok. Lower the speaker into its mounting hole, and screw it down.

Finally, drill a hole in the rear wall of the jug, directly in line with the wood dowel on the speaker. Drive a 1"-long wood screw through the rear wall and into the dowel. Seal the mating surfaces between the speaker basket and jug with caulking compound or other suitable material. If necessary, mount a protective screen over the exposed speaker to prevent damaging the cone by rough handling.

—David B. Weems



A pair of "L'il Tiger" amplifiers and common power supply can be mounted in a chassis for stereo use.

crease above 10 mA; reduce the value of the resistor used for R_6 to the next smaller standard value if it does.

The "L'il Tiger" can be used with almost any transistor preamplifier, but the 5000-ohm input impedance is too low for many tube preamps.

Caution: Be careful not to short the heat sinks to each other while you are working on the amplifier with the protective cover removed. Remember that the heat sinks are connected directly to supply voltage and ground, respectively. Shorting them together will not harm the circuit, but will blow the fuse. Conventional microphone jacks have been used as output connectors to minimize chances of shorting the output of the amplifier. With no signal applied, a shorted output will cause no harm, but it could damage the output transistors if a large signal were applied.

—50—

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HOW TO STAY EMPLOYED,
AND WHO
DOESN'T GET ANYWHERE

THE ELECTRONICS TECHNICIAN SHORTAGE

THERE IS, according to almost any personnel manager, a serious shortage of electronics technicians. Perusal of the "Help Wanted" ads in almost any metropolitan newspaper reveals many openings for electronics technicians. Even such prestige employers as Bell Telephone Laboratories and Hewlett-Packard now seek out technicians whereas, not so many years ago, the waiting list for jobs at Bell Labs was longer than the personnel roster.

This shortage of electronics technicians is critical in many parts of the country. A few firms have even established training courses, tuition free, with guaranteed jobs for all who complete the course. Ads reading "Learn to be an Electronic Technician at our expense" offer a real opportunity to those with ambition, reasonable intelligence, and limited education, since some of these training courses are quite good.

Why a Shortage? The major cause of the electronics technician shortage is the enormous growth of the electronics industry. This growth includes not only the proliferation of the "amusement" part of the industry, but also the great expansion of military electronics, communication electronics, industrial controls, and the computer field. Medical



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SPECIAL BONUS FEATURE

By RONALD L. IVES

electronics, geophysical electronics, navigational electronics, and meteorological electronics are other branches of the industry which are expanding at a rapid rate. Even law-enforcement agencies are now extensive users of electronics equipment.

But expansion of the electronics industry accounts for only part of the technician attrition in the ranks of electronics technicians. Most of the electronics and radio pioneers have now retired, died, or stepped up to administrative positions. Few, if any, of those who built the Paragon RA-10 receiver, once world-famous, are still working as technicians.

There is also a "loss off the bottom"—the lowest grade technicians, those who put the wires on the round gimmick with colored stripes through holes 6 and 7 of the printed-circuit board, work for a few months, or even a year, and then come down with "nerves," "the misery," etc., quit and go back on relief. Many of these jobs are being eliminated by automation.

The "loss off the top" is more serious, as it removes from the technician ranks some of the best workers. Often, these technicians, after working for a couple of years, leave to start businesses of their own. Some have saved up enough money to finish college; and some, after attending night classes for several years, earn a degree, and get hired as engineers by competitors. Also, many technicians graduate to better jobs as supervisors, field representatives, sales representatives, troubleshooters, computer programmers, etc.

... almost any competent technician can get a job ...

Although the combination of industry growth and the attrition of technicians gives the personnel office ulcers, it also keeps the pay of technicians at a healthy level and insures that almost any competent technician can get a job.

Who Gets Hired. When a firm advertises for electronics technicians, what do they actually want and who will they hire? Suppose the company of your choice has not advertised recently. Should you apply? If you belong to some minority group (almost everyone does), will it affect your chances of employment?

These questions are easy to ask but sometimes almost impossible to answer. Some companies have "secret" employment policies, interpreted by those in the personnel office. Although illegal, the department with the vacancy can be a closed corporation that will only accept applicants of a specific religion, race, political belief, or national origin. As a very general rule (there are exceptions), successful medium-sized to large companies have honest liberal employment policies. In many of them, you will find John Lowell, Seamus O'Hara, Ikey Cohenstein, Woe Sin Wong, Atanacio Tafoya, and Crispus Attucks Jones working harmoniously on the same project. In the Southwest, you may also find Luis Oacipicagigua on the project roster. He is familiarly called "Chief."

Despite stories that women are employed only on the production line and as equipment operators, many laboratories employ women as electronics technicians in all categories. Some of them do outstandingly good work.

Assuming that you have applied for a job, either directly at the personnel office or by mail, you will probably be interviewed by several people. The first interview will be quite short, in most instances, to determine only your general suitability for employment. If you look

like a disappointed beatnik or have applied for a chief engineer's job when you are only qualified for a position as assistant janitor (trainee), the first interview is as far as you will get.

Following this first interview, many companies give some sort of a written test. Most of these tests are quite fair and provide a pretty good evaluation of a man's ability; others are badly off the beam, being loaded with questions about

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variometers, gravity cells, electrolytic interrupters, and other pieces of radio equipment that are now relegated to the museum.

A few firms give what purports to be a psychological test, its aim being to eliminate "undesirable types" from among the applicants. Some of these tests are successful in eliminating the "lunatic fringe" but others are so loaded with "Hobson's choice" questions ("The lost books of Sennacherib state that Jehu was Constantine's charioteer, yes—no—") which *must* be answered, that no ordinary person can get a pass-

... don't claim to know all about electronics ...

ing score. There is no place, on many of these questionnaires, for "don't know." If you get stuck with one of these, play it by ear, remembering that almost any statement containing *always* or *never* is likely to be false.

Because of Government contracts, most prospective employees must undergo a loyalty check of some sort, leading to a security clearance. This involves a fingerprint check and an investigation of the applicant's background. The loyalty "test" can be anything from a simple and straightforward outline of past experience and associations to a detailed questionnaire that might well make J. Edgar Hoover sweat. There is usually a lecture on security, sometimes given by an ex-FBI man who knows the score and at other times by a retired Army sergeant who "knows Communists."

After or while passing these hurdles, which may take from a few days to a few months, you will finally see the head of the department where the vacancy exists and get an idea of what the job will actually be. There may be a practical test at this stage of the game—soldering, reading wiring diagrams, using the oscilloscope, or something of the sort. Most of the questions are pretty straightforward and to the point, but watch out for a "stinker." If you are asked for the characteristics of an inverse bilateral frammistat or the circuit of a hypsometric depediculator, the correct answer might well be "I don't know." If you are qualified for the

specific opening, this interview may be the shortest and simplest of them all.

Smaller companies usually have a shorter procedure in hiring but are often pretty demanding when it comes to qualifications and experience. Many non-electronic concerns have a semi-autonomous electronics department which maintains electronics equipment and fills the recurring demand "make me a widget that—".

Who Doesn't Get Hired. Many applicants for electronics jobs don't get hired. Folklore has it that they are not hired because they aren't competent. Actual reasons for "no hire" do include lack of training or experience, but most "no hires" are due to other things.

One of the surest ways of not getting hired is to have an overinflated resumé. Be sure that your statements of education and experience will stand checking. Even if you are pretty good, don't claim to "know *all* about electronics."

If, when applying for a job, you look like an exhibit from an anthropology museum, a fugitive from the barber shop, or are several months estranged from the laundry and the bathtub, the personnel manager is not going to be favorably impressed. Unless you want to be a geek in the sideshow, a little attention to personal appearance will help chances of employment.

Most employers have had sad and costly experiences with alcoholics, so don't show up for an interview smelling like a brewery. Likewise, if you are a hophead, weedhead, or acidhead, stay out of the personnel office.

Too many grievances about previous employers impress most personnel men unfavorably. Unless you are out of a job because of a contract termination or a company merger, you left your previous employment because of some unsatisfactory condition. This is understood. But if you left each of the last six places you worked (for two months each) because

ABOUT THE AUTHOR

Ronald L. Ives is a prolific author and has published hundreds of articles on electronics. Mr. Ives is currently associated with Metronics, Inc., Palo Alto, Calif. Born in 1909, he has a doctorate in geography, geology and anthropology. His long career in electronics—dating back to 1926—has kept him in close contact with technicians.

... a technician's job is not usually a dead end ...

everyone there was a !\$#-//!! the interviewer is going to be a bit skeptical. Sometimes he knows the facts about your previous employer and if your tale of woe and injustice disagrees with his knowledge, he may have reservations about your employability.

Although most electronics employers are fairly sophisticated, an applicant whose vocabulary is overloaded with four letter words is likely to find himself on the street again. Save the "blue" words for when you spill the solder pot into your right-hand pocket.

Who Doesn't Stay Hired. In any newly hired group of electronics technicians, some, or many, work out satisfactorily, remain on the job, and in the course of time get raises and promotions. In some of the older companies, we find senior technicians with twenty or more years of service and paychecks that make the Internal Revenue Service very happy. Many technicians who were trained during WW II are now section heads. A few have become engineers, chief operators, traveling troubleshooters, and customer contact men. A few are now either in business for themselves or have graduated "upstairs" to the board of directors. A technician's job is not usually a "dead end."

But, in any newly hired group, there are a number of technicians who don't stay hired because they are technically incompetent in one way or another. One of the most common failings is the inability to use technical knowledge. The sufferer from this fault can pass every written test, fill blackboards with correct formulas and wiring diagrams, discuss theory impressively, and generally act like a genius (junior grade)—but he can not make anything work.

Some relatively new employees are called to the security office after a few weeks of work and are seen no more. The trouble could be false statements on

the employment application, concealment of a criminal record, or denial of security clearance for various reasons.

The technician who shows up for work under the influence of anything intoxicating or stupefying usually goes on permanent vacation rather suddenly. Absences every Monday morning, the day after every holiday, and the two days after each payday, usually make the section chief suspicious. So do shaky hands on return to work after each reported bout with "the virus." Filling your thermos full of "Old Bust Head" instead of coffee sounds like an excellent idea, but the foreman's grandfather knew about that one, too.

One sure way of getting plenty of leisure (without pay) is to try to force your religious or political beliefs on your fellow employees. If, while ostensibly employed by an electronics company, you spend a lot of time recruiting for the Charles Ash Society, organizing compulsory prayer sessions during coffee breaks, or bawling people out for not attending the Whoop and Holler Pentecostal Tabernacle, you are greasing the skids under your feet.

A related, but less serious evil, is taking off too many religious holidays. Most employers allow time off for religious observances, but if you take off on Good Friday, don't also take off for Yom Kippur and the first day of Ramadan.

Unreasonable friction on the job is a cause of many firings, as is intolerance of the reasonably normal traits of your fellow employees. A department where a number of the employees are "not speaking" is an unhealthy one and usually undergoes changes in personnel pretty regularly. Meddling in the personal affairs of your fellow workers just won't do, and loud personal criticism of the man at the next bench is completely out of line.

A very common employee trait, carried on the books as "stock shrinkage"

... "pilferage" causes a lot of technicians to lose jobs ...

or "pilferage," but more commonly known as stealing, causes a lot of technicians to change jobs involuntarily. This ranges from the occasional "borrowing" of a resistor to fix the home radio to wholesale thefts of expensive or scarce components for sale. Many employers are pretty liberal about a few

There is also the recurrent and disturbing condition of a sterling character, of unquestioned competence and laudable diligence, who just doesn't fit in in a given department. Very often the reason for this cannot be determined and nobody seems to be at fault. Happily, most of these individuals recognize the situation, get jobs elsewhere before a crisis occurs, and frequently do well at the new job.

Where Employers Fail. Some "prestige" employers have an appreciable number of technical employees who stay with the company until retirement. However, a rather disturbing number of electronics employers have very high labor turnovers, so that anyone who has been on the job for as long as six months is regarded as a "veteran." Most of the stable electronics manufacturers and research laboratories fall somewhere between these extremes.

Almost any freshman student of economics can point out, with examples, an inverse relationship between company profits and labor turnover. But by the time he graduates, this student of economics will find that the situation isn't that simple; he will be firmly convinced that labor recruiting costs money and that excessive labor turnover indicates something wrong somewhere.

Many firms, usually the smaller and newer ones, start all applicants at minimum rate, regardless of training and experience; lay off whole departments indiscriminately at the termination of a contract; and then search madly for new help, a few weeks later, when they get a new contract. Such companies soon get a bad reputation in the community and the more competent and skilled workers will not apply there. New "hires," in consequence, are almost all from the bottom of the barrel—inexperienced, uneducated, or with very bad employment records elsewhere.

small parts but get downright "unreasonable" about recurrent disappearances of special integrated circuits, machine tool parts, or even oscilloscope plug-ins. Great care in keeping "company property" separate from "personal property" will not hurt your job tenure or chances for promotion.

over

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Some employers, as a matter of policy, regard all technicians as second-class citizens and flood them with advice and admonitions on the intellectual level of the third grade in a school for retarded children. They sometimes even meddle in the personal affairs of their employees, usually in the guise of "security." These policies often alienate the more competent and experienced employees who begin "looking around" and usually find jobs where there is no meddling.

Employing (and usually paying) technicians at levels far below their competence also accelerates labor turnover. A frozen table of organization, with promotions only by seniority (if at all), leads to employee losses "off the top."

Employee irritation is also increased by a book of company rules as thick as a telephone directory, worded by a shyster lawyer, so that no matter how hard the employee tries to do the job right, he is in hot water. If the supervisor also gives hourly public bawl-outs, he will soon be calling on personnel for more technicians.

Incompetent supervision of various sorts also reduces the effectiveness of the technician staff and leads to either less than optimum production or increased labor turnover, or both. One of the chief problems, in many places, is an administrative section head who doesn't know how long it takes to do a given job. This same man is also prone to giving vague and unclear instructions and then complaining about incompetence when he doesn't get what he thinks he might have wanted.

A surprising number of companies do not supply adequate work space, sufficient tools in good order, and proper materials for their technician staff. Although a good technician can produce pretty good equipment with a box full of junk and some garage-type tools, the work will be better done, at much lower cost, if the tools and equipment are adequate. Most technicians get heartily sick of unnecessary "Goldberging" and soon go looking for jobs in places which are better equipped.

What Can Be Done. The shortage of competent electronic technicians has been with us for some time and will worsen in coming years. There just

aren't enough people entering the profession to make up for normal attrition and the expansion of the electronics industry. This shortage may retard industry growth and make maintenance and repairs of electronics equipment inordinately costly.

The electronics industry is not alone in having technician shortages. Good automobile mechanics, medical technicians, nurses, secretaries, engineers, etc. are also in short supply. As one personnel man remarked recently "there just aren't enough brains to go around." Lunkheads, it is true, are still plentiful, but there aren't many jobs available for the man who can't learn to pick up both handles of the wheelbarrow at the same time.

Part of the technician shortage can be alleviated by increasing training programs, provided people can be persuaded to respond. Most technician jobs today require high school graduation plus some additional training or experience. The Associate in Science (E.E.) programs in some of our junior colleges are a step in the right direction, but are hampered by a shortage of teachers. Some of the military training programs are quite good. Several of the correspondence schools give excellent theoretical background, but are unavoidably weak in practical applications. There are still a few self-taught electronics men of respectable competence, but most of them are not only already employed but are nearing retirement age.

There is a small reservoir of competent technicians which has not been tapped because of various company regulations and prejudices. For example, is it necessary for electronics technicians to pass an "Air Force" physical exam? This will eliminate the man with a wooden leg, but may not detect another man's wooden head. Does the use of bifocals bar a technician from employment? Why? Do all technicians have to be less than 35 years old? Should a minor juvenile record bar a man from employment permanently? Is the "male only" restriction valid? Should a "solid citizen" of a neighboring country, such as Canada or Mexico, be barred from employment in most places because he is not a U. S. citizen? Is security being overused? Are

(Continued on page 152)

CHAPTER

3

LAB & TEST EQUIPMENT PROJECTS

Stuffy electronics engineers who think hobby electronics is beneath their dignity received a severe blow to their pride when POPULAR ELECTRONICS (February, 1968) published plans for an in-line decimal counting unit. Adding insult to injury, the cost of building one DCU reached a rock-bottom price of \$12—about \$40 less than the major manufacturers of electronic equipment had been able to offer for a similar item of much less flexibility.

Your editors are proud of their part in bringing this new development to the attention of engineers, technicians and hobbyists alike. We are doubly proud to announce that the DCU in this issue of the ELECTRONIC EXPERIMENTER'S HANDBOOK is a revised version of the original concept. The new DCU requires one IC less, uses considerably less power, and is designed to eliminate the afterglow from the unused lamps. With appropriate IC's, the new DCU may be used on battery power without worrying about the current drain.

Numerous projects using this DCU are scheduled for publication in both POPULAR ELECTRONICS and the ELECTRONIC EXPERIMENTER'S HANDBOOK. We urge you to save the plans for this DCU and keep them handy for future reference—a digital voltmeter, frequency counter, etc. are in the works.

80	LOW-COST COUNTING UNIT.....	Don Lancaster
86	IC 'TESTONE'.....	Don Lancaster
89	ULTRA-FAST ELECTRONIC STOPWATCH.....	Don Lancaster
98	NGW TRANSISTOR TESTER.....	Don Lancaster
101	EXPERIMENTER'S SHORT-PROOF POWER SUPPLY.....	James W. Cuccia
107	LOW-COST HIGH-QUALITY ELECTRONIC VOLTMETER.....	Frank H. Tooker
113	VERSATILE REGULATED LOW VOLTAGE POWER SUPPLY.....	Frank H. Tooker

BUILD A

Low-Cost Counting Unit

YOU CAN ASSEMBLE TRUE DIGITAL READOUT
AT \$12 PER DECADE

BY DON LANCASTER

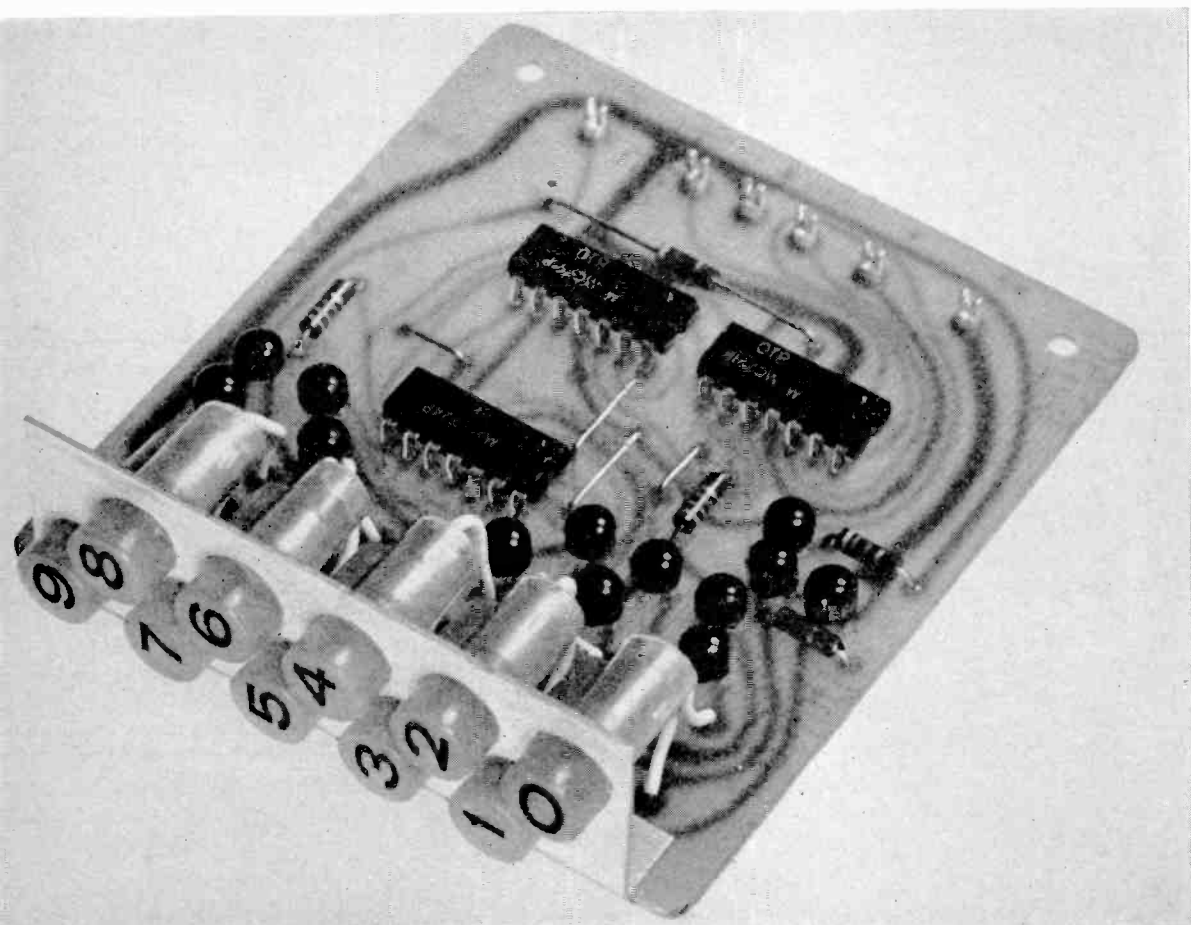
DIRECT, unambiguous numerical readout at low cost—the dream of most electronics experimenters, technicians, and engineers—is now made possible by inexpensive integrated circuits and a few seldom-used circuit tricks. For just \$12 per decade *total* cost, you can have a complete, resettable decimal counter with a bright staggered-line 0 to 9 incandescent readout, good from one count per day to 10 MHz.

You can cascade many of these decades together as you need for almost any digital display. Using these decimal counters, *ELECTRONIC EXPERIMENTER'S*

HANDBOOK will, in future issues, show how you can make a digital voltmeter, digital multimeter, and a universal frequency counter.

You'll be able to create an adding machine, a ballistic-velocity meter, or an event counter. And the list does not end there. Using this low-cost DCU, you can also make digital thermometers, electronic clocks, engine tachometers, direct-reading CE crystal (or other frequency) crystal checkers, photographic shutter checkers—and even a digital computer.

The basic decimal counter, whose schematic is shown in Fig. 1, uses three IC's,



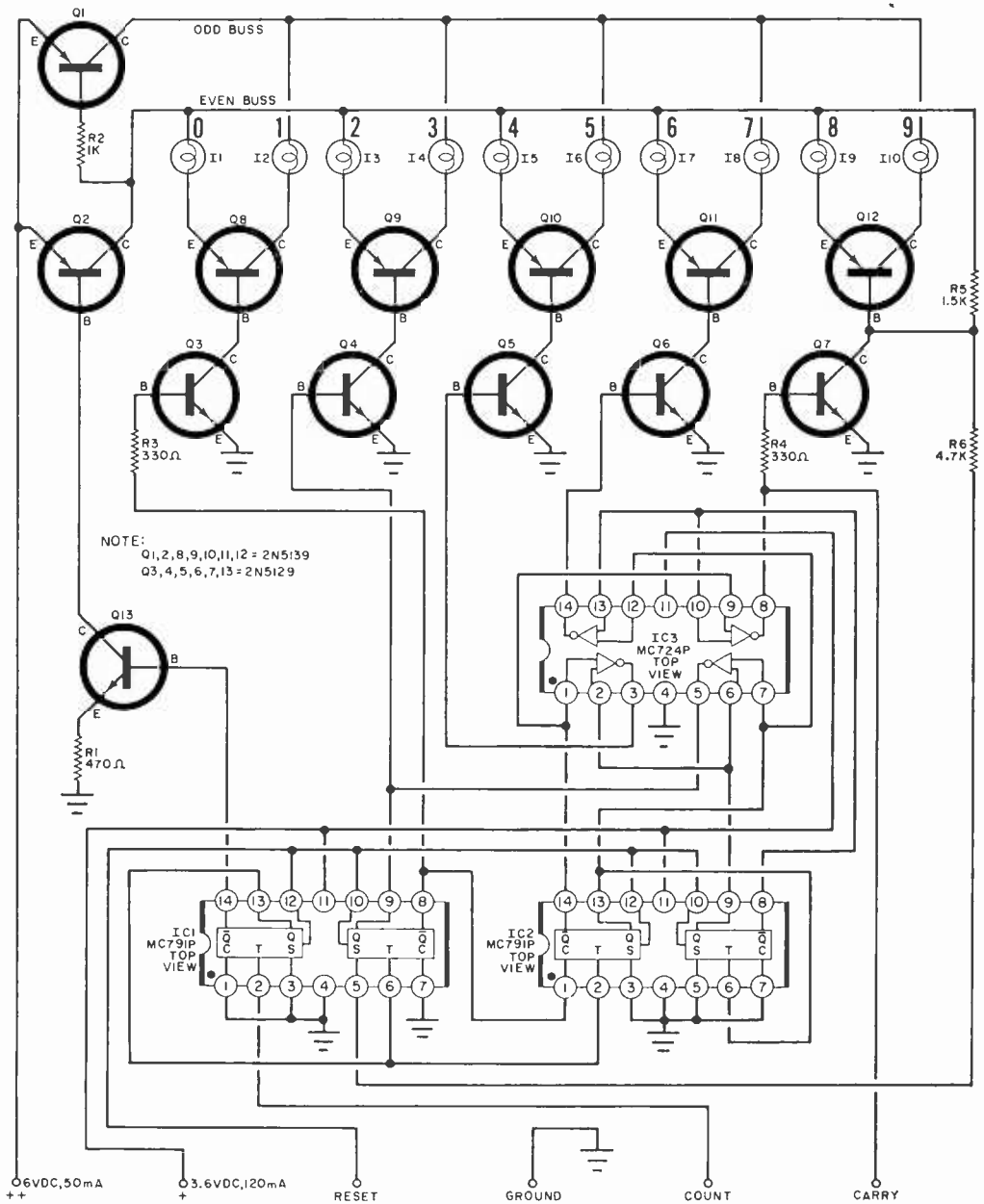


Fig. 1. In IC1 and IC2, the rectangles represent flip-flops while in IC3 and IC4, the triangles with circles represent multiple input gates. Logic symbols replace complicated circuitry.

six resistors, 13 transistors, and 10 incandescent bulbs. If desired, a complete decade kit is available (see Parts List).

Construction. An actual-size printed circuit board appears in Fig. 2, while Fig. 3 shows how the board is drilled, and also indicates the positions for in-

serting the four jumpers required. These jumpers are made from #24 solid wire and are added on the component side of the board.

When mounting the components (as shown in Fig. 4), be sure to observe the polarities for all semiconductors—making doubly sure that the IC's are mounted as

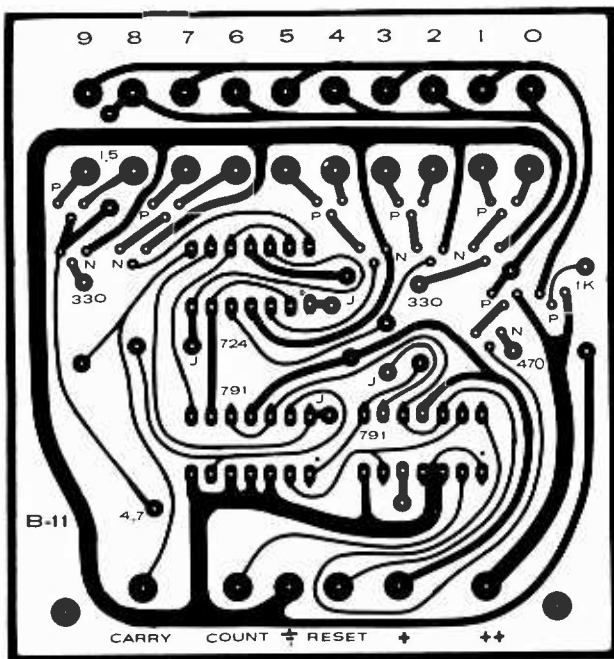


Fig. 2. Because of the complex wiring involved, it is almost mandatory that a printed circuit board, such as the one shown here actual size, be used. An etched and drilled board is available (see the Parts List).

PARTS LIST

11-110—6.3 Volt, 50-mA pilot lamp and lens assembly [Southwest Technical Products #0-6.3 or similar]*

IC1-IC2—MC791P Dual JK Flip Flop Integrated Circuit Motorola MRTL**

IC3—MC724P Quad Two Input Gate Integrated Circuit Motorola MRTL**

Q1, Q2, Q8, Q9, Q10, Q11, Q12—2N5139 PNP Transistor National Semiconductor***

Q3, Q4, Q5, Q6, Q7, Q13—2N5129 NPN Transistor National Semiconductor***

R1—470 ohm, 1/4 watt carbon resistor

R2—1000 ohm, 1/4 watt carbon resistor

R3, R4—330 ohm, 1/4 watt carbon resistor

R5—1.5K, 1/4 watt carbon resistor

R6—4.7K, 1/4 watt carbon resistor

MISC—Aluminum bracket (See Fig. 5); pop rivets (2); #24 solid wire jumpers (4); PC terminals (6); 3/16"-high instant transfer numerals, black; protective plastic spray; solder; etc.

*The following parts are available from Southwest Technical Products Corp. 219 West Rhapsody, San Antonio, Texas, 78216: Etched and drilled PC Board #148. \$3.00; Set of 10 lamps with plastic covers and spare bulb \$2.75; Complete kit of all parts, \$10.90, postpaid in U.S.A.

**Data sheet and distributor list available from Motorola Semiconductor, Box 955, Phoenix, Arizona, 85001. One distributor is Allied Electronics, 100 N. Western Avenue, Chicago, Illinois, 60680. IC1 and IC2 is stock #5E26-MC791P-MOT priced at \$2.35 each. IC3 is stock #5E26-MC724P-MOT at \$1.08.

***Data Sheet and distributor list available from National Semiconductor, 2950 San Ysidro Way, Santa Clara, California, 95051. The 2N5139 costs 22¢ each in single quantities; the 2N5129 costs 25¢ each in single quantities.

indicated. Use a low-wattage soldering iron and fine solder to make all connections.

The readout lamp display bracket is cut and bent out of 1/32" aluminum following the layout in Fig. 5. Two pop rivets secure the lamp bracket to the board. The indicator lamps press-fit into the holes in the bracket, through the front, and are secured by the wedging action of the plastic lens caps. Each bulb lead is

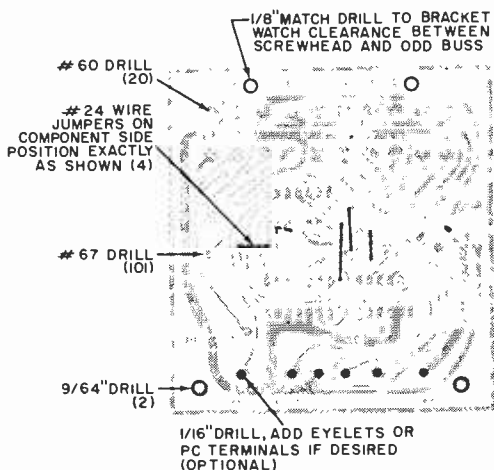


Fig. 3. Drilling details for the board. Don't forget to include the eight insulated wire jumpers.

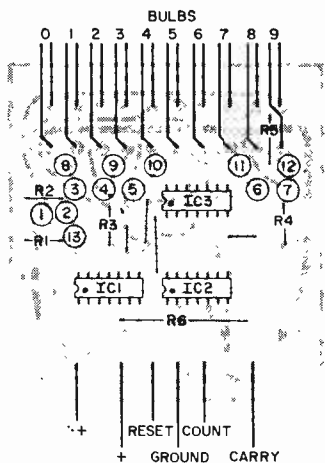
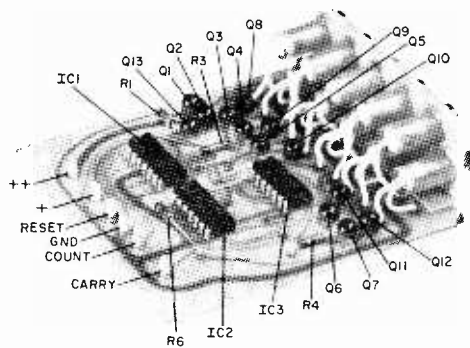
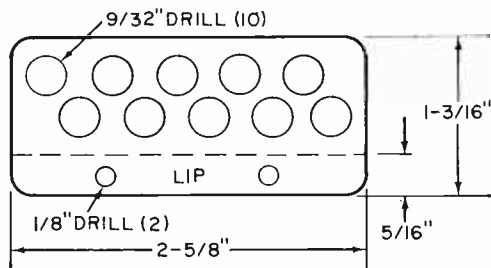


Fig. 4. Placement of the components on the board. Note that all IC's are notch- and dot-identified.



The PC board with all of the components installed.



soldered to its respective PC board terminal. Bulb marking (0 through 9) is done with $\frac{3}{16}$ " black instant transfer numerals, which are applied to the plastic lens cap, then coated with a clear acrylic spray.

Power Supply. There are three power supply connections to be made to the decimal counter. "+ +" requires 6.0 volts at 50 mA; "+" requires 3.6 volts at 120 mA (with less than 0.7-volt peak-to-peak ripple), while "GND" is the common supply return. The power supply shown in Fig. 6 will power up to six decimal counters.

In constructing the power supply, don't skimp on the value of $C2$ or the resultant a.c. ripple may be too great. All power supply leads must be of heavy-gauge wire.

Operation. There are three signal connections to be made to the decimal counter—"Count" input, "Reset" input, and "Carry" output. The "Count" input will advance the decade counter one count each time the input signal *abruptly drops* from +3 volts to ground. However, it is *important* that all input signals be properly conditioned to insure that they are noise-free and drop *abruptly once and only once* per count cycle. Failure to do this will result in erratic counting.

There are several ways to make a "bouncelless" input signal. If you want to use an s.p.d.t. push button, use the set-reset conditioning flip-flop in Fig. 7(a). If you want to use an s.p.s.t. "make" contact, use the monostable circuit in Fig. 7(b). This conditioning is mandatory for *any* mechanical contact.

Clean sine or square waves from 100 kHz to 10 MHz can be directly applied to the decimal counter "Count" input with-

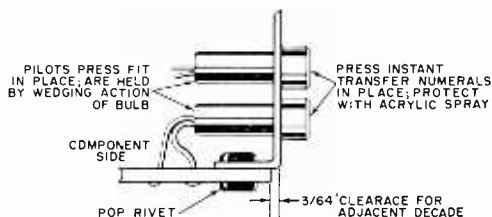


Fig. 5. Drilling details for the lamp bracket are shown at the left. The bracket is secured to the printed board and bulbs inserted as shown above.

HOW IT WORKS

Where most divide-by-ten circuits use a relatively complex, multi-transistor arrangement of decoder gates and readout drivers, the decimal counter described in this article first divides by *two*, and then by *five* to produce a *biquinary* counter. Such an arrangement is considerably simpler than the conventional decimal counter in that it requires three less transistors and seven less decoding gates to produce the same results.

The input pulse train is fed to a divide-by-two counter (part of *IC1*), a conventional flip-flop which changes state with each pulse input. One state of the input divided-by-two counter will indicate an odd number input while the other state will indicate an even number. The odd-even signal is processed by a section of *IC4* and used to switch transistors *Q1* and *Q2* so that on even numbers the "Even Bus" will be supplied with power, and on the odd numbers the "Odd Bus" is powered. The schematic of the complete decimal counter shows how the indicating bulbs are connected in pairs to the odd and even buses. Each pair of bulbs is connected to ground through a transistor switch (*Q3* through *Q7*) which is open when not energized, and closed when energized.

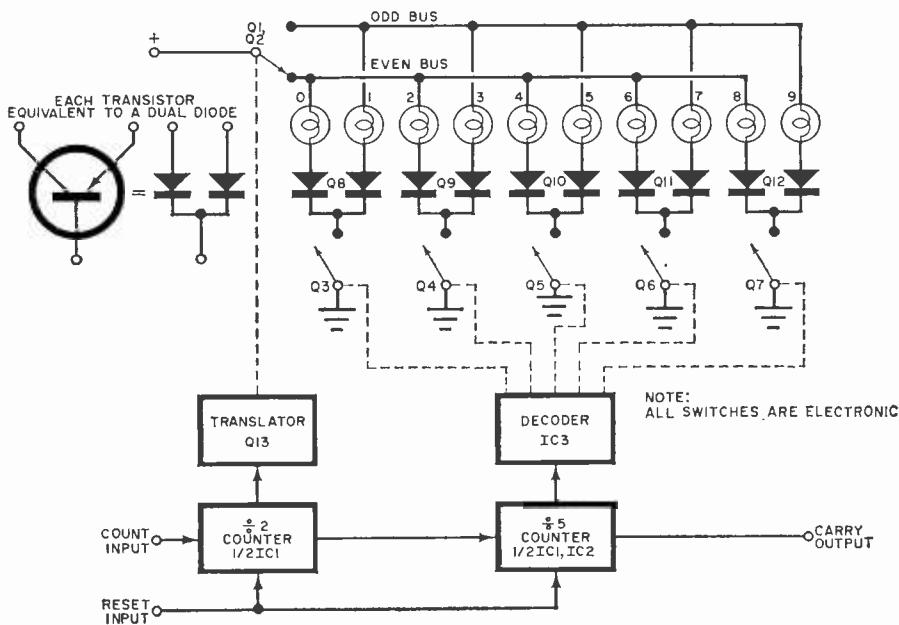
After division by two, the input pulses are fed to the divide-by-five counter, consisting of the remaining part of *IC1* and all of *IC2*. This counter decides whether the input signal is 0 or 1, 2 or 3, 4 or 5, 6 or 7, 8 or 9—and its selected output signals are processed by decoder *IC3* and the remainder of *IC4*. The output signal from the decoder will energize the appropriate transistor

switch, effectively closing it and allowing current to flow from the selected odd or even bus, through one bulb and through the transistor switch to ground, illuminating the pertinent bulb.

For example, assume the count has reached the number 7. The divide-by-two counter has determined that it is an odd number and has energized the odd bus. The divide-by-five counter decoder has determined that this pulse is either 6 or 7, and energized transistor *Q6*. Under those conditions, bulb 7 is the *only* bulb illuminated. Weak glow of the bulbs is prevented by the insertion of transistors *Q8* through *Q12* in the appropriate lines. Each transistor serves as a dual diode. Cycling of the counter is controlled by feeding a portion of the "8 or 9" signal back to *IC1* through *R6* (see Fig. 1).

On each tenth input pulse, the divide-by-ten characteristic of the decimal counter circuit causes it to cycle to 0 indication while simultaneously providing one output pulse which is used to start the count on another counter. Assume that two decimal counters are connected in cascade and the count is 9. The first decimal counter (indicating "one's") displays a 9, while the second decimal counter (indicating "ten's") displays a 0. When the count reaches 10, the "one's" counter cycles to its 0 indication, while the "ten's" counter receives one pulse to display a 1. The overall illuminated readout is then 10. Still another decimal counter can be connected to the "ten's" counter "Carry" output to provide a "hundred's" column, which will start indicating when the total count exceeds 99. And so on.

Although what appear to be six mechanical switches are shown here, actually they represent high-speed transistor switches that are driven by the electronic circuits shown connected to them by the six dashed lines.



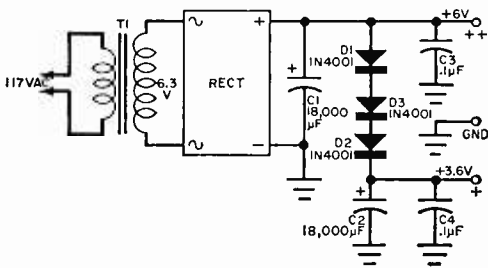


Fig. 6. This recommended power supply will handle up to three decimal counter modules simultaneously.

POWER SUPPLY PARTS LIST

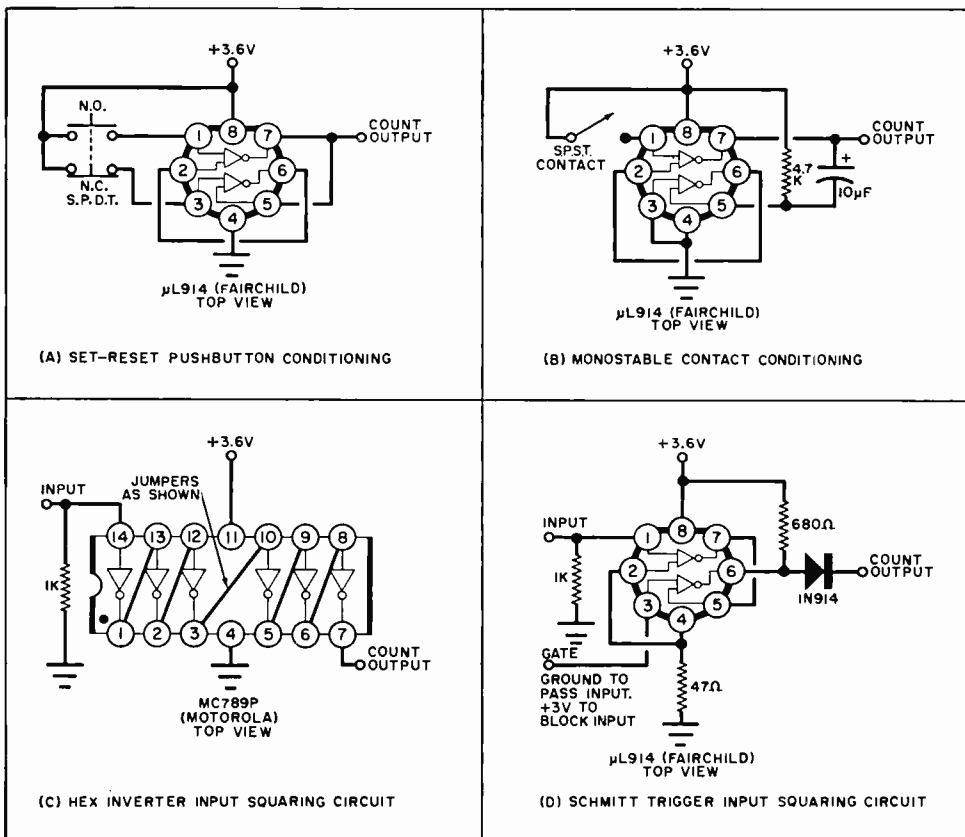
C1, C2—18,000- μ F, 10-volt electrolytic capacitor (Sprague 183G010AC or similar)
C3, C4—0.1- μ F capacitor
D1, D2, D3—1N4001 diode
 RECT—1½-ampere full-wave bridge rectifier assembly (Motorola MDA942-1, or similar)
 T1—Filament transformer: primary, 117 volts a.c.; secondary, 6.3 volts a.c.; 1½ amperes (Allied Electronics 54 E 1419, or similar)

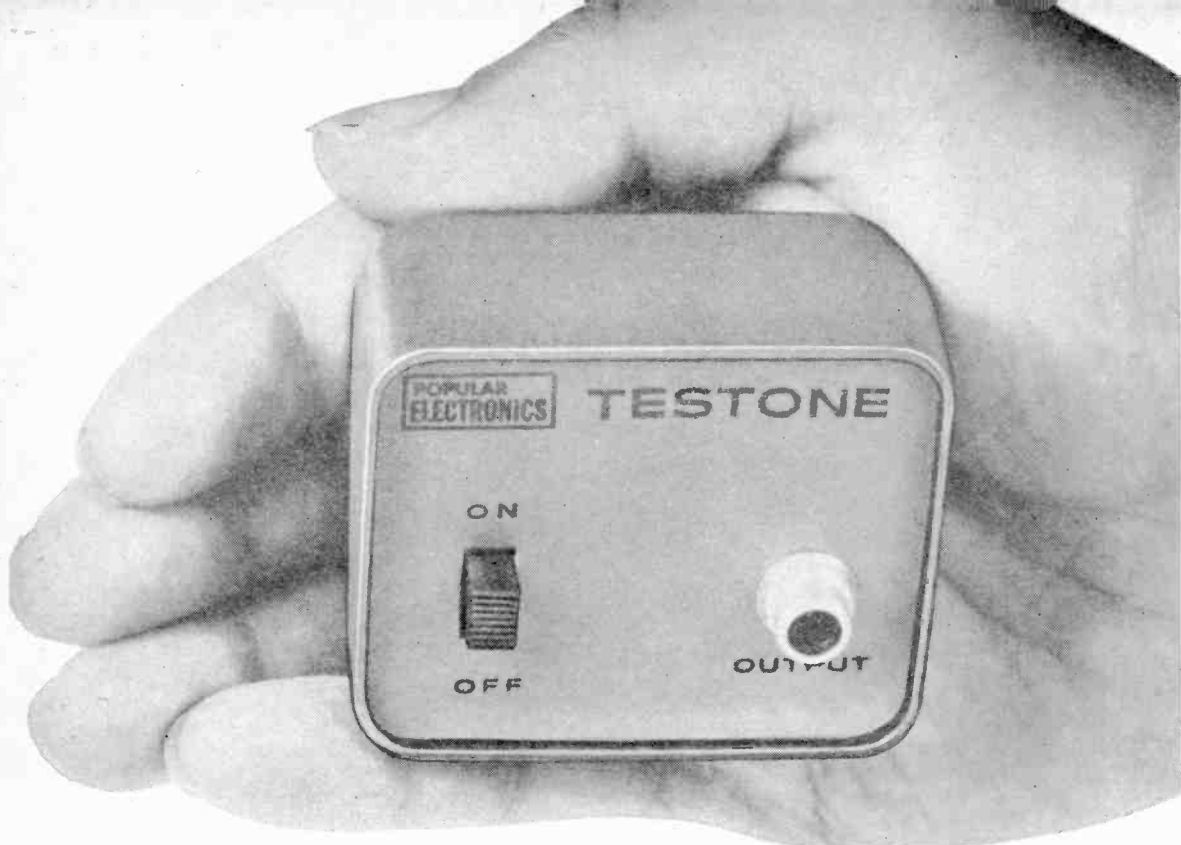
Fig. 7. Pin 8 of the μ L914 is identified by a dot. The MC789P is identified by a notch and dot code.

out conditioning. Slower signals must be squared up using either the hex inverter squaring circuit in Fig. 7(c), or the Schmitt trigger of Fig. 7(d). Either of the latter two circuits work well with 3 to 5 volts of peak-to-peak input signal. The Schmitt trigger can also be gated by holding its "Gate" input at ground when "Count" signals are to be passed, or at +3 volts or so when "Count" signals are *not* to be passed.

The decimal counter "Reset" input is normally grounded. It will automatically return the counter to its "0" condition any time this input is connected to a +3 volt source. The "Reset" push button need not be made "bounceless."

The "Carry" output is used when two counters are cascaded by directly connecting the "Carry" output of the first unit to the "Count" input of the second. The second counter will register "ten's," a third counter will register "hundred's," and so on. -30-





Build an IC 'Teststone'

UTILITY SQUARE-WAVE GENERATOR

FEATURES HIGH OUTPUT AND LOW COST

BY DON LANCASTER

HERE'S A LOW-COST IC audio signal source powerful enough to directly drive a speaker, yet so tiny it fits easily into the palm of your hand. The "Teststone" puts out a 1-kHz square wave of 2.5 volts amplitude, runs on two internal AA penlight cells for 50 hours or more, and has a special buffered output stage that can drive any impedance load—and even be short-circuited—without stalling.

The "Teststone" is handy for audio, p.a., and hi-fi service work, particularly in checking out cables, speaker lines, and anywhere else where a physically larger audio oscillator unit would become an awkward burden. It tucks away in the smallest tool kit or tube caddy. In conjunction with an oscilloscope, the "Tes-

tone" will help you obtain approximate quality checks on a hi-fi system—frequency response, distortion, etc. The sharp-rise output square wave has harmonics well out into the MHz region, making the "Teststone" an ideal signal injector whose thousands of harmonics can be most useful for AM radio and other high-frequency service work. Add a key and a speaker, and you have a low-cost CPO or signaling system.

A breadboard version of this circuit could cost you less than \$2 (the price tag on IC1 is only \$1.08), while a fancier, boxed version will go from \$3 to \$5, depending upon your taste in enclosures. A professional dialplate is available, and all parts are easy to get.

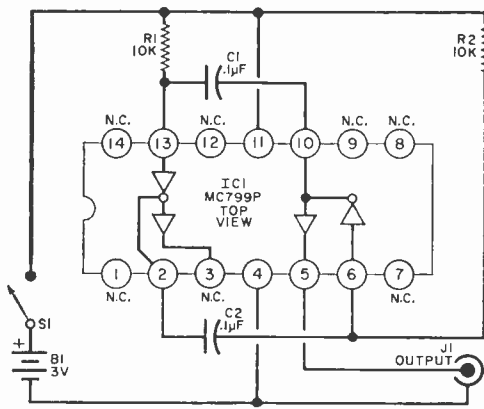


Fig. 1. Although the IC contains two sets of inverting buffers, not all of the internal circuits are used. The output can drive any load impedance—even down to a short circuit.

PARTS LIST

- B1—“AA” penlight cell, 1.5 volts (2 needed)
 C1, C2—0.1- μ F, 10-volt miniature ceramic capacitor (Centralab UK-10-104 or similar)
 IC1—Motorola MC799 dual buffer (Allied Radio #50-E-26-MC799P-MOT)
 R1, R2—10,000-ohm, $\frac{1}{4}$ -watt resistor
 S1—S.p.s.t. slide switch
 J1—RCA phono jack
 1—Small enclosure (Bud CU-2100.A, Davies #220 plastic case, Zero Z-32-40A-24 box, or similar)
 1— $\frac{3}{16}$ " x 1" x $1\frac{3}{4}$ " single-sided printed circuit board
 1—Dialplate (optional)*
 Misc.—Holder for 2 “AA” penlight cells (Keystone #140); chassis (optional—see text); pop rivets (-) optional; threaded rivet-type spacers (5) optional; #6 x $\frac{1}{4}$ binder-head plastic screws, optional; wire, solder, etc.

*Metalphoto hard anodized aluminum dialplate is available from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Arizona 85014, in black and white for \$1, red or copper for \$1.25, postpaid in U.S.A.

HOW IT WORKS

The heart of the “Testone” is an integrated circuit (IC1) containing two inverting buffers, each having a high- and low-power output. The low-level outputs are coupled to the opposite inputs by C1 and C2, thus forming an astable multivibrator. Recharging resistors R1 and R2, together with the capacitors, determine the waveform symmetry and operating frequency. Values of the resistors and capacitors have been selected to produce an approximate 1-kHz operating frequency. The signal output is taken from one high-level output (at pin 5), and routed to the output jack.

The IC contains 6 transistors and 12 resistors, divided equally into two identical circuits. Transistors Q1 and Q4 form the active part of the astable multivibrator, while Q5 and Q6 provide a push-pull output stage for load drive and isolation. Transistors Q2 and Q3, and a pair of 1000-ohm resistors (all within the IC), are not used.

Construction. Figure 1 is the schematic for the “Testone” and Fig. 2 shows the equivalent circuit board of the IC. An actual-size printed circuit board appears in Fig. 3, while Fig. 4 gives you the layout and drilling details. You can make the PC board from a $1\frac{3}{4}$ " x 1" x $\frac{1}{16}$ " scrap of printed circuit material.

Component layout is shown in Fig. 5. Note that IC1 is identified by a dot and code notch and that all pin connections are shown from the top. Use a small soldering iron and fine solder to mount the components. While not required, three PC terminals (one for each lead coming off the PC board) add a professional touch and aid in making circuit interconnections.

You can use any enclosure you wish—

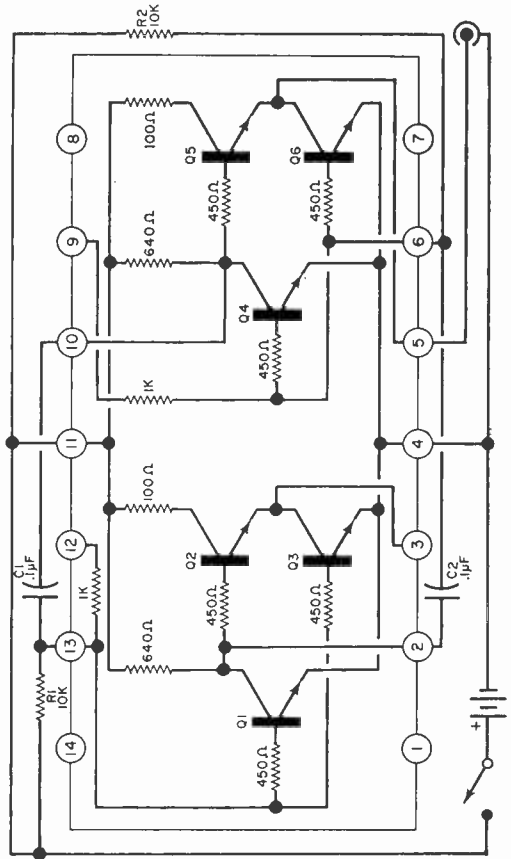


Fig. 2. The IC contains six transistors and 12 resistors, all diffused on a tiny piece of silicon, and packaged in a dual in-line, injection-molded 0.75" x 0.3" plastic case.

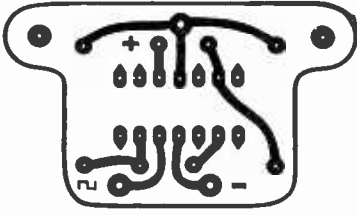


Fig. 3. Use this actual-size printed board if you want to make the "Testone" as small as possible.

a small metal box, a small plastic instrument case, or a deep-drawn aluminum box. Inside case dimensions should be greater than $1\frac{1}{8}'' \times 1\frac{1}{8}'' \times 2\frac{3}{8}''$ to allow enough room for the battery holder and the IC. Some enclosures may call for a small aluminum chassis, particularly if a dialplate is being used.

In the prototype "Testone," rivet-type standoffs secure the PC board to the chassis, while *S1* and the battery holder are pop-riveted in place. If you're using a dialplate, be sure to dimple the chassis or case so the dialplate will lie flush and

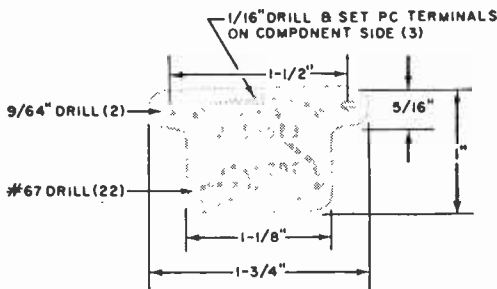


Fig. 4. Drilling information for the PC board. Use of PC terminals makes a professional-looking job.

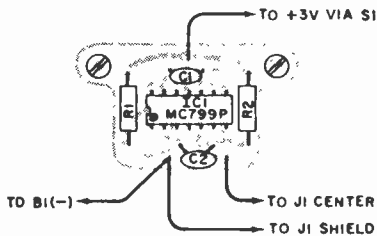
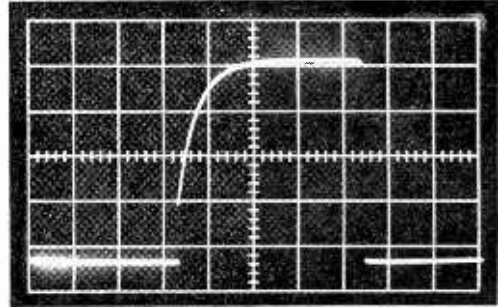


Fig. 5. Component layout. Note that the IC carries both a coding dot and notch for proper positioning.

hide the switch hardware. The dialplate is secured with the hardware on *S1*. If #6 plastic binder head screws are used, their heads can double as no-mar cabinet feet for the complete instrument. Be sure to observe polarity when you install the penlight cells.

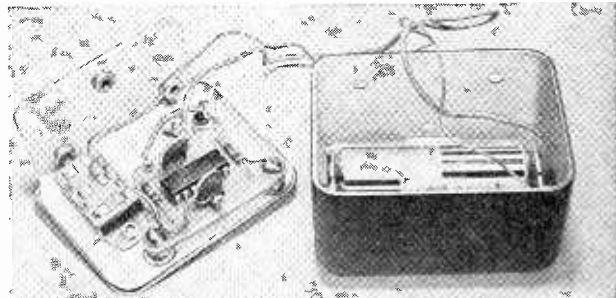
Operating Hints. To use the "Testone," just connect it to a speaker or an amplifier input, switch to ON—and away you



Abrupt trailing edge of the output waveform of the Testone produces harmonics out to the MHz region.

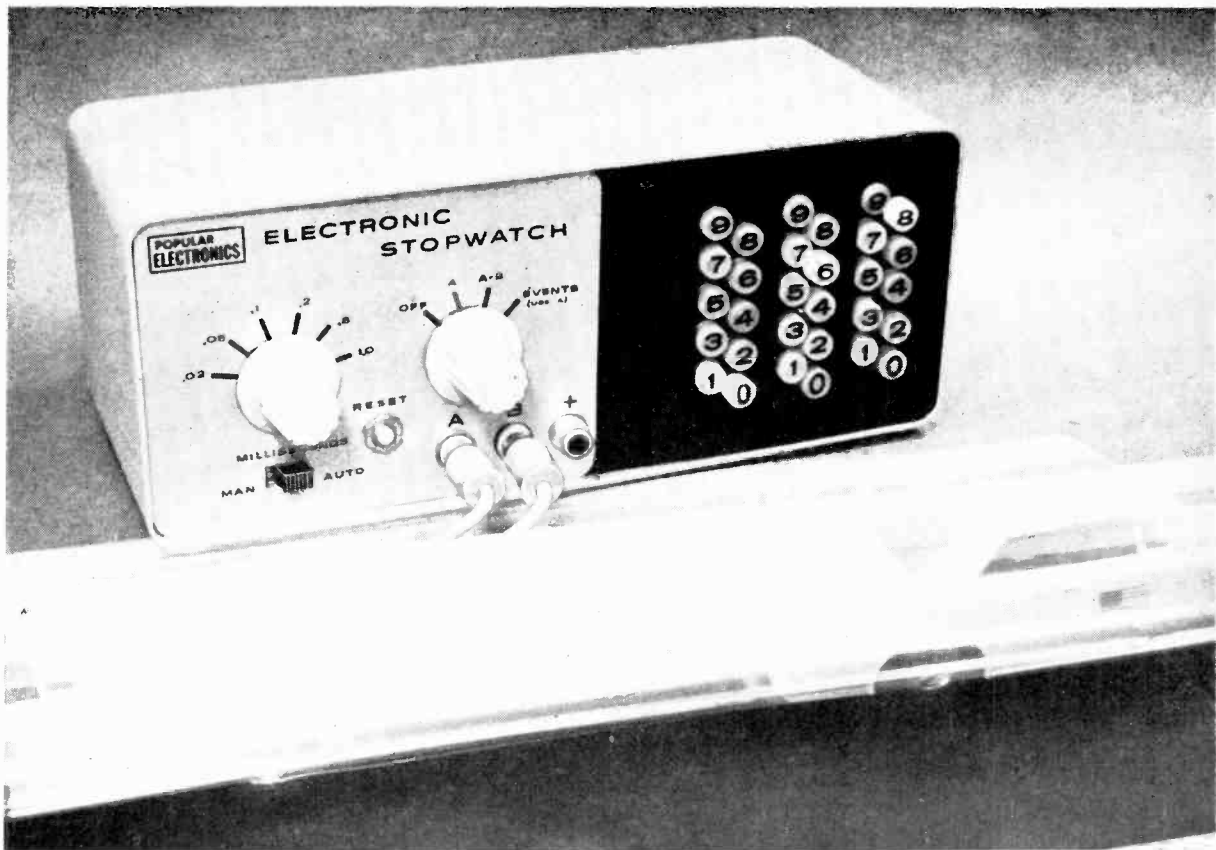
go. Although the "Testone" has a small d.c. output offset current, its value is safely within that of even the smallest speaker, and no harm will be done.

DO NOT apply any voltage to the "Testone" output terminal or use the "Testone" on any live circuit carrying



Author's prototype shows PC board mounting, location of on/off switch, batteries, and output jack.

d.c. without adding a coupling capacitor. For AM radio service and signal injecting, use a 100-pF mica coupling capacitor which will permit only the high frequency trailing edges of the "Testone's" output waveform to be injected into the circuit under test.



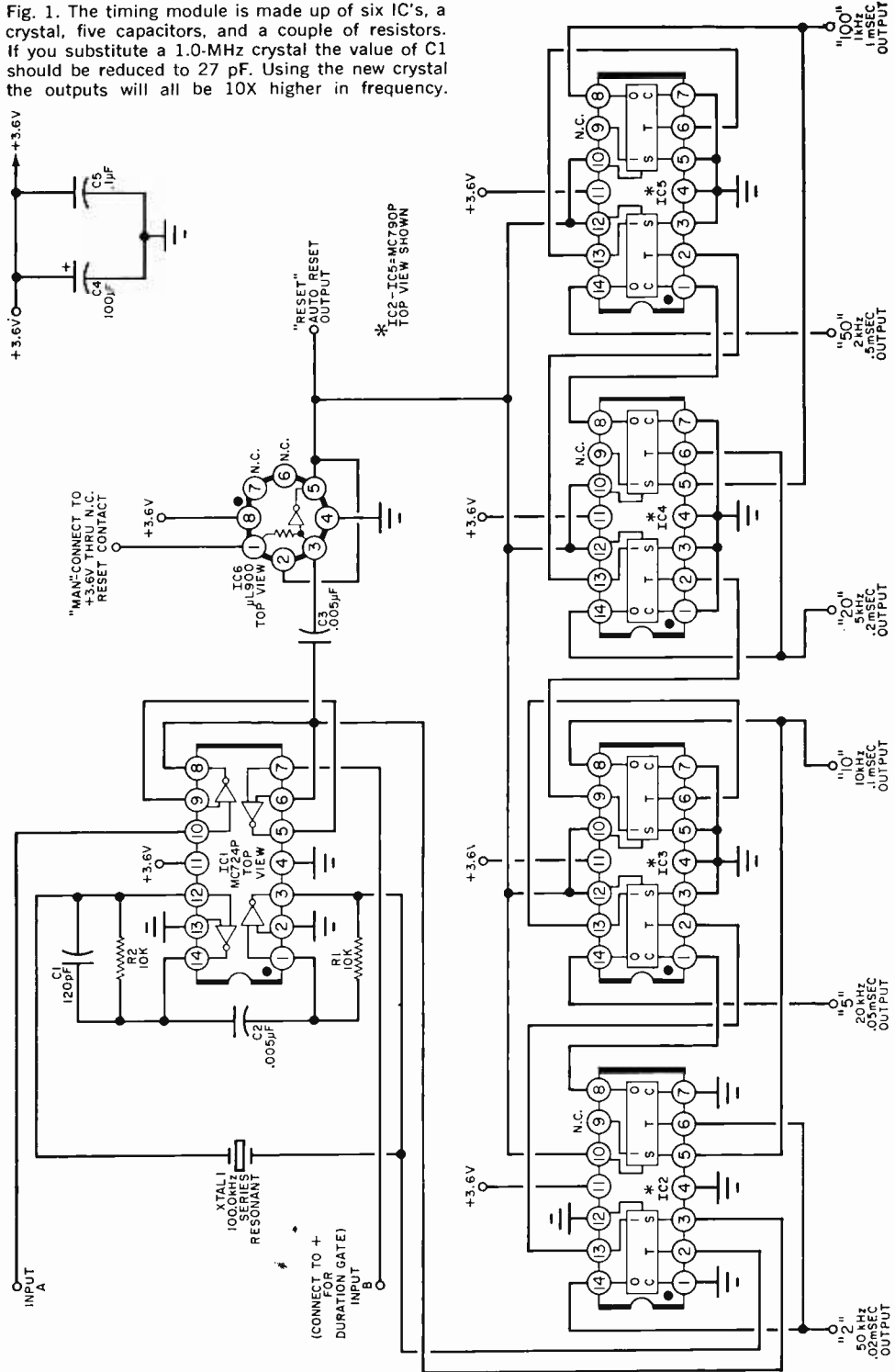
Build Ultra-Fast Electronic Stopwatch

BY DON LANCASTER

USING THE
LOW-COST
DECIMAL COUNTING
UNITS

PROBABLY the most accurate time measurement instrument ever to be made available to the electronics experimenter, this "Electronic Stopwatch" is a small-size, precision, multi-use instrument that can count events from 0 to 999 at any speed up to 10 million counts per second. It can accurately time the *duration* of any single event with 0.1% accuracy, or it can indicate the time interval *between* two different events with both occurring within a one-second time interval—in fact, it can very easily time a speeding bullet in flight!

Fig. 1. The timing module is made up of six IC's, a crystal, five capacitors, and a couple of resistors. If you substitute a 1.0-MHz crystal the value of C1 should be reduced to 27 pF. Using the new crystal the outputs will all be 10X higher in frequency.



TIMING MODULE PARTS LIST

C1—120-pF, dipped mica capacitor
C2, C3—0.005- μ F, 50-volt Mylar capacitor
C4—100- μ F, 6-volt electrolytic capacitor
C5—0.1- μ F, 10-volt disc capacitor
IC1—Quad two-input gate (Motorola MC724P)
IC2, IC3, IC4, IC5—Dual JK flip-flop (Motorola MC790P or MC791P)
IC6—Buffer (Fairchild μ 1.900)
R1, R2—10,000-ohm, $\frac{1}{4}$ -watt resistor
XTAL—100.0-kHz series-resonant crystal
1— $\frac{1}{16}$ " x 3" x $3\frac{1}{2}$ " printed circuit board—see text
Misc.—Crystal clip (1), small eyelets (2), #22 solid wire jumpers (7), PC terminals (14), mounting hardware, solder

NOTE: The following are available from Southwest Technical Products Corp., Box 16297, San Antonio, Texas, 78216: Etched and drilled PC board, \$3.25; complete kit of timing module parts, \$21.00.

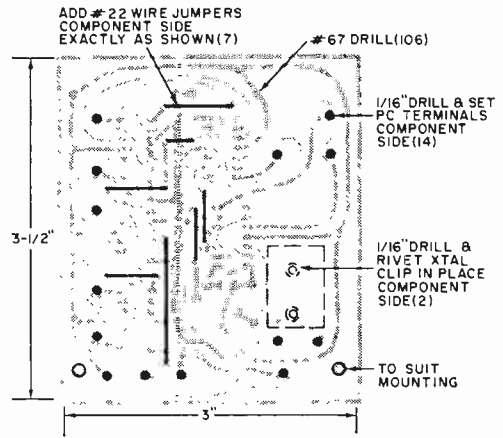


Fig. 3. Drilling guide for the timing module PC board. Mount parts called out on component side.

There are six built-in switch-selectable time resolutions ranging from 20 microseconds to one millisecond; or, you can select external manual timing up to as long as you want. Readout is on a series of three decimal counters (see "Low-Cost Counting Unit," page 80).

The circuit includes a special synchronizer that prevents any last digit "bobble," while a reset selector allows either

automatic or manual resetting of the instrument, or will allow the reading to pile up for long-term accuracy.

If desired, you can add an optional output jack to get very precise one-second timing pulses for use in electronic clocks or other timing applications. You can also scale any input frequency by 10, 100, or 1000, as well as use the instrument as a highly accurate oscilloscope

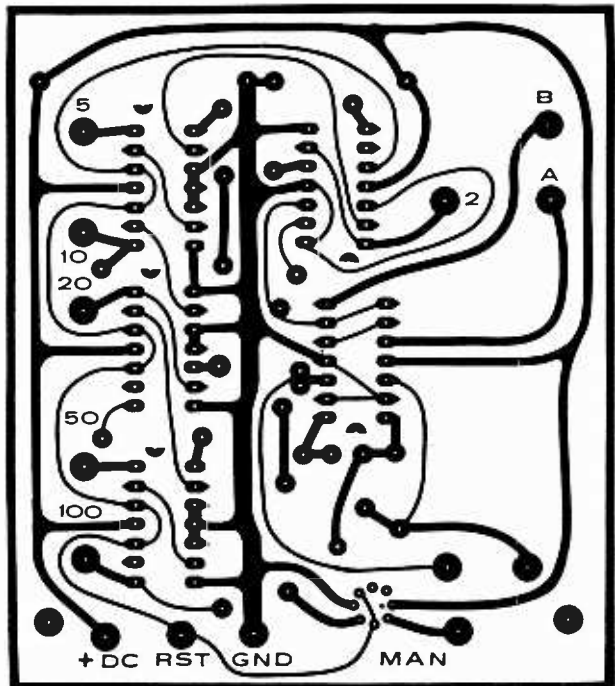


Fig. 2. Actual-size printed board for the timing module. This board is the same size as that used for the decimal counting unit, greatly simplifying the packaging of the completed stopwatch.

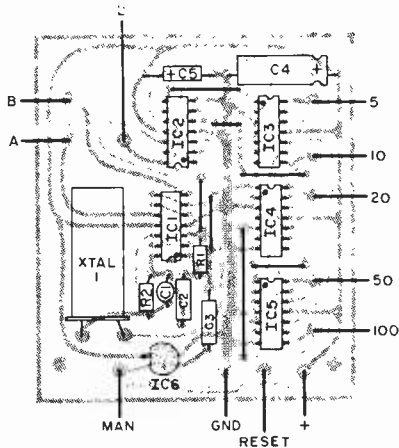


Fig. 4. Timing module components. Observe polarity of the capacitors and alignment of the six IC's.

sweep time calibrator. It even generates random three-digit numbers for contests or probability studies, and it does all this powered by either the a.c. line or a six-volt battery.

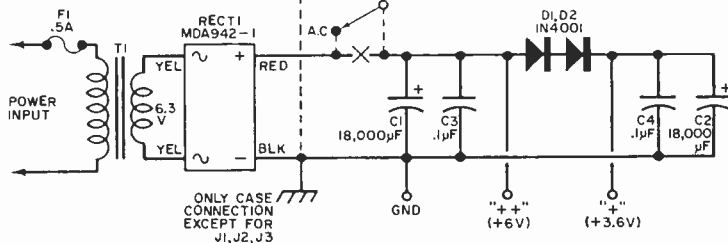
Cost of this project? You can build one complete for \$50 to \$80 depending

POWER SUPPLY PARTS LIST

- C1, C2—6000- μ F, 10-volt computer-grade electrolytic capacitor (Sprague 602G010AC or similar)
- C3, C4—0.1- μ F, 10-volt disc capacitor
- D1, D2—1N4001. 1-ampere, 50-volt silicon power diode
- F1—0.5-ampere fuse
- RECT 1—1.5-ampere, full-wave bridge rectifier (Motorola MDA942-1 or similar)
- T1—Filament transformer, 6.3 volts, 1.2 amperes (Knight 54B1419, Stancor P6134, Thordarson 26F60 or similar)
- Misc.— $\frac{1}{2}$ " x 3" x 3" aluminum mounting bracket to suit enclosure, capacitor mounting clips (2), fuse holder, small terminal board, pop rivets (4), ground lug, #6 hardware, terminals for C1, C2, wire, solder

NOTE: A complete kit of all the above parts is offered by Southwest Technical Products Corp., Box 16297, San Antonio, Texas 78216 for \$11.00 (plus 2 pounds postage).

NOTE: This power supply should be used only with the modified DCU's featured on page 80.



Optional Parts for battery operation

- D1—1N4001 diode
- F2—1-ampere slow-blow fuse
- S1—S.p.d.t. slide switch
- Misc.—Fuse holder, rear case terminals and battery connectors, 6-volt automotive storage battery, optional mounting for BATT/A.C. switch

NOTE: Integrated circuits IC2, IC3, IC4, IC5 should be type MC719P for battery operation.

Fig. 5. Suggested power supply for use with the "Stopwatch." Break at "x" and use dotted circuit if unit is to be battery powered.

on how fancy a cabinet and finish you want. Dialplates, circuit boards, and complete kits are available (see Parts Lists). While not a beginner's project, the stopwatch is not difficult to construct; and when it is finished, you will have a piece of test equipment equal in performance to units costing ten times as much.

Timing Module. Because complete construction information for the decimal counting unit is presented on page 80, only the remainder of the "Electronic Stopwatch" will be covered here: the timing module; associated power supply; and all internal switching.

The schematic for the timing module is shown in Fig. 1. As with the decimal counters, because of the complexity of the circuit, the printed circuit board shown actual-size in Fig. 2 should be used. The board should be drilled and the seven wire jumpers installed as shown in Fig. 3. Then, install the components in accordance with Fig. 4.

Use a small, clean soldering iron and fine solder, double-check the orientation of all parts, and make clean solder joints.

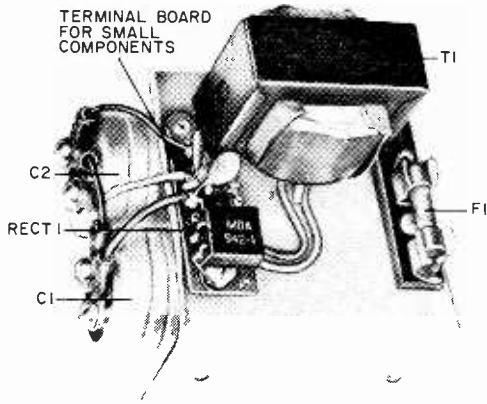


Fig. 6. The power supply is built on a 3" x 3" piece of heavy-gauge aluminum with a 1½" mounting lip.

STOPWATCH PARTS LIST

- J1, J2, J3—Phono jack (RCA type)
- M1—Electronic stopwatch timing module
- M2, M3, M4—Decimal counter module (see "Low-Cost Counting Unit")
- M5—Power supply module
- R1—47-ohm, ½-watt resistor
- R2, R3—1000-ohm, ¼-watt resistor
- R4—100-ohm, ¼-watt resistor
- S1—Three-pole, four-position, non-shorting selector switch (Mallory 3234J or similar)
- S2—Single-pole, six-position non-shorting selector switch (Mallory 3226J or similar)
- S3—S.p.d.t. slide switch
- S4—S.p.d.t. push-button switch
- Misc.—Case, chassis, line cord and strain relief, knobs (2), backup plate for controls, feet, module mounting hardware, trim panel, wire nut, wire, solder

NOTE: Hard anodized aluminum dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Arizona 85014, as Stock ESW-1: in silver for \$2.75; red, gold, or copper for \$3.25; postpaid in U.S.A.

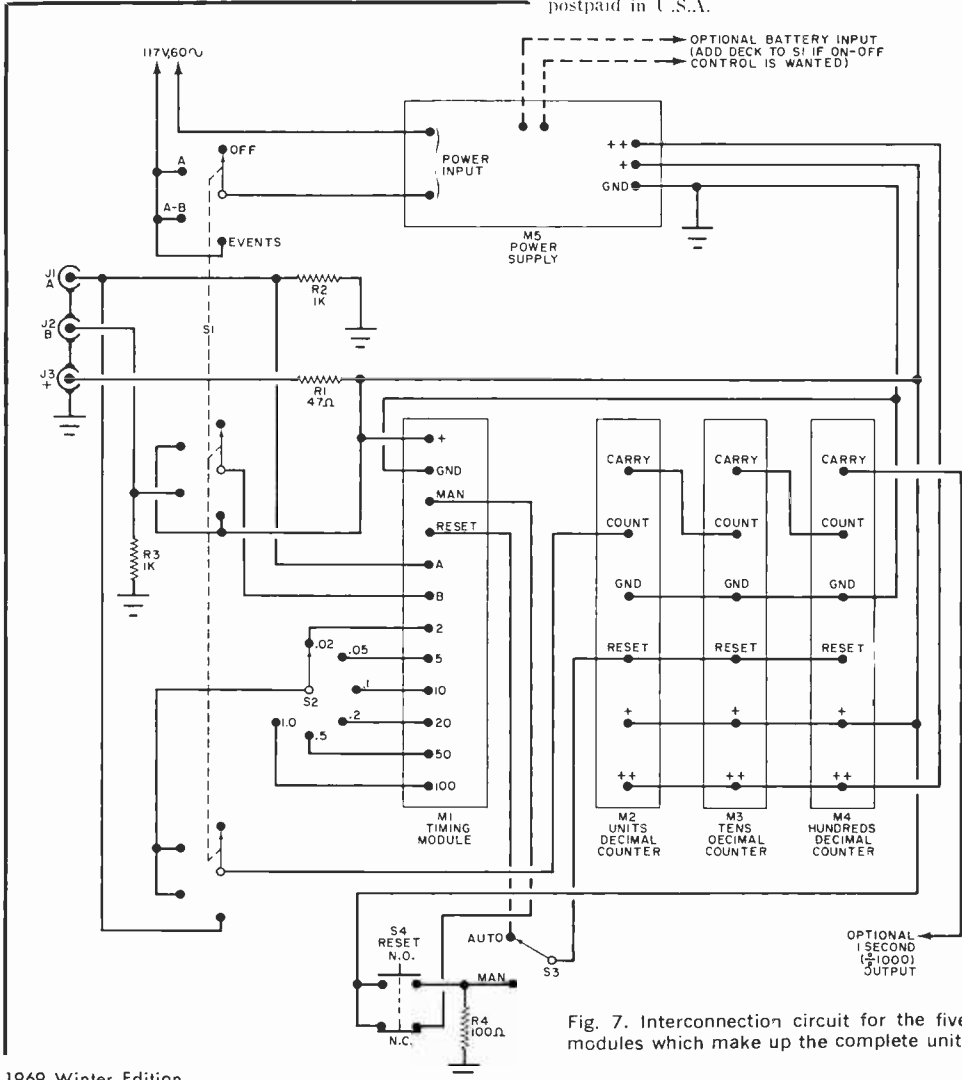


Fig. 7. Interconnection circuit for the five modules which make up the complete unit.

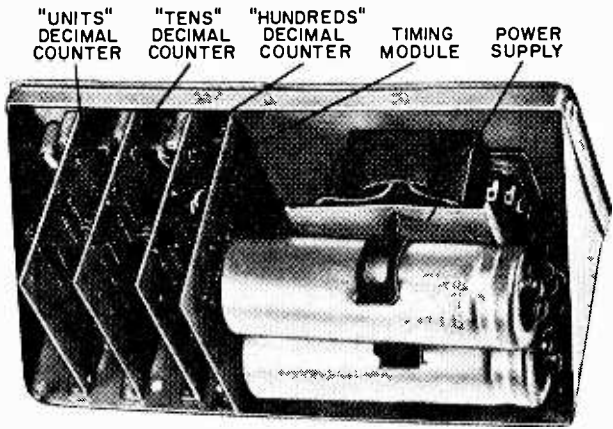


Fig. 8. Rear of author's "Stopwatch" before wiring. Looking from the front, the "units" counter is on the right, the "tens" counter in the center, and the "hundreds" counter at left. Power supply occupies the empty area behind the switching.

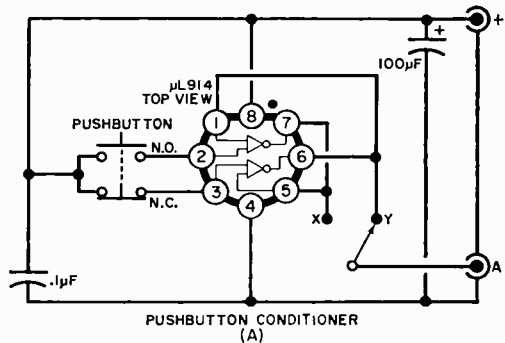
Note that all rectangular IC's are identified by a notch and dot code on one end, while the one round one (IC6) has a flat side opposite pin 8.

Power Supply. The power supply has to supply both 3.6 volts (+) and 6 volts (++) at 0.5 ampere and with a low ripple. A suitable supply, shown in Fig. 5, consists of a transformer-powered bridge rectifier followed by a capacitor-input dynamic two-diode regulator. Do not skimp on the value of C1 or C2, as the values given are the smallest satisfactory capacitance values.

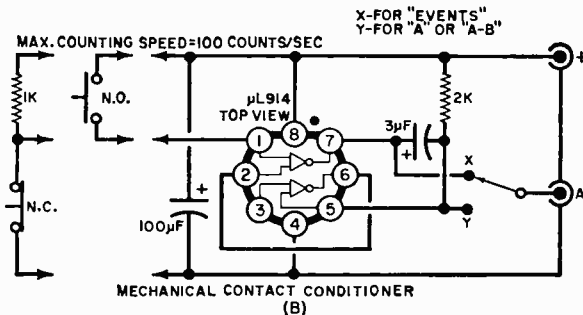
It is probably best to build the power supply on its own small subchassis, as illustrated in Fig. 6, which is simply an L-shaped aluminum bracket, cut to suit your particular case. Mount all components on this bracket, using a small terminal board to support the smaller electronic components. Make certain that you use only one ground lug (as shown in Fig. 5), and make sure that no other wiring touches the metal chassis.

If you desire the convenience of battery operation (6 volts only), add the circuit shown by the dotted lines of Fig. 5. The power supply circuit must be broken at point "X" and a battery/a.c. selector switch installed so as to switch the filter circuit from either the a.c. power source, or the external battery d.c. source.

Overall Assembly. Figure 7 is the complete stopwatch interconnection schematic diagram. The overall assembly



PUSHBUTTON CONDITIONER (A)



MECHANICAL CONTACT CONDITIONER (B)

Fig. 9. A push-button signal conditioner is shown above (a), while a mechanical contact signal conditioner is shown at left (b). Both of these circuits provide a bounceless pulse each time they are operated by the external switches.

consists of three decimal counter modules, the timing module, the power supply module, four resistors, four switches, and three input jacks.

Almost any case configuration can be used for the instrument, and the photo on page 89 shows the one used by the author. A commercially available dial-plate (see Parts List) can be used as a layout guide for the front-panel selector switches and input jacks. Figure 8 shows the author's version before the interconnections were made.

Wire the various modules and switches together in accordance with Fig. 7. Use color-coded leads, and note that the deci-

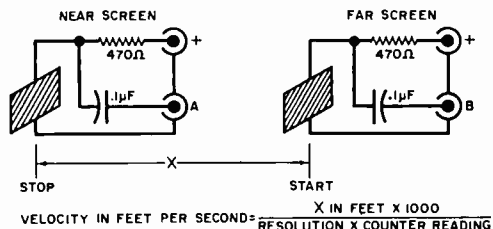


Fig. 10. For ballistic velocity measurement (vehicle, projectile, or other speeding object), use a break-wire contact. Set the "Stopwatch" in the "A-B" position to make the measurement. Break-wire "A" must be broken before break-wire "B" for correct operation.

mal counters are wired from left to right, viewed from the rear—so that when viewed from the front (in the normal operating position), "unit's" are indicated on the right, "ten's" on the middle, and "hundred's" on the left counter.

Preliminary Checkout. Once you are sure that all wiring is correct, place the function switch (*S1*) in any position other

than "OFF." One lamp in each counter should light. Depressing the "RESET" push button (*S4*) should return all counters to "000."

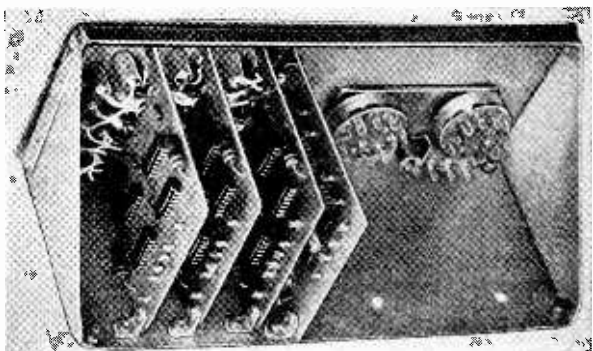
Place the function switch in the "A" position, and the timing switch (*S2*) in the 1.0 millisecond position. Plug a phono cable into the front-panel "+" jack and touch the other end of the cable (center contact) to the "A" input internal contact. The counters should cycle only *during* the time that this connection is made.

Note that the "unit's" indicator lamps have a dull glow (signifying very rapid counting), the "ten's" lamps flicker slowly, while the "hundred's" counter ripples from 0 to 9 (and repeats) once each second. Rotating the timing switch progressively through the .5-, .2-, .1-, .05-, and .02-millisecond positions produces a corresponding speedup of the flicker on all counters.

Place the function switch in the "A-B" position and "RESET" for all zeros on the counters. Return the timing switch to 1.0 for best viewing of the counters. Using the phono cable, application of the "+" to input "A" should start the counters cycling, and they should continue cycling even after the cable is removed from "A." Inserting the "+" to input "B" should stop the counters.

Place the function switch in the "EVENTS" position, and "RESET" for all zeros. Place the "MAN/AUTO" switch (*S3*) in the "MAN" position. In this mode, the instrument will count once for each time that you apply the "+" to the "A" input. This count will be erratic since there is no way that you can keep from bouncing the contact as you make and break it; this is also why you have

Author's unit before the power supply was mounted and interconnections made. Any other arrangement can be used depending on cabinet available. The dial-plate will give exact front-panel layout, and also has switch position identification.



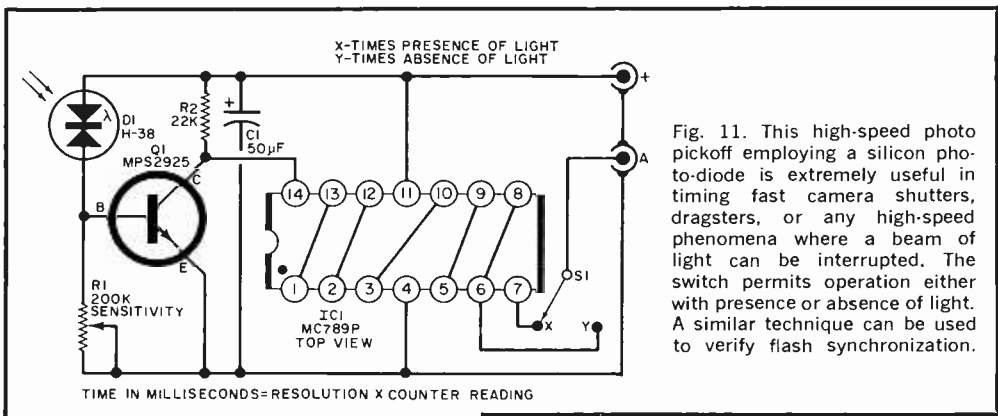
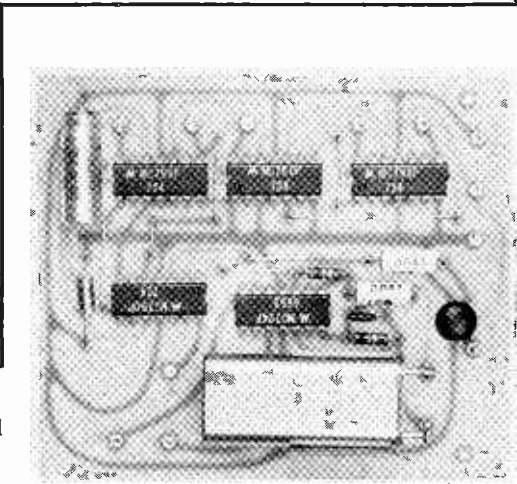


Fig. 11. This high-speed photo pickoff employing a silicon photo-diode is extremely useful in timing fast camera shutters, dragsters, or any high-speed phenomena where a beam of light can be interrupted. The switch permits operation either with presence or absence of light. A similar technique can be used to verify flash synchronization.

PHOTO PICKOFF PARTS LIST

- C1—50-µF, 6-volt electrolytic capacitor
- D1—Silicon photodiode (Texas Instruments H-38 —Do NOT substitute)
- IC1—Hex inverter (Motorola MC789P)
- Q1—MPS2925 transistor (Motorola)
- R1—200,000-ohm miniature potentiometer
- R2—22,000-ohm, ¼-watt resistor
- S1—S.p.d.t. slide switch
- Misc.—Photocell shroud, interconnecting cables, phono plugs, solder

NOTE: A complete photo pickoff kit is available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216, for \$8, postpaid in U.S.A.



Top view of the timing module PC board with all components mounted. Connections to the board are made via the PC terminals affixed to the board.

to “condition” all inputs for meaningful measurements.

Signal Conditioning. Proper signal conditioning is a *must* for accurate use of the stopwatch. As the counters “read” each input pulse, the input signal must be bounceless; that is, there must be one, and only one, pulse for each time that the sensor operates.

A signal conditioner for use with a mechanical push button is shown in Fig. 9(a), while Fig. 9(b) shows one method of signal conditioning for use with a mechanical contact.*

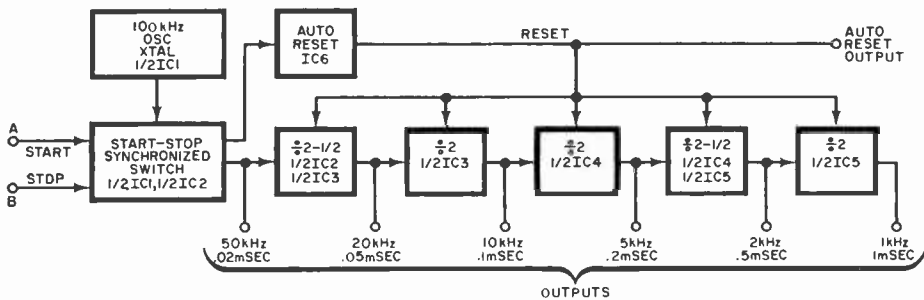
Velocity Measurement. For a ballistic velocity meter (bullet or “break-wire” pickoff), use the circuit shown in Fig. 10. In this case, make sure that event “A” stops before event “B” starts, and that the spacing between the two pick-

offs is measured to within 0.1% accuracy, if you want your instrument to be that accurate.

If you are going to measure the speed of a bullet, place the first screen (“A” input) far enough from the gun muzzle to avoid blast effects. As the bullet passes through the first screen, it starts the “Stopwatch”—when it passes through the second screen the instrument stops counting.

To measure the velocity of a car, or other speeding objects, make sure that the same portion of the object whose speed is being measured breaks both wires. The velocity in feet-per-second for an object traveling between the screens is clearly shown in Fig. 10. For example, if counter resolution is set at .02 milli-

*A few signal-conditioning circuits are shown in Fig. 7 of the “Counting Unit” article which appears on page 80. Figure 7(a) and (b) shows two approaches with mechanical switches, while Fig. 7(c) and (d) illustrates two methods of signal conditioning with sine-wave generators.



HOW IT WORKS

Operation of a decimal counting unit is described in this issue on page 80; therefore, only the operation of the timing module will be described here.

As shown above, the basic timing circuit consists of a 100-kHz crystal-controlled oscillator consisting of one-half of *IC1*—two of its four gates are biased to their class-A region and capacitor-coupled to form the oscillator—in conjunction with a 100-kHz crystal. The oscillator output pulses drive a synchronizing switch made up of one flip-flop of *IC2*.

If allowed to run freely, the synchronizer switch would merely divide the oscillator output by two, and drive the remainder of the divider chain. However, a set-reset gate, made up of the two remaining gates of *IC1*, determines how long the synchronizer switch remains open. Operation of the set-reset gate, in turn, is controlled by signals applied to its two inputs—"A" (start) and "B" (stop)—which are located on the front panel of the electronic stopwatch.

A positive-going voltage pulse applied to input "A" will open the synchronizing gate and allow the 100-kHz oscillator pulses to pass down the divider chain until a positive-going signal applied to input "B" shuts down the set-reset gate, thus preventing the oscillator signals from reaching the divider chain. When input "B" is connected to a constant positive voltage source, the set-reset gate becomes a *duration* gate that remains open, allowing the oscillator pulses to pass down the divider only as long as a signal is applied to input "A."

Because the synchronizer switch is basically a flip-flop, it automatically divides the 100-kHz oscillator signal by two, producing a 50-kHz output. (Divide the frequency in kHz into 1 to get the time period in milliseconds; in this case, the 50-kHz output is also the 0.02 millisecond output.) The remaining divider chain produces outputs at 20 kHz (0.05 msec), 10 kHz (0.1 msec), 5 kHz (0.2 msec), 2 kHz (0.5 msec), and 1 kHz (1.0 msec). The final IC (*IC6*) is the reset generator which synchronizes the low frequency outputs and provides an automatic reset signal for the decimal counters.

The 100-kHz crystal may be replaced with almost any other low-frequency unit if a different set of output frequencies (or pulse time intervals) is desired.

seconds, and an eight-foot screen spacing is used (accurate to $\frac{1}{16}$ "), a counter indication of 162 will correspond to a velocity of 2470 feet per second.

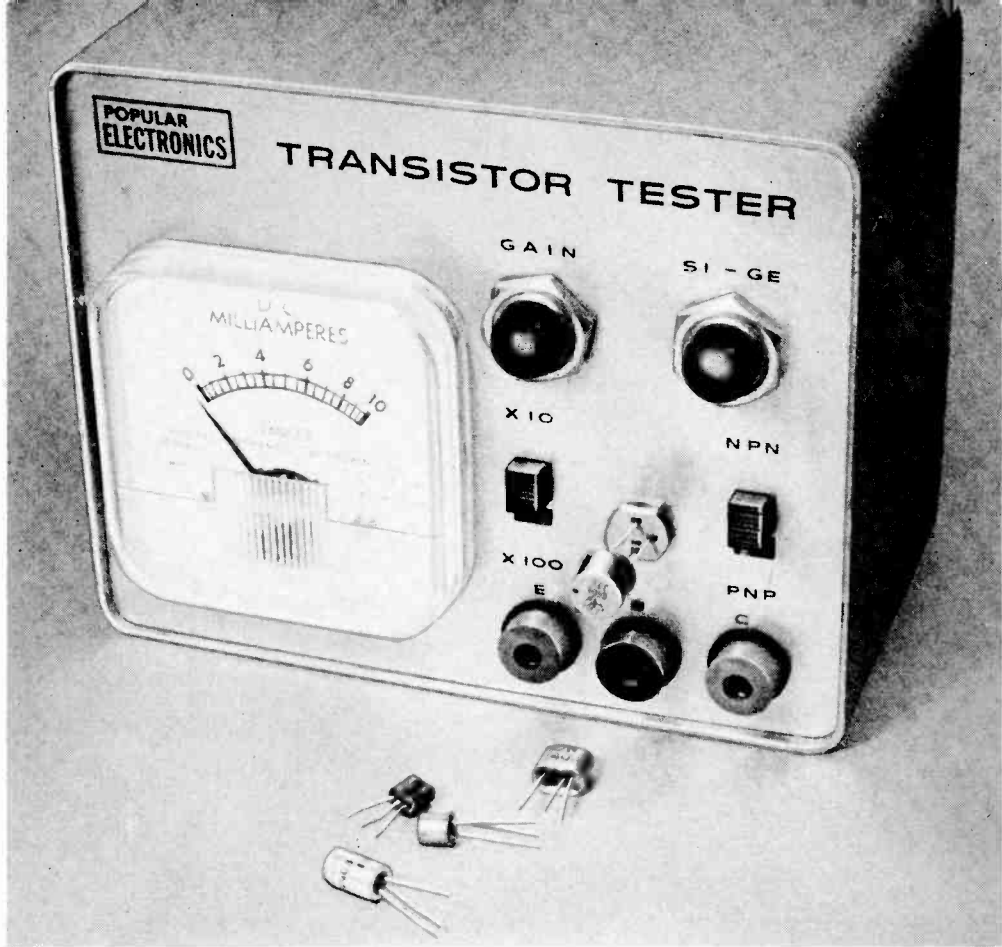
Photo Pickoff. A photo pickoff is shown in Fig. 11. The pickoff selector switch decides whether the "Stopwatch" operates on the presence or absence of light at the sensor. You must use a high-speed photocell for this circuit, as conventional cadmium sulfide cells are too slow for accurate timing. To test the speed of camera shutters, place the counter function switch in the "A" position, and allow the camera shutter to interrupt the light from the light source to the photocell.

For timing dragster or other vehicle races, two photo pickoffs can be used with

the "Stopwatch" function switch at the "A-B" position. One pickoff starts the timer at the "A" input, while the second pickoff stops the timer at the "B" input. The elapsed time in milliseconds equals the numerical value on the timing switch multiplied by the decimal counter indication. For example, the timing switch at 1.0 millisecond and the counters at 725 means a total time value of 725 milliseconds or 0.725 second.

If desired, the optional one-second output line in Fig. 7 can be used to drive an external "seconds" counter. -30-

Editor's Note: Further projects using the low-cost DCU will appear in both the ELECTRONIC EXPERIMENTER'S HANDBOOK and POPULAR ELECTRONICS. A digital voltmeter appears in the December 1968 issue that will be on sale around mid-November.



BUILD THE

NGW Transistor Tester

STOP WONDERING—
THE "NO-GUESS-WORK"
TESTER CHECKS FOR
SILICON-GERMANIUM
AND NPN OR PNP

BY DON LANCASTER

HAVE YOU been tempted to buy a package of those transistor assortments that are being offered for only pennies-per-transistor? Perhaps you have some unmarked transistors (or transistors with production numbers that are meaningless to you) collecting dust in your spare parts box. How can you tell what types of transistors you have and what condition they are in? The answer is simple: build the transistor tester described on the following pages.

This transistor tester is a simple instrument that you can construct for \$10 or less. It will check just about any transistor or semiconductor diode for interelement shorts, opens and leakage, and will check transistors for gain. The tester will tell you if a transistor under

test is *npn* or *pnp* and whether it is silicon or germanium.

Construction. The transistor tester's circuitry can be housed in any convenient size metal or plastic case, and since

the parts arrangement is not critical, almost any type of chassis construction can be used. The photo on page 100 shows the method used in the prototype.

Since most transistors you are likely to test will have a TO-5 type case con-

HOW IT WORKS

When a small amount of base current controls a large amount of collector current in a transistor, amplification takes place. In most modern transistors, d.c. current gain is essentially equal to the small-signal a.c. current gain all the way up to the low MHz region. This tester measures d.c. current gain by applying a known amount of base current to the test transistor, and then displays the collector current gain on meter *M1*. (When the collector current is divided by the base current, the result will be the d.c. gain of the transistor under test, and this is the figure that will be indicated on the meter.)

All transistors are tested under 1 to 10 mA collector current conditions—about the operating range of most small-signal transistors. Gain for power transistors will be lower than for small-signal types since the power transistor's gain curve peaks somewhere between 100 and 1000 mA. Resistor *R1* serves as a collector load—or current limiter—for all transistors under test, and *R2* and *R3* (when *S3* is set to *X100*) control base current.

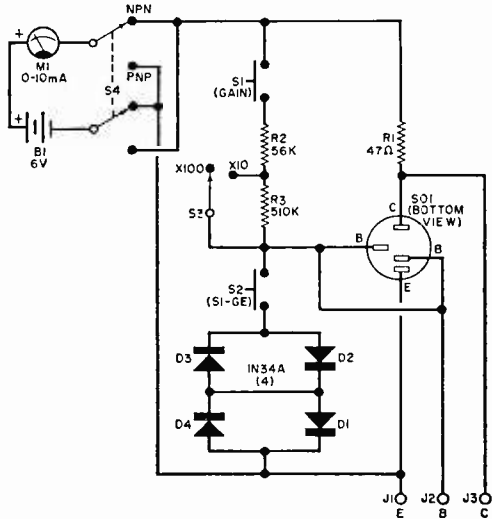
Switch *S2* and diodes *D1* through *D4* form the *SI-GE* test circuit. For normal bias, the base voltage of a silicon transistor will be 0.6 volt and base voltage of a germanium transistor will be 0.2 volt. Two germanium diodes connected in series (*D1* through *D4* are germanium types) require 0.4 volt to conduct—a potential halfway between *GE* and *SI* base voltages. To eliminate complex switching, two germanium diodes are operated in each direction, providing *npn* and *pnp* testing capability.

Diodes are tested on a go/no-go basis when they are connected to the tester as described in "Testing Diodes" (see text).

PARTS LIST

B1—Four 1.5-volt "AA" penlight cells
D1, D2, D3, D4—1N34A germanium diode
J1, J2, J3—Banana jack (one red, one blue, one green)
M1—0-10-mA d.c. milliammeter*
R1—47-ohm, ½-watt resistor*
R2—56,000-ohm, ½-watt resistor
R3—510,000-ohm, ½-watt resistor
S1, S2—S.p.s.t. momentary-action, normally-open push-button switch
S3—S.p.s.t. slide switch
S4—D.p.d.t. slide switch
SO1—TO-5 transistor socket
 1—3" x 4" x 5" aluminum box—see text
 Misc.—Double AA battery holders (2), external test leads (3), banana plugs (3), #10 nylon cup washers for feet (4), wire, solder, hardware, etc.
 Optional—Metalphoto hard-anodized aluminum dialplate, available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Ariz. 85014, in silver color for \$2.75, in red, gold, or copper for \$3.25, postpaid in U.S.A.; specify stock #TRT-1

*The combined resistance of *R1* and *M1* should lie between 200 and 300 ohms.



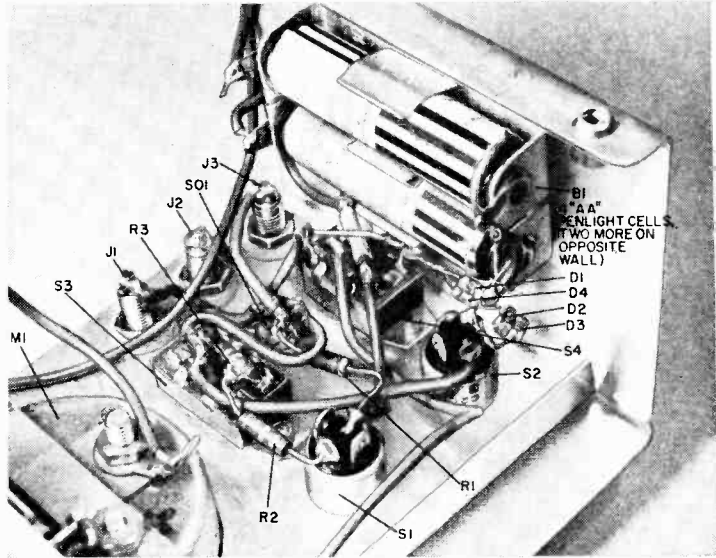
Note that there are two base contacts on *SO1* to accommodate both the TO-5 triangular lead configuration and the older in-line arrangement.

TESTING TRANSISTORS

- 1 Set multiplier switch to X100 and identity switch to NPN. Insert transistor into socket or connect transistor to appropriate leads
- 2 Meter should not deflect—if meter does deflect, discard transistor; it is shorted.
- 3 Depress SI-GE push button. If meter deflects, transistor is PNP. If meter does not deflect, transistor is NPN. If there is no meter reading in either position of identity switch, transistor can be discarded; it is open.
- 4 Change identity switch to proper position for type of transistor and note meter reading—it should be very low. Silicon transistors produce a zero reading; germanium transistors (non-power) will read less than 1 mA.
- 5 Depress GAIN push button and adjust multiplier switch for less than full-scale reading. This reading is d.c. current gain of transistor (scale times multiplier).
- 6 Verify silicon/germanium transistors by depressing both GAIN and identity push buttons. If meter reading remains the same or drops slightly, transistor is germanium. Drop of meter reading to zero indicates silicon.

If you wish, you can cut out this convenient chart and paste it on the case of the transistor tester.

Internal layout of the author's model showing location of all parts. This layout is recommended for best duplication.



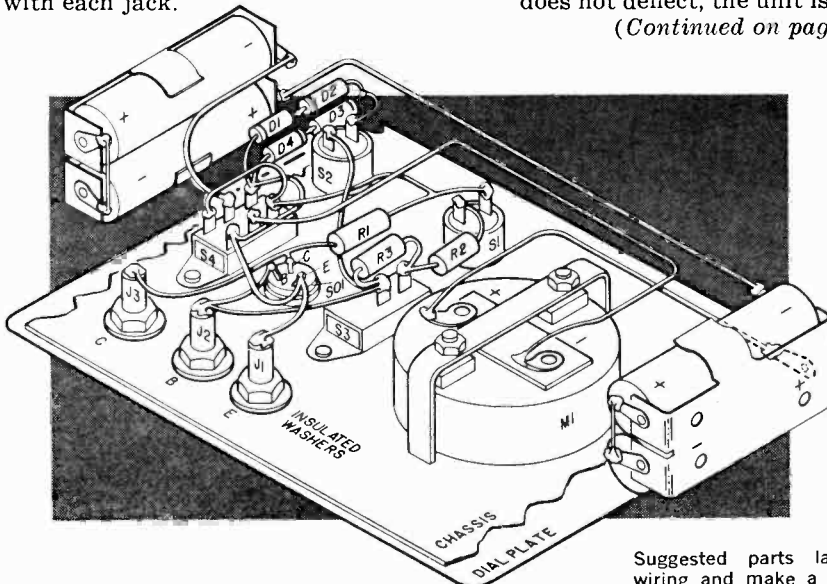
figuration, you should mount a TO-5 transistor socket in a convenient and accessible location on the front panel of the instrument (see photo on page 98). For transistors with other than a TO-5 case configuration, three banana jacks are mounted at the bottom of the front panel to make the proper connections via short test cables.

The banana jacks (*J1* through *J3* in the schematic diagram) must be insulated from the chassis, using one shoulder and one flat fiber or nylon washer with each jack.

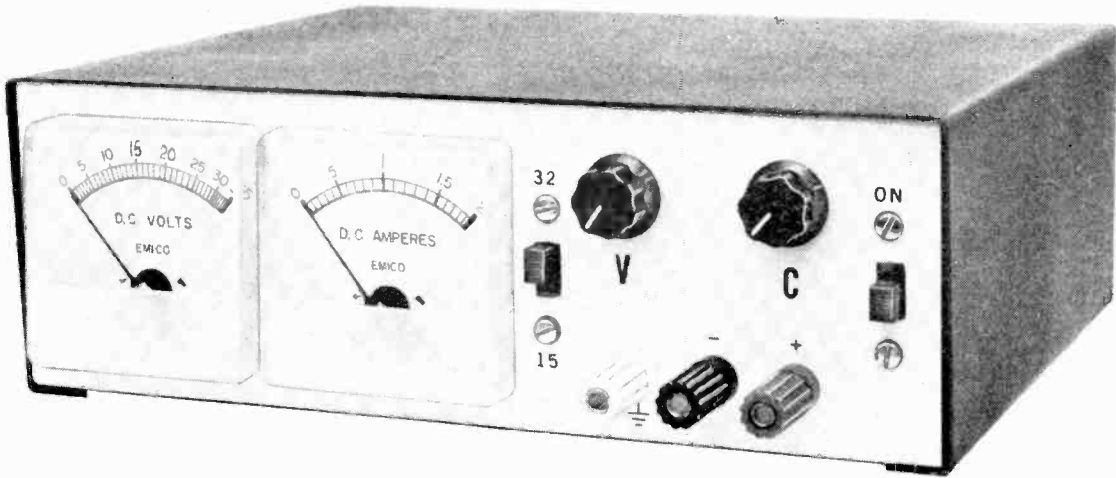
Testing Transistors. The approach to testing a given transistor is simple and straightforward. The procedure need not take more than a minute, and with practice, you can cut the testing time down to a few seconds.

First set switches *S3* and *S4* to the *X100* and *NPN* positions, respectively, and connect the transistor to be tested via the external test cables or plug it into the transistor socket. If the pointer of meter *M1* should swing fully up-scale, the transistor is shorted; if the pointer does not deflect, the unit is okay.

(Continued on page 112)



Suggested parts layout to simplify wiring and make a clean-looking unit.



Experimenter's Short-Proof Power Supply

BUILD 2-AMPERE, 0-32 VOLT POWER SOURCE FOR YOUR BENCH

BY JAMES W. CUCCIA

THE biggest problem that can be encountered with a bench power supply occurs if you accidentally short it—poof go the rectifiers, fuse, or assorted components, either singly or in various combinations. Work comes to a grinding halt while you dig away in the power supply and try to fix things up. If this has happened to you, your power supply is not one of the new breed—the automatic current limiter—which is very likely so, since the current-limiting feature has usually been incorporated only in relatively expensive industrial power supplies. Until now.

If you have never worked with a current-limiting power supply, you are in for a pleasant surprise. First, you decide what the maximum safe current would be in the circuit you are testing. Then you short (yes, *short*) the power supply leads together and set the current con-

trol until the ammeter indicates this value. Now connect the power supply to the circuit under test, crank up to the desired voltage and go to work. If you should short the power supply leads (either accidentally or because of circuit component failure), instead of a puff of smoke coming from the power supply, the current limiter will not allow the supply to deliver more current to the short than you originally specified for the circuit. You just remove the short, and go back to work.

The complete electrical specifications for this power supply given in the accompanying table compare favorably with those of power supplies costing far more than this project. The schematic for this unit is shown in Fig. 1.

Construction. An actual-size printed circuit board should be made up in ac-

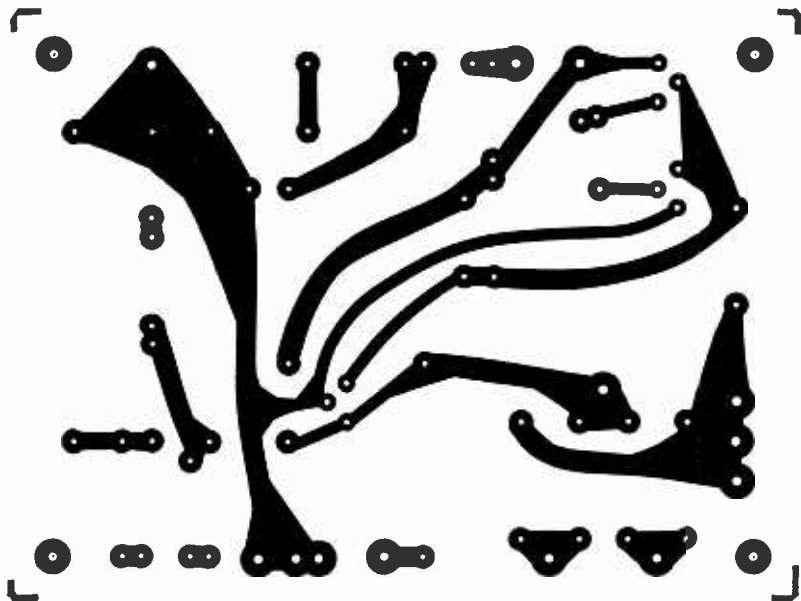


Fig. 2. This actual-size printed board can be copied to remove the possibility of wiring errors. The four corner holes are used in mounting the board.

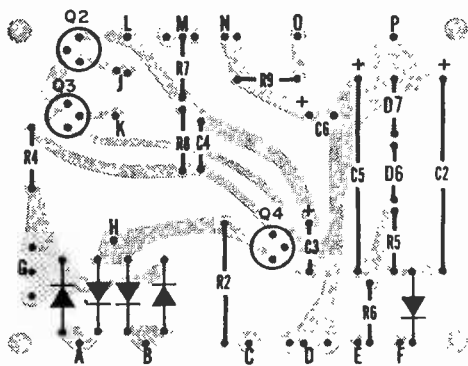


Fig. 3. Flip the board over so that the foil side is down, and install the components as shown here. Observe polarities of semiconductors and capacitors.

HOW IT WORKS

The power supply circuit is basically a series-type regulator in which power transistor $Q1$ is made to act as a voltage-variable power resistor controlled by a voltage error amplifier ($Q2$ and $Q3$). Power transformer $T1$ supplies both the main power and bias for the unit, diodes $D1$ through $D4$ form a full-wave bridge rectifier, and $C1$ is the main filter capacitor.

Because the voltage difference applied between the base and emitter of $Q3$ is reflected in a change in resistance of series transistor $Q1$ (and thus a change in voltage output), the base of $Q3$ is connected to voltage control potentiometer $R10$ which, in turn, is connected between the positive output and a negative voltage developed by bias rectifier $D5$. This voltage is filtered by $C2$, $R5$, $C5$, $R6$, and level-controlled by zener diodes $D6$ and $D7$. The level of output voltage is indicated on voltmeter $M2$.

When power resistor $R1$ is not in the circuit, the power supply can deliver up to 32 volts output; with $R1$ in the circuit, the output level can only reach 15 volts. When $R1$ is switched in or out of the circuit, a simultaneous switching ac-

tion introduces a series resistor ($R9$) into the voltage control potentiometer ($R10$) circuit.

If the load tends to lower the output voltage, the voltage at the rotor of $R10$ will be lowered. Transistors $Q3$ and $Q2$ then react to lower the series resistance of $Q1$, thus raising the voltage. When the output voltage tends to increase, the reverse action occurs. Obviously, any ripple on the output lead is reflected back as voltage variations, the three transistors make high-speed compensation, and ripple is reduced to a very low level (see Specifications Table). Capacitors $C3$ and $C4$ are bypass units which reduce the high-frequency gain and suppress parasitics.

Current limiter $Q4$ senses the voltage drop across $R2$ and $R3$ (the latter is the current control potentiometer). The voltage drop increases as more current is drawn by the load until it reaches the value required to turn $Q4$ on. When this happens, $Q4$ reduces the base voltage of $Q2$ and $Q1$ which, in turn, lowers the output voltage until only the current set by $R3$ flows in the load. The current-limiting circuit is arranged so that $R3$ can be preset from 12 mA to 2 amperes of maximum load current. Load current is indicated on ammeter $M1$.

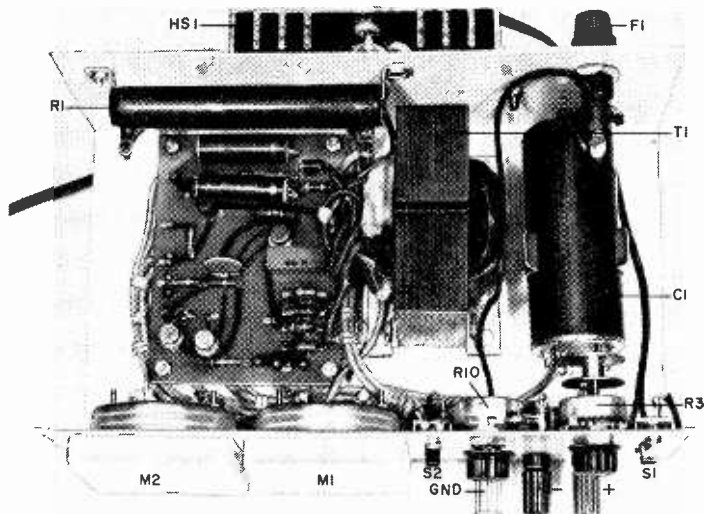


Fig. 4. Interior view of author's prototype. Capacitor C1, power resistor R1 and the printed board are supported by standoffs. All other components are mounted directly to the chassis as shown here.

board using small spacers to stand it off the chassis.

Mount $Q1$ on its heat sink using insulated washers for the mounting screws, and a mica washer between the transistor and the heat sink. Be sure to apply silicon grease to both sides of the transistor mica washer before mounting $Q1$. Failure to use the grease may result in $Q1$'s overheating and possibly burning out. Place a soldering lug on one transistor case mounting lug to provide the collector connection to the transistor.

Remember that the case of transistor $Q1$ is also the collector connection and is "hot" to ground, and since the heat sink is ground, take care when mounting the transistor on the heat sink, and when placing the power supply on the bench so that a short circuit cannot occur. Figure 5 shows the rear of the author's prototype and how the transistor and heat sink are mounted to the cabinet.

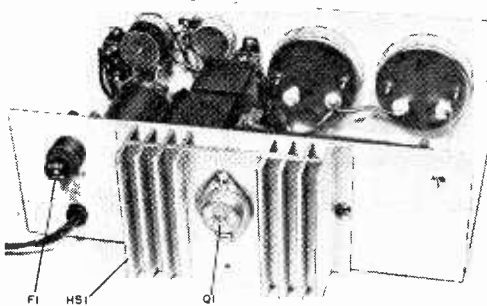


Fig. 5. Rear view of power supply chassis. Transistor $Q1$ is thermally (not electrically) connected to heat sink HS1. The heat sink is mounted to the rear apron of the chassis, as is the line fuse.

Operation. The power supply is simple to use. Plug it in and turn on $S1$ (the primary power on/off switch). For voltage output from 0 to 15 volts, place $S2$ ("15/32" volt selector switch) in the "15" position; for voltages above 15 volts, place $S2$ in the "32" position. Adjust voltage control $R10$ ("V") for the desired output voltage.

Rotate current control $R3$ ("C") to maximum counterclockwise position. Place a short circuit across the power supply output terminals and adjust $R3$

until the ammeter indicates the desired maximum current. When making this current calibration, the voltmeter indication will obviously drop to zero. Remove the short and connect the power supply to the circuit being tested.

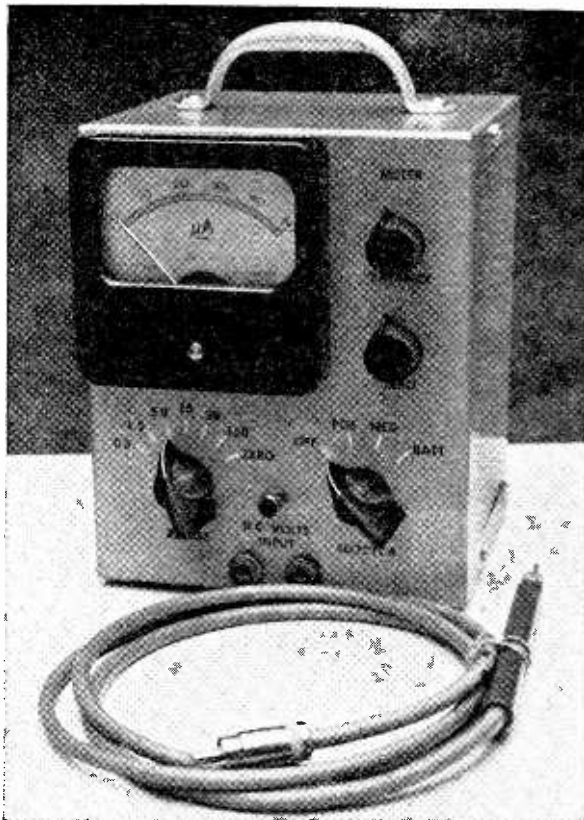
Note that the chassis of this power supply is floating so that you need not be concerned about the chassis shorting to any external ground.

-50-

Low-Cost High- Quality Electronic Voltmeter

ALMOST NON-LOADING
VOLTMETER
MEASURES FROM
0.5 to 150 VOLTS
FULL SCALE, AND IS
IDEAL FOR TESTING
SEMICONDUCTOR
CIRCUITS

BY FRANK H. TOOKER



MEAURING the very low d.c. voltages in a solid-state circuit is almost impossible with most VOM's. Why? Because of the shunting effect of the low input resistance of the VOM (it could be about 1000 ohms-per-volt) across what usually is a very low resistance within the circuit. The resulting parallel resistance produced by this combination is, in most cases, far below what the circuit needs to operate properly. The effect: improper operation due to wrong voltages, excessive current flow, and associated electrical changes within the circuit.

It was to remove this excessive loading that the VTVM was developed. Its very high input impedance (typically about 11 megohms) alleviated the parallel resistance problem, and in essence produced a non-loading measuring instrument. Unfortunately, most VTVM's in use have 1.5 volts as their lowest full-scale range—making it difficult to read many of the fractional voltages usually found within solid-state circuits.

The DCEV (direct-current electronic voltmeter) diagrammed in Fig. 1, combines the high input resistance of the VTVM with the portability of the VOM. It uses a couple of low-cost transistors, and has the impressive specs shown in the table on page 109. Note that the DCEV has an input resistance of one megohm-per-volt over the four lowest ranges, making it an ideal voltmeter for solid-state checkout. The cost? Just about \$20, plus a few hours of work.

Basic Operation. The DCEV is, in a sense, a resistance multiplier. It may be visualized as taking the moderate resistance of a conventional voltmeter circuit and building it up by a factor of 50. It does so by current amplification. A voltmeter having a 50- μ A meter movement provides a resistance of 20,000 ohms-per-volt. When a 50- μ A meter is preceded by an amplifier having a fixed gain of 50, the resulting resistance becomes $50 \times 20,000 = 1$ megohm per volt.

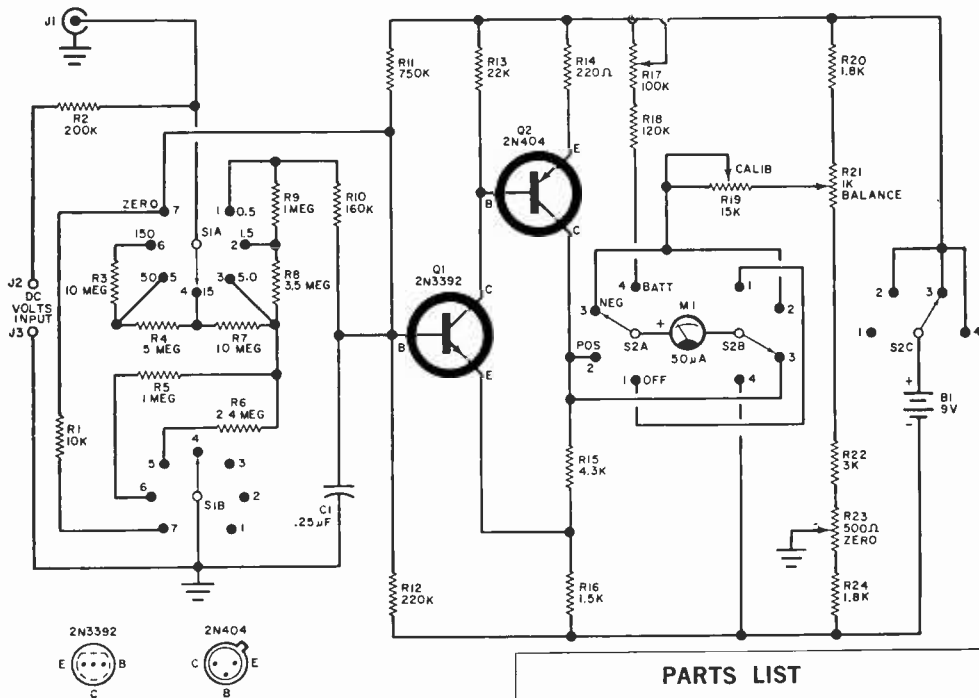


Fig. 1. The DCEV is basically a two-transistor TVM (transistor voltmeter) having the very high input impedance of the VTVM and the portability of a VOM. Unlike most VOM's, the DCEV has a 0 to 0.5 volt full-scale lower range, making it ideal for use with any type of semiconductor circuit including IC's.

Both the microammeter and the series resistor of the conventional voltmeter have a linear response, i.e., if sufficient voltage is applied to the combination to make 50 μ A flow in the circuit, the meter deflects to full scale; if a voltage equal to one-half that required for full-scale deflection is applied, then 25 μ A flows in the circuit and the meter deflects to half-scale.

When the voltmeter is incorporated in a DCEV, a similar order of linearity must be designed into the transistor amplifier, if the meter readings of the DCEV are to be reliably accurate. In fact, to measure both positive and negative voltages at high impedance and with equal accuracy for both, the transistor amplifier must be linear over the whole range of full-scale deflection of the meter with a positive input potential to full-scale deflection of the meter with a negative input potential—twice the range of the meter movement alone. The linearity of a DCEV in

PARTS LIST

- B1—9-volt transistor battery
- C1—0.25- μ F, 200-volt Mylar capacitor
- J1—Probe jack (Lafayette 99 C 6234 or similar)
- J2—Banana jack, red
- J3—Banana jack, black
- M1—3" meter, 0-50- μ A (Lafayette 99 C 5042 or similar)
- Q1—2N3392 transistor
- Q2—2N404 transistor
- R1—10,000 ohms, \pm 10%
- R2—200,000 ohms, \pm 5%
- R3, R7—10 megohms, \pm 5%
- R4—5 megohms, \pm 5%
- R5, R9—1 megohm, \pm 5%
- R6—2.4 megohms, \pm 5%
- R8—3.5 megohms, \pm 5%
- R10—160,000 ohms, \pm 5%
- R11—750,000 ohms, \pm 5%
- R12—220,000 ohms, \pm 5%
- R13—22,000 ohms, \pm 10%
- R14—220 ohms, \pm 10%
- R15—4300 ohms, \pm 5%
- R16—1500 ohms, \pm 5%
- R17—100,000-ohm potentiometer
- R18—120,000 ohms, \pm 10%
- R19—15,000-ohm potentiometer, wire-wound
- R20, R24—1800 ohms, \pm 5%
- R21—1000-ohm potentiometer, wire-wound, miniature (Mallory VW-3K, or similar)
- R22—3000 ohms, \pm 5%
- R23—500-ohm potentiometer, wire-wound, miniature (Mallory VW, or similar)
- S1—2-pole, 9-position, non-shorting rotary switch (Mallory 3229J, or similar)
- S2—3-pole, 4-position, non-shorting rotary switch (Mallory 3234J, or similar)
- I—6" x 5" x 4" utility cabinet
- Misc.—Handle, transistor sockets (2), rubber feet, $\frac{1}{2}$ "-long #8 spacers (2), pointer knobs for R21 and R23, 4 $\frac{3}{4}$ " x 2 $\frac{3}{4}$ " x 1/16" insulated mounting board, battery clip, battery connector, small L-bracket, wire, solder, etc.
- Accessories—Test leads (1 red, 1 black) with banana plugs, isolating probe (see Fig. 3)

All fixed resistors $\frac{1}{2}$ watt

HOW IT WORKS

Transistors *Q1* and *Q2* are connected as a high-gain, direct-coupled amplifier. Input is applied to the base of *Q1* and the resulting output at the collector of *Q2* is measured by microammeter *M1* in series with calibrating potentiometer *R19*. A current proportional to the deflection of *M1* flows in collector resistors *R15* and *R16*, and a voltage proportional to the current flowing in *R16* is fed to the emitter of *Q1* as negative feedback.

In addition to stabilizing the gain of the amplifier, this feedback accomplishes four other important functions: (1) it increases the input resistance of *Q1*; (2) it decreases the effective output resistance of *Q2*; (3) it makes the performance of the amplifier largely independent of the current gains of the transistors; and (4) it stabilizes the operating bias of *Q1* and *Q2* in the presence of temperature variations. Residual drift due to thermal activity is nulled out by adjustment of *Balance* potentiometer *R21*, which is connected in the conventional manner of a bridge. *Zero* potentiometer *R23* is adjusted to set the ground potential of the instrument equal to the base potential of *Q1*.

Amplifier *Q1-Q2* is preceded by a conventional resistive attenuator which enables the DCEV to measure from 0.5 volt full scale to 150 volts full scale in six settings of the *Range* switch. Reduction of the input resistance on the two higher ranges is limited to 20-plus megohms, which helps to keep the DCEV accurate during hot summer days when humidity percentages run high and insulation tends to behave like a very high

resistance. As it is, the input resistance of the DCEV on the 150-volt range is more than twice that of a VTVM.

Capacitor *C1* bypasses to ground any "hash" picked up on the test leads. The presence of this capacitor also increases the rise time of the input circuit to where very little overtravel of the meter needle occurs when a potential is suddenly applied to the DCEV's input terminals.

Selector switch *S2* not only makes provision for the measurement of either positive or negative voltages at the DCEV input, but it also has a position for accurately checking the battery while the amplifier is in operation. To calibrate this part of the circuit, set potentiometer *R17* at maximum resistance, then connect a VOM (so you can read 10 volts conveniently) in parallel with the battery. Set the *Selector* switch to *Batt*, and read the battery voltage on the VOM. Multiply the VOM reading by 5 and adjust *R17* until the meter of the DCEV reads this value. Thereafter, the DCEV battery can be checked at any time simply by setting *S2* to *Batt* and dividing the DCEV's meter reading by 5. When the battery voltage begins to drop, replace the battery. Power consumption of the DCEV is low, so battery life is long.

When the *Selector* switch is set to *Off*, the battery is disconnected and the terminals of the microammeter are simultaneously short-circuited. So doing damps the meter movement substantially, thus helping to protect the movement from damage and pivot wear while the DCEV is being handled or transported. This refinement is seldom, if ever, found even in instruments costing many times the DCEV.

this respect is termed its "turnover linearity," and in the instrument described in this article, turnover linearity is better than in many a VTVM.

The best way to obtain linearity in an amplifier is to provide means of automatically and continuously comparing the output level with the input level, and to maintain a fixed ratio between the two. In other words, it is essential to stabilize the gain of the amplifier over a wide range of current input. This has been done by designing a high-gain amplifier with a response that is as linear as possible and then employing negative feedback to bring the gain down to the required level. The linearity improves in the same ratio as the gain reduction. Thus, if an amplifier is linear within, say, 10%, without negative feedback, and a gain-reduction factor of 20 is obtained as a result of adding feedback, the linearity with feedback will be 10%/20, or 0.5%.

Construction. The DCEV can be assembled in a 4" by 5" by 6" aluminum utility box with room to spare. The at-

tractive appearance of the instrument depends in large measure upon how carefully and accurately the front panel is laid out and machined. Layout dimensions are given in Fig. 2. If the layout

SPECIFICATIONS

Range	0.5, 1.5, 5.0, 15, 50, and 150 volts d.c.
Input Resistance	1 megohm-per-volt on four lower ranges; 300,000 ohms-per-volt on 50-volt range; and better than 150,000 ohms-per-volt on 150-volt range
Linearity	1% from full scale to 1/5 full scale
Turnover Linearity	1% or better
Accuracy	± 5% with unselected resistors
Power Consumption	2 mA at 9 volts
Other Features	Special switching provides meter damping to avoid damage in transport, and also permits easy battery voltage check

lines are kept short, confined to the point of measurement, they will not show when the instrument is assembled. When all machine work is finished, deburr the openings, then degrease the panel by washing it thoroughly in a conventional detergent-water solution, rinse well, and dry.

Panel lettering can be done with either decals or dry-transfer labels. The important thing is to work slowly and carefully, keeping in mind that there is as much satisfaction to be had in the appearance of a good instrument as there is in its use. The switch positions will be

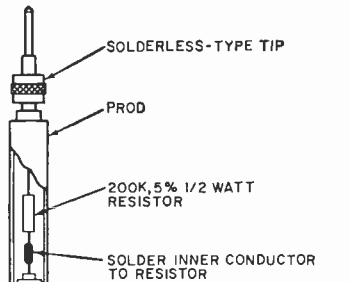
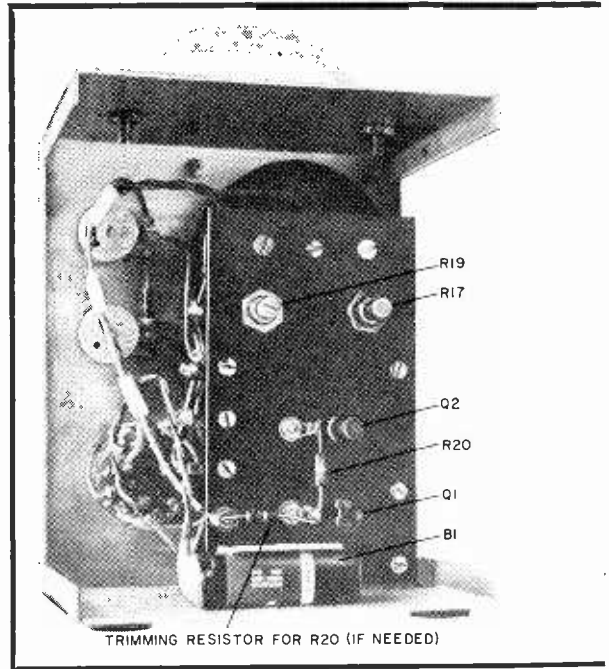


Fig. 2. Layout dimensions for front panel. Panel lettering can be done with almost any type of dry transfer or decal kit.

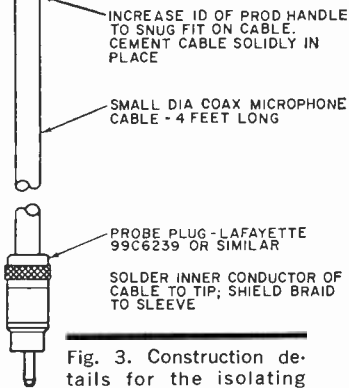
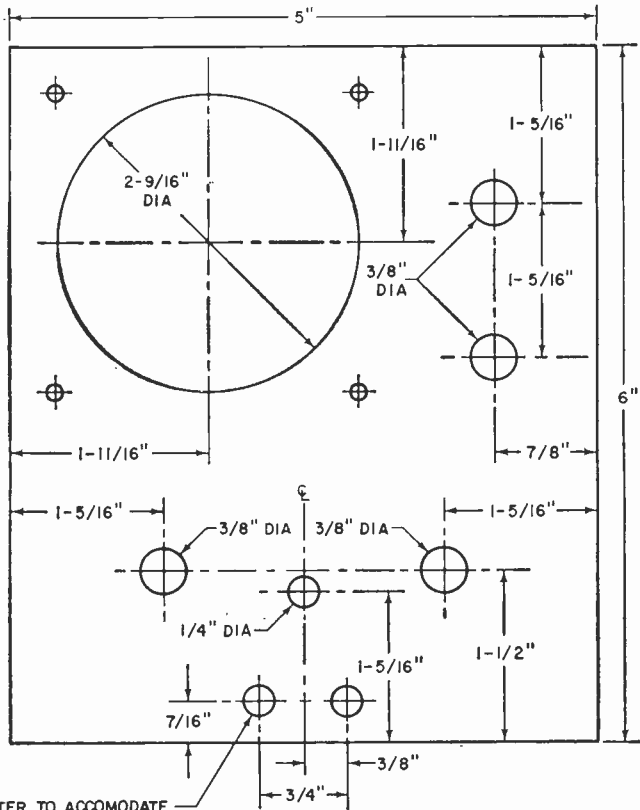
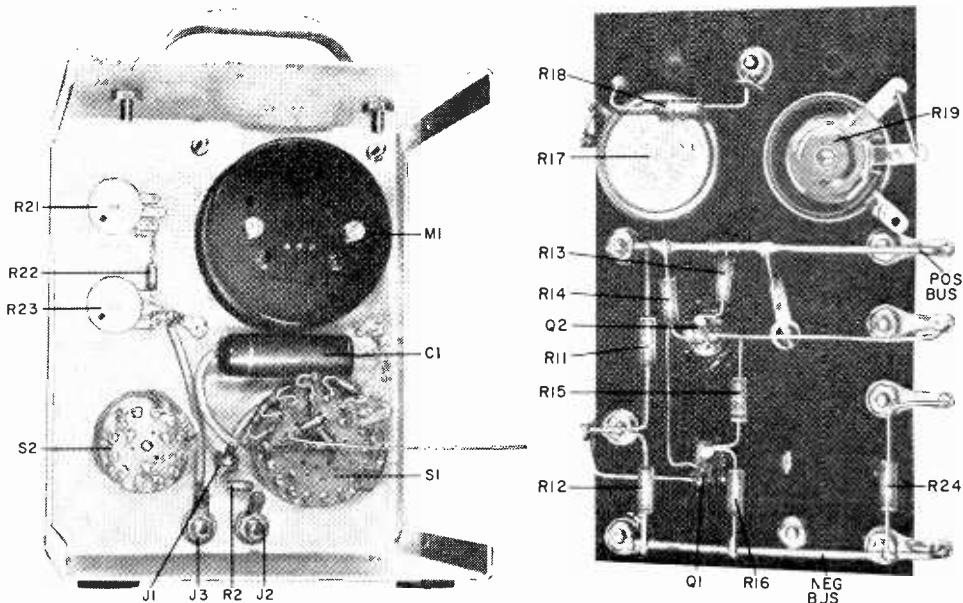


Fig. 3. Construction details for the isolating probe for use with the DCEV. These parts are not included in Parts List.



2 HOLES, DIAMETER TO ACCOMODATE INSULATING WASHERS OF BANANA JACKS OR BINDING POSTS, AS DESIRED



The completely assembled DCEV (left, above) is made up of the front-panel assembly (center), and the insulated board assembly (above, right). Battery is clamped to bottom of case as shown. Note that R20 is mounted on the transistor side of the board (see text).

most legible and attractive if the lines are white and the legends black.

Range switch *S1* is a 9-position unit, but only seven of the positions are used in the DCEV. The stop provided with the switch specified in the Parts List should be located so as to confine rotation to these seven positions. Prewire the *Range* switch with the multiplier resistors (*R2* through *R9*) before mounting it on the panel.

The accuracy of the readings obtained depends largely upon the accuracy of the multiplier resistors. Best accuracy will be achieved when the exact values specified in the Parts List are used. These resistors can be selected from 5% units tested on an accurate resistance bridge. If stock (unselected) 5% resistors are used, the DCEV will still be of considerable value in practical applications, however, for much of the electronic equipment to be tested with it will not require an accuracy greater than $\pm 5\%$ in operating voltages.

Most of the parts associated with the amplifier are assembled point-to-point on a $4\frac{3}{4}'' \times 2\frac{3}{4}'' \times \frac{1}{16}''$ insulated mounting board. Wire terminals are used where multiple connections are needed. In the author's model, resistor *R20* has been located on the outer surface of the board where it is easily accessible for trimming its value to obtain optimum initial centering of the *Balance* and *Zero* controls. If you are not interested in such splitting of hairs, this resistor can just as well be located below deck along with the others.

The board is mounted on the meter terminals with $\frac{1}{2}''$ spacers at the top and secured at the bottom by a small L-bracket under one of the screws holding the battery clip. Layout is not critical, and any other method of assembly—perforated mounting board and flea clips, or a printed circuit board—can be used instead, if desired.

Construction details of an isolating probe for the DCEV are given in Fig. 3.

NGW TRANSISTOR TESTER

(Continued from page 100)

Calibration. After the instrument has been completely assembled, checked and rechecked to make certain there are no errors or omissions, set the *Selector* switch at *Off* and install the transistors and the battery. Then proceed as follows.

(1) Set the *Range* switch (*S1*) at any position except *Zero*; set calibration control *R19* at maximum resistance; set *Balance* control (*R21*) and *Zero* control (*R23*) at about mid-position.

(2) Set the *Selector* switch (*S2*) at *Pos* and adjust the *Balance* control for zero indication on the meter. When this control is properly set, moving the *Selector* switch from *Pos* to *Neg* and then back to *Pos* again should produce no change in the zero indication of the meter.

(3) Set the *Range* switch at its *Zero* setting and adjust the *Zero* control (*R23*) for zero indication on the meter.

(4) Set the *Range* switch at 1.5 volts, apply an accurately known potential of this value to the input jacks, and adjust the calibration control (*R19*) until the meter indicates exactly full scale. If no other source is available, a fresh flashlight cell can be used for this purpose.

Maximum inaccuracy is likely to occur on the 0.5-volt range, since on this range the input resistance of the amplifier is a significant fraction of the multiplier resistance. In an individual instrument, some slight adjustment of the value of *R10* may be advantageous to improve the accuracy. Once the optimum value has been selected, it need not be changed.

Using the Meter. Although it would have been quite simple, the author decided not to re-scale the original 0-50 microampere meter scale. If the builder desires otherwise, numerous articles have appeared in print on how to draw up a new meter scale. The author found it relatively easy to simply ignore the microampere sign and to mentally substitute the word "volts."

Thus, the meter indicates directly on the 50-volt range, and on the 150-volt range the indication is multiplied by three. On the lower ranges, the decimal point is moved, mentally, one or two places to the left (as the setting of the *Range* switch requires) and, when necessary (on the 1.5- and 15-volt ranges), the reading is multiplied by three. -30-

Depress the *SI-GE* (*SI* for silicon and *GE* for germanium) switch (*S2*). If the meter pointer goes to full-scale deflection, the transistor is a *npn* unit; if no deflection is observed, it is an *npn* unit. If the meter deflects, move switch *S4* to *PNP* and the pointer should return to zero. If no deflection is observed in either position of *S4*, the transistor is open.

With the *NPN-PNP* switch (*S4*) in the proper position, as determined above, read the transistor's leakage current. Leakage for a germanium transistor should generally be less than 1 mA, zero for silicon transistors. (Consult a transistor manual if you observe excessive leakage for germanium power transistors. Leakage in excess of 1 mA for some germanium transistors can be normal.)

Depress *GAIN* switch *S1*, and if the meter shows less than 1 mA, set *S3* to *X100*. Multiply the meter reading by the value indicated by the position of *S3*. This is the d.c. current gain of the transistor. No meter indication means that the transistor has an interelement open.

With *S1* closed, depress *S2*. If the meter pointer deflection remains the same or drops slightly, the transistor is a germanium unit. If the indication should drop to zero, the transistor is silicon. A simplified step-by-step testing procedure that can be pasted on the tester appears on page 99.

Testing Diodes. Connect the anode of the diode to be tested to the *Collector* jack (*J3*); the cathode goes to the *Emitter* jack (*J1*). When *S4* is then set to *NPN*, the meter should deflect fully up-scale. Now set *S4* to the *PNP* position; there should be no deflection. (Full-scale deflection is obtained in both positions of *S4* when the diode under test is shorted; there is no deflection when the diode is open.)

Zener diodes with less than 6 volts breakover potential (E_{bo}) will normally produce a slight meter indication when *S4* is set to *PNP*. The tester will *NOT* check tunnel diodes, trigger diodes, constant-current diodes, or four-layer diodes. -30-



VERSATILE REGULATED LOW VOLTAGE POWER SUPPLY

JUST THE THING FOR YOUR WORKBENCH

HAVE YOU a need for a voltage-regulated power supply—one that will regulate all the way down to zero output voltage with a maximum current capacity sufficient to handle 90% of your test and experimental setups—yet not cost too much to build? If so, want no longer. The instrument described in this article employs a simple, inexpensive, yet clean-working and reliable circuit designed to do just what you've been waiting for.

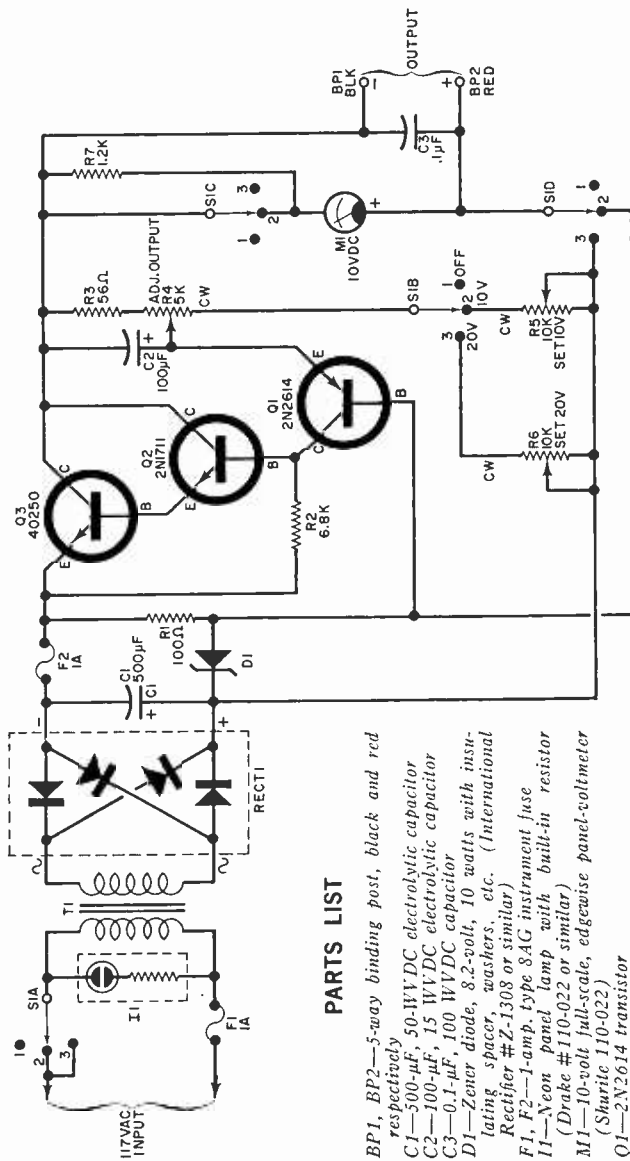
The specifications tell the story. On the low range, the voltage is variable between zero and 10 volts up to 250 mA. On the high range, the voltage can be set between 8 and 20 volts with a current drain up to 500 mA. Regulation on the low range is within 4% at 10 volts and 250 mA output, while on the high range it is within 2% at 20 volts and 500 mA. Output hum and noise averages 10 mV at maximum output on either range. The schematic for this power supply is shown in Fig. 1.

Construction. If you purchase the recommended 6" by 5" by 4" metal box,

the U-shaped sides will not be used. To assure adequate ventilation for efficient heat dissipation, the sides are replaced with a thin, perforated aluminum screening made to the same dimensions and shape as the original. If the screening is made to fit snugly in the mating part of the cabinet, screws will not be needed to keep it in place. Enlarge one of the perforations to take a rubber grommet for the line cord. When all work on the metal box is finished, spray-paint it with the desired color, then put it aside while work proceeds on the remainder of the supply.

Dimensions for the front-panel layout are given in Fig. 2. After drilling and deburring are finished, wash the part briefly in a conventional solution of household detergent, rinse well, and dry thoroughly. Apply the lettering, using either decals or dry transfer. Then mount and wire the components required on the panel, as shown in Fig. 3.

The chassis-plate, shown in Fig. 4, cut to 5 $\frac{1}{16}$ " by 4 $\frac{1}{16}$ ", should be at least $\frac{3}{32}$ " thick, not just for rigidity, but because it



PARTS LIST

- BP1, BP2—5-way binding post, black and red respectively
 C1—500-µF, 50-1WVDC electrolytic capacitor
 C2—100-µF, 15 WVDC electrolytic capacitor
 C3—0.1-µF, 100 WVDC capacitor
 D1—Zener diode, 8.2-volt, 10 watts with insulating spacer, washers, etc. (International Rectifier #Z-1308 or similar)
 F1, F2—1-amp. type 8AG instrument fuse
 I1—Neon panel lamp with built-in resistor (Drake #110-022 or similar)
 M1—10-volt full-scale, edgewise panel-voltmeter (Shurite 110-022)
 Q1—2N2614 transistor
 Q2—2N1711 transistor
 Q3—40250 transistor (RCA) (with hardware for insulated mounting)
 R1—100-ohm, 25-watt power resistor
 R2—6800-ohm, ½-watt resistor
 R3—56-ohm, ½-watt resistor (see text)
 R4—5000-ohm wirewound miniature potentiometer (Mallory type VW-5K or similar)
 R5, R6—10,000-ohm wirewound miniature potentiometer (Mallory type VW-10K or similar)
 R7—1200-ohm, ½-watt resistor*
 RECT1—1.8-amp., 200-PIV silicon full-wave bridge rectifier assembly (International Rectifier #10DB2A or similar)
 S1—4-pole, 3-position non-shorting rotary switch (Mallory type 3243J or similar)
 T1—Power transformer: secondary 24 volts @ 1 amp.

Fig. 1. Dual-range power supply uses conventional circuit. Output is up to 10 volts at 250 mA and 20 volts up to 500 mA. Ripple voltage is extremely low. Output is controllable from front panel.

1—6" x 5" x 4" utility cabinet
 1—5¹⁵/₁₆" x 4⁵/₁₆" x 3¹/₂"-thick aluminum-alloy sheet (for heat-sink chassis-plate)
 1—Double fuse holder (for size 8AG fuses)
 Misc.—Thin perforated sheet steel for back/sides cover, 2" x 2 1/2" x 1/8"-thick piece of phenolic, knob for R4, cabinet handle, rubber foot (4), sturdy L-brackets (4), Z5 silicone compound, transistor sockets (3), line cord, rubber grommet, screws, nuts, washers, wire terminals, wire, solder, etc.
 *—The value of R7 depends on the internal resistance of M1; 1200 ohms is correct for the meter specified in this Parts List. If a different meter is used, a different value may be needed for R7.

functions as a heat-sink for the power transistor Q3 and the zener diode D1. Make the cutout at the bottom large enough to clear the power transformer. Rectifier RECT1, capacitor C1, and resistor R2 are mounted on a 2 1/4" by 2" by 1/8"-thick piece of phenolic held in place by two #6 screws and spaced from the chassis plate by a narrow strip of the

same material. The location of the remainder of the components on the chassis plate may be seen in Fig. 4 and Fig. 5. Hardware for insulated mounting of Q3 and D1 is supplied when you buy these components. When mounting Q3 and D1 on the chassis plate, handle the thin mica insulating washers carefully, and coat all mating parts adequately

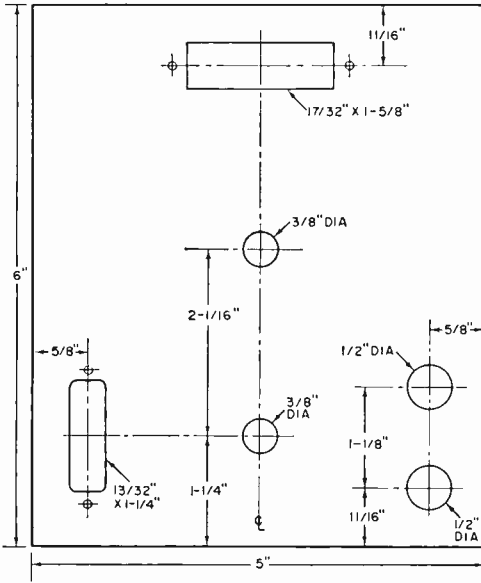


Fig. 2. Front panel cutout and drilling information. The author used a standard size aluminum utility box and discarded the mating section. A new section was bent from perforated aluminum. The new section provides ventilation and eliminates the shock hazard of accidentally touching components.

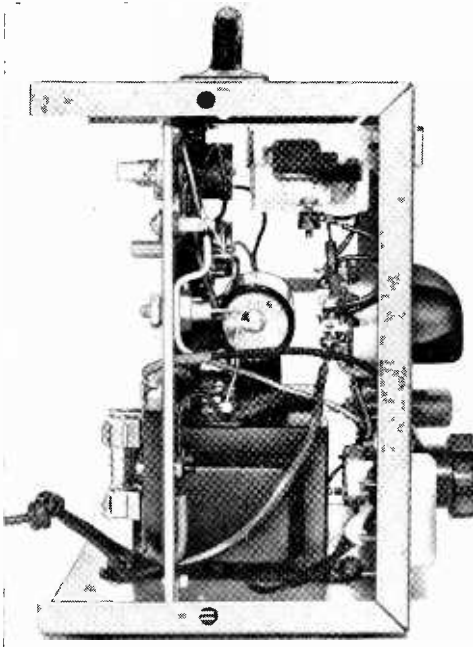


Fig. 6. Side view of the completed power supply. Note the location of the special chassis plate to provide easy clearance between components mounted on the front panel and those on the chassis plate.

with silicone grease compound to assure maximum heat transfer.

Use four L-brackets, two at the top and two at the bottom, to mount the chassis plate in the cabinet. These must support the weight of the transformer and provide rigidity to prevent distortion of the cabinet while the completed instrument is being carried around. The side-view of the completed instrument (Fig. 6) shows the location of the chassis plate to provide clearance between the components on the rear of the front panel and those below-deck on the chassis plate. Adequate clearance to allow free circulation of air is highly desirable, inasmuch as heat is produced in the cabinet, not just by *D1* and *Q3*, but by the transformer, power resistor *R1*, etc.

In the course of wiring the supply, pay particular attention to the fact that no part of the circuit is electrically connected to the chassis plate or cabinet.

Adjustment Procedure. Adjustment of the completed power supply consists of setting potentiometers *R5* and *R6* for full-scale reading on voltmeter *M1* at 10 volts and at 20 volts output respectively. It is important, however, that these settings be made in the following manner.

After all assembly and wiring is completed, check and recheck to make cer-

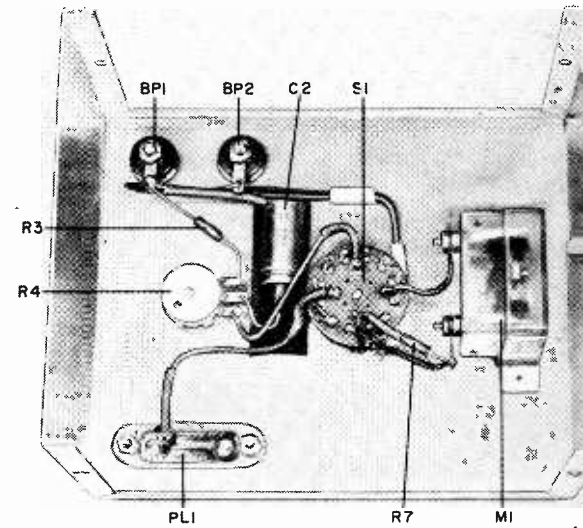


Fig. 3. In this rear view of the front panel, the location of those components attached to the panel can be seen. All of these components should be attached after the front panel has been lettered.

tain there are no errors or omissions, then insert the fuses in the holder and transistors $Q1$ and $Q2$ in their respective sockets. Set RANGE switch $S1$ at OFF; set ADJ OUTPUT potentiometer $R4$ in its maximum counterclockwise position; set $R5$ and $R6$ for maximum resistance in the circuit; then plug the line cord into an a.c. outlet.

Set $S1$ to the 10V position. The neon pilot light ($I1$) should glow and the me-

HOW IT WORKS

Transformer $T1$, silicon bridge-rectifier assembly $RECT1$, and electrolytic capacitor ($C1$ step-down, rectify, and filter the a.c. line voltage. The d.c. output is applied through fuse $F2$ to zener diode $D1$ and the output-voltage regulator which consists of transistors $Q1$, $Q2$, $Q3$, and associated components. Resistor $R1$ is $D1$'s current limiter.

When RANGE switch $S1$ is set at its 20V position, transistor $Q1$ compares the output voltage of the supply with that across $D1$ and automatically produces, at the $Q1$ collector, a control potential of the proper magnitude to correct the output voltage for variations due to load and line-voltage changes. Varying the setting of ADJ OUTPUT potentiometer $R4$ alters the ratio of the output voltage to the reference voltage (obtained across $D1$), thereby making a continuously variable range of output voltage available. Minimum output voltage on the 20-volt range is equal to the voltage across zener diode $D1$ (about 8 volts). Maximum output is determined by potentiometer $R6$. When $S1$ is set to its 20V position, multiplier resistor $R7$ is switched into the circuit, and the output voltage is then equal to the reading on voltmeter $M1$ multiplied by two.

The control potential at the collector of $Q1$ is coupled to the base of series-regulator transistor $Q3$ via emitter-follower $Q2$. The collector of $Q2$ supplies a small fraction of the output current, but by far the greater part of the output current is obtained via the emitter-to-collector resistance of $Q3$. This resistance depends on $Q3$'s base current, which is varied automatically by the control potential to maintain the value of output voltage determined by the setting of $R4$.

When RANGE switch $S1$ is set at its 10V maximum output position, operation of the regulator is exactly the same as described for the 8 to 20-volt range, but the voltage across zener diode $D1$ is now subtracted from the output voltage. Since the output voltage is equal to the voltage across $D1$ when ADJ OUTPUT potentiometer $R4$ is set for minimum output, the net result of this subtraction is zero. The regulator, however, is still performing efficiently, for it is actually operating at the 8-volt level.

Attainment of actual zero voltage output depends on the small voltage drop developed across resistor $R3$. Without this resistor, the minimum output voltage would be of reversed polarity and equal to the base-to-emitter voltage of $Q1$. Where precise setting of the zero is needed, $R3$ can be made a 100-ohm potentiometer with a panel knob for control. However, the value specified for fixed resistor $R3$ holds the zero to within 20 millivolts (depending on the exact value of the other components in the voltage-divider string and the accuracy with which potentiometer $R5$ is set). This is sufficiently close for most practical applications.

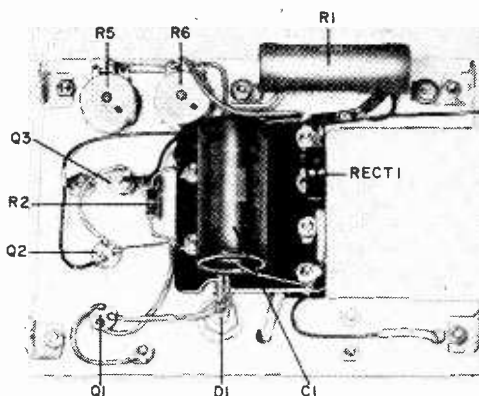


Fig. 4. Chassis plate is cut out according to instructions in the text. Plate fits over the power transformer. It is held upright by 4 "L" brackets.

ter needle should remain at zero. Advance $R4$ slowly to its maximum clockwise position. The needle of $M1$ should now be upscale but well below the full-scale position. Advance $R5$ slowly until the meter reads exactly full scale.

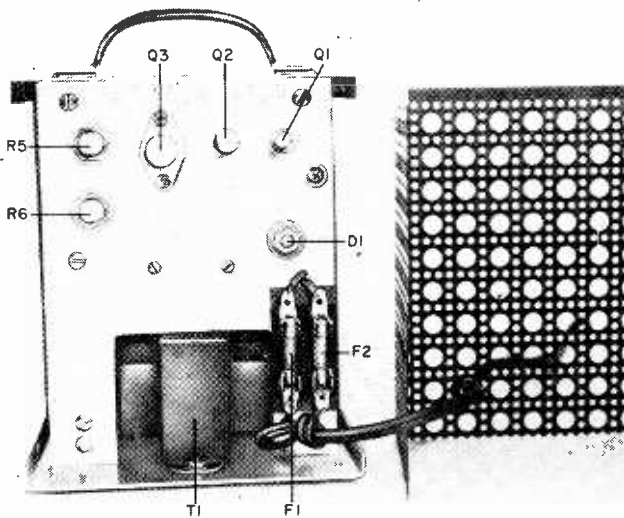


Fig. 5. Note how chassis plate is slipped into the utility box. Perforated aluminum replaces section.

Some slight sluggishness will be noted in the response of the output voltage to a change in the setting of ADJ OUTPUT control $R4$. This is a perfectly normal occurrence, due to the functioning of capacitor $C2$, the purpose of which is to keep output hum and noise at a minimum and to assist $Q1$ in opposing rapid
(Continued on page 153)

CHAPTER

4

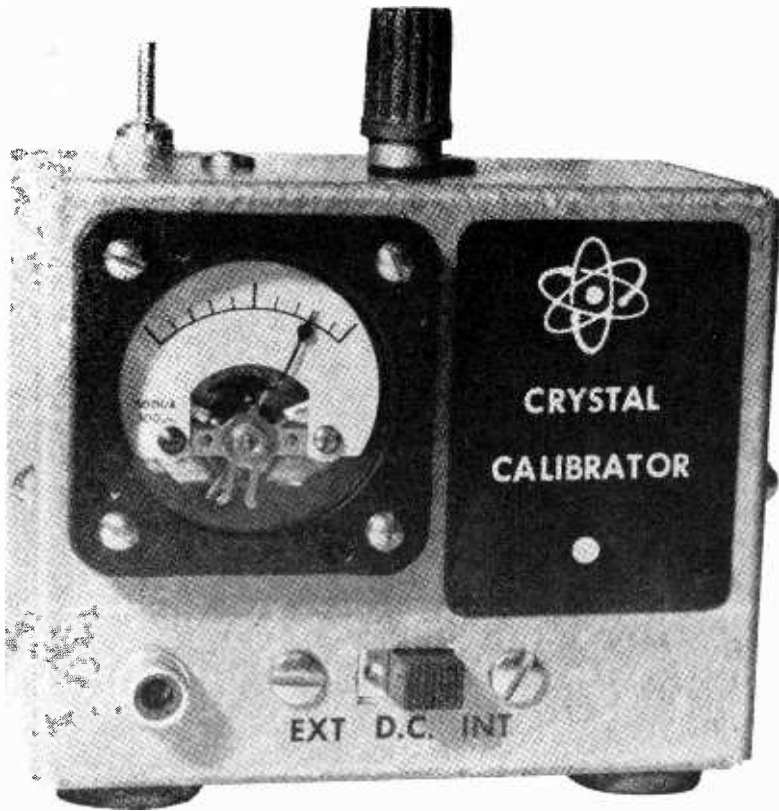
COMMUNI- CATIONS SWL CB & HAM

Because of space limitations, this chapter in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK contains only three construction projects. However, each of the three is an item of equipment that thousands of electronics hobbyists are seemingly anxious to build.

The "Police Special" receiver is a 1968-69 version of a similar project published in the 1960 ELECTRONIC EXPERIMENTER'S HANDBOOK. This receiver has been converted to solid state from tubes, from a superregenerative to superhet circuit, and from tuning the low-band to tuning the high-band police/fire frequencies. We have carefully detailed construction information on this project and it is our feeling that this is a receiver that almost any novice experimenter can build without hesitation.

For the short-wave listener this edition of the HANDBOOK has two important projects. The first is a crystal calibrator designed around a FET (field-effect transistor). The second is an r.f. preselector also using FET circuitry. We are particularly pleased by the operation of this preselector and recommend it to any SWL for use with a receiver tuning 7-30 MHz. The noise figure of this preselector is low and the signal gain is quite high. It will really make weak short-wave signals leap out of the static and background noise.

118	FET CRYSTAL CALIBRATOR.....	Frank H. Tooker
121	POLICE SPECIAL II.....	George J. Whalen, K2BIE
131	THE "FERRET" DRAGS THEM IN.....	George J. Whalen, K2BIE



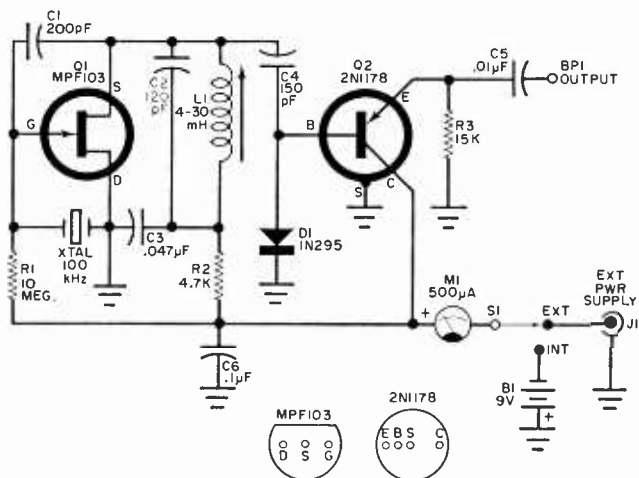
Build FET Crystal Calibrator

COMBINATION OF FET AND
DRIFT-FIELD TRANSISTOR
WILL PRODUCE 100-kHz
HARMONICS GALORE

BY FRANK H. TOOKER

IF YOU WANT a 100-kHz frequency calibrator designed for just that purpose, and therefore probably better than average, this project is for you. It uses the latest technological advancement in transistors—the field-effect transistor—as an oscillator and incorporates a harmonic generator to provide usable signals well into the MHz range. Temperature stability of the FET calibrator is excellent, and total power consumption is about 400 microamperes at 9 volts, or approximately 3.6 milliwatts.

A built-in meter monitors the performance of the calibrator by providing a continuous indication of current consumption. This meter isn't otherwise essential to the performance of the calibrator, and may be omitted if desired. Although a meter is useful in the initial adjustment of the calibrator, an external meter, temporarily connected in series with the battery, can be used for this purpose.



PARTS LIST

B1—9-volt transistor battery

BP1—5-way binding post

C1—200-pF silver mica capacitor

C2—120-pF silver mica capacitor

C3—0.047-μF Mylar capacitor

C4—150-pF silver mica capacitor

C5—0.01-μF ceramic disc capacitor

C6—0.1-μF ceramic disc capacitor

D1—1N295 diode

J1—Panel-mount phono jack

L1—Variable inductor, 4 to 30 mH

(Miller No. 6315 or similar)

M1—500-μA meter movement (optional)

Q1—Motorola MPF103 junction field-effect transistor

Q2—2N1178 transistor

R1—10-megohm, ½-watt resistor

R2—4700-ohm, ½-watt resistor

R3—15,000-ohm, ½-watt resistor

S1—S.p.d.t. slide switch

XTAL—100-kHz frequency-standard crystal
(Petersen Z-6A or similar)

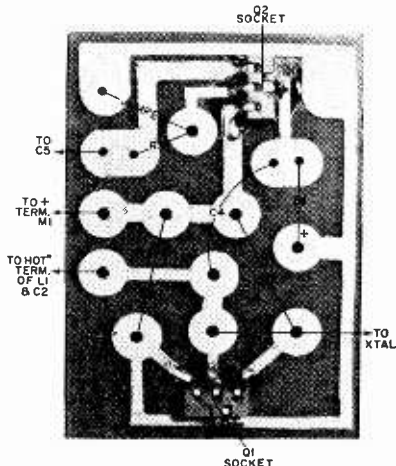
Misc.—Cabinet (3¼" x 3" x 2⅛"), etched circuit board, crystal socket, battery clip, battery connector, wire terminals, wire, solder, etc.

Circuit of the FET calibrator is designed around commonly available solid-state components. A phono jack on the front panel permits operation of the calibrator from an external power source.

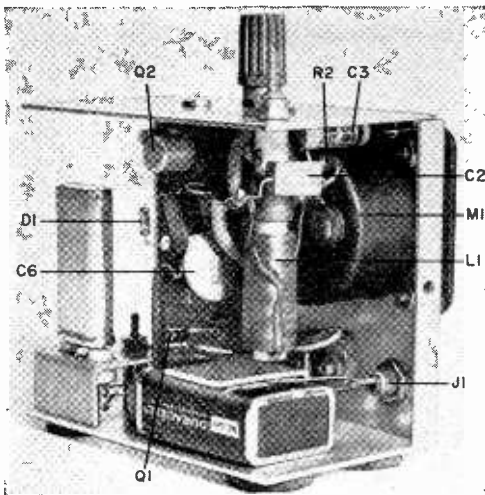
An ordinary transistor battery, such as the VS323, 2U6, 216, etc., can be used if necessary, but an alkaline battery, such as the Mallory "Duracell" MN1604B, will make for better frequency stability because of its superior voltage regulation in the course of aging.

Construction. Almost any technique that meets two requirements—short leads and a minimum of stray capacitance across the crystal—can be used to build this calibrator. Stray capacitance across the crystal reduces its operating frequency and contributes to frequency instability. Long leads in the signal circuits attenuate the amplitude of higher frequency harmonics.

Components of the calibrator shown in the photos are mounted partially on a 2¼" by 1½" etched circuit board and partially point-to-point. With the excep-



Although the author used this PCB layout, you could build the FET calibrator on a sturdy perforated board.



Inside-of-box view of the author's prototype. Aluminum bracket prevents battery from jarring loose. Output is via the binding post on the unit's cover.

tion of $C2$, which is connected directly across the terminals of $L1$, all sensitive components are mounted on the etched circuit board. An etched circuit board is, in fact, a "natural" for this type of instrument (even in experimental setups),

HOW IT WORKS

A 100-kHz crystal (*XTAL*) is connected in a Colpitts oscillator circuit, utilizing an n-channel junction field effect transistor, $Q1$, in a common-drain configuration. The gate of $Q1$ is at a very high impedance, and the crystal, connected between gate and drain, operates—largely unrestricted by loading—in its parallel-resonant mode.

Resistor $R2$ limits $Q1$'s starting current. Provided r.f. feedback is adequate, oscillation occurs when the power supply voltage is sufficient to operate $Q1$ above the "knee-point" in its characteristic curve. Once oscillations begin, drain current drops abruptly, for the circuit generates its own bias, and in this way adjusts itself automatically for operation at maximum efficiency. Transistor $Q1$ oscillates quite cleanly, although harmonic generation is restricted. On the other hand, harmonics are needed for frequency checking and calibration purposes. Output is taken from the relatively low-impedance source of $Q1$ and fed through coupling capacitor $C4$ to the harmonic generator and limiter circuit $D1$ - $Q2$.

Diode $D1$ advances the clipping of the positive-going alternations of the oscillator output voltage begun by $Q1$, while drift-field transistor $Q2$ clips the negative-going alternations. Clipping of both positive and negative peaks is quite sharp and very nearly equal. Thus, the signal appearing at the output terminal ($BP1$) is a well-sheared sine wave full of harmonics. With a 9-volt battery, or other power source, and the clipping level employed in this instrument, the signal voltage at the output terminal is approximately 3 volts peak-to-peak.

for it not only provides for the shortest possible leads but also insures lead rigidity—another important consideration in calibrator frequency stability.

Inductor $L1$ should be located where its adjusting screw is easily available with the back/sides cover of the cabinet in place. In the author's instrument, $L1$ is snapped into a hole in the top left rear corner of the $3\frac{3}{4}$ " x 3 " x $2\frac{1}{8}$ " cabinet housing the calibrator. Keep the winding at least the diameter of the coil away from nearby sheet metal (such as the back and sides of the enclosure).

Adjustment. After the calibrator is assembled, check to make certain that there are no errors or omissions, then install the transistors, the crystal, and the battery. Put the back/sides cover in place and tighten the mounting screws. Run the core of $L1$ about one-third of the way out of the winding, and switch $S1$ to *INT*. If all is well, the meter will read anywhere from 300 to 350 microamperes—indicating that $Q1$ is drawing its maximum limited value of current because it is not oscillating, and $Q2$ is drawing only its leakage current.

While observing the meter, turn the screw on $L1$ slowly in the direction that will move the core into the winding. A point will soon be reached where the meter needle deflects suddenly up-scale to about $450\ \mu\text{A}$. This increase in current is the net result of $Q1$ going into oscillation and $Q2$ increasing its collector current. Advance the core of $L1$ another two complete turns into the winding, and the meter reading should settle down to about $400\ \mu\text{A}$.

Switch $S1$ to *EXT* (to turn the calibrator "off"), wait a moment or two, then switch it back to *INT*. The meter needle should swing up-scale and come to rest immediately at about $400\ \mu\text{A}$. If the needle swings up to a higher value and hesitates briefly before dropping back, advance the core of $L1$ one more full turn into the winding.

The exact value of the meter readings may vary *slightly* with a different set of transistors, a different meter, or a battery other than the "Duracell" but the *direction of deflection* and the approximate *extent of the deflections* during the adjustment procedure should be the same.

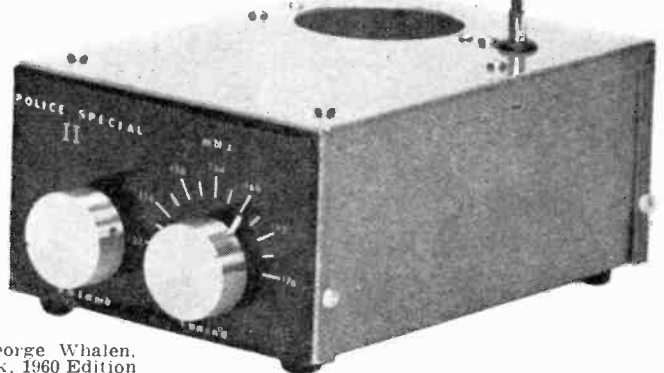
Police Special II

LISTEN TO THE BAND THAT
CRACKLES WITH EXCITEMENT

BY GEORGE J. WHALEN, K2BIE

SOME of the most fascinating radio activity you will ever hear takes place 24 hours a day in the band of frequencies lying between 152 and 176 MHz. It is here where the listener can almost "ride along" with police and fire department patrol or emergency crews, or speed through the night with an ambulance driver as he races against time and death, hear movie companies at work, or listen to the animated conversations between fishing boats. If you live near the coast, 24-hour-a-day weather reports are yours, courtesy of your local weather bureau. If you live in a wooded mountain area, you can hear the forest rangers going about their business, or timber crews reporting in. The list of things to hear is long, but at all times, there is a feeling of participation on the part of the listener that no other band can match.

The original "Police Special"* made lots of friends for the old 30 to 50 MHz Public Service band. However, in the past year or so, Public Service stations have rapidly been moving "upstairs" to the 152-176 MHz VHF Public Service band, and unique new classes of stations have



*"Police Special Receiver," by George Whalen,
ELECTRONIC EXPERIMENTER'S HANDBOOK, 1960 Edition

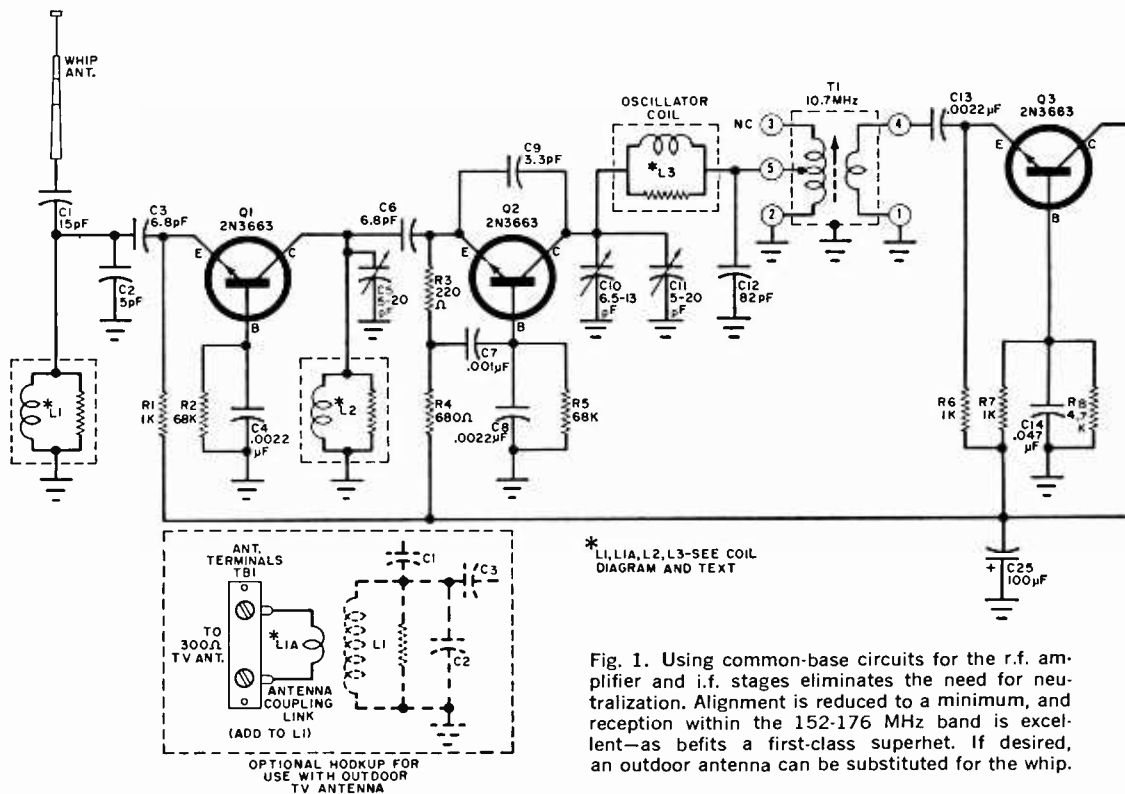


Fig. 1. Using common-base circuits for the r.f. amplifier and i.f. stages eliminates the need for neutralization. Alignment is reduced to a minimum, and reception within the 152-176 MHz band is excellent—as befits a first-class superhet. If desired, an outdoor antenna can be substituted for the whip.

come on the air, never heard in the old low-frequency band.

The "Police Special II" is a simple, single-conversion FM communications receiver that tunes the entire 152-176 MHz VHF Public Service band. It is entirely self-contained, in a 7" x 5" x 3" aluminum cabinet, and features a built-in audio amplifier, speaker, telescoping whip antenna, vernier-drive tuning, and portability gained through battery operation. The "heart" of the receiver is a printed-circuit r.f. module, featuring a grounded-base r.f. amplifier, stable VHF autodyne converter, two 10.7-MHz i.f. amplifiers, and a solid-state ratio detector circuit.

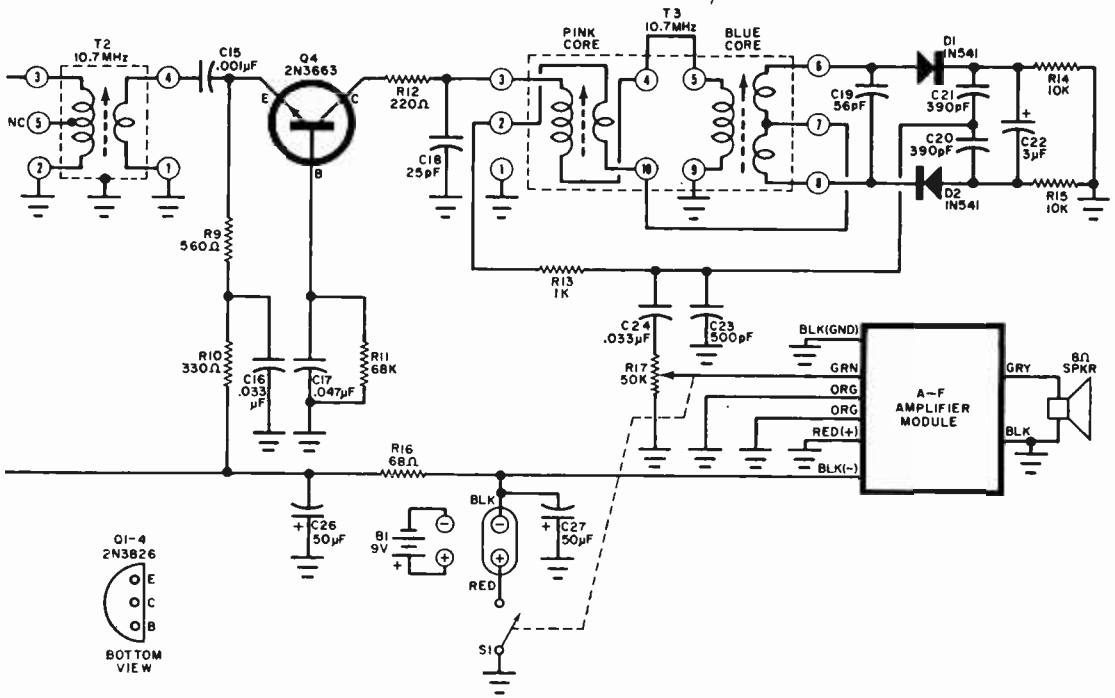
The transistorized r.f. module performs the work of amplifying, selecting, and detecting the desired signals. Boosting the detected signals to speaker volume is the job of the a.f. module, a prefabricated, imported four-transistor audio amplifier. The combination of these two modules produces an eight-transistor VHF receiver that is sensitive, stable,

low in noise, high in economy, and best of all, "buildable."

Circuit Details. The schematic is shown in Fig. 1 and contains a few surprises for those of you who thought a VHF receiver had to be complex to be good. For instance, the r.f. amplifier (Q1) and i.f.

PARTS LIST

- B1—9-volt battery (Burgess 2N6, or RCA VS-305)
- C1—15-pF disc ceramic capacitor
- C2—5-pF disc ceramic capacitor
- C3, C6—6.8-pF disc ceramic capacitor
- C4, C8, C13—0.0022- μ F disc ceramic capacitor
- C5, C11—5-20 pF trimmer capacitor (Centralab 820-B, or similar)
- C7, C15—0.001- μ F disc ceramic capacitor
- C9—3.3-pF NPO tubular ceramic capacitor (Centralab TC2, or similar)
- C10—6.5-13 pF variable capacitor, fitted with reduction vernier drive (Lafayette 32 C 0917)
- C12—82-pF disc ceramic capacitor
- C14, C17—0.047- μ F disc ceramic capacitor
- C16—0.033- μ F disc ceramic capacitor
- C18—25-pF disc ceramic capacitor
- C19—56-pF disc ceramic capacitor
- C20, C21—390-pF disc ceramic capacitor
- C22—3- μ F, 3-volt electrolytic capacitor
- C23—500-pF disc ceramic capacitor
- C24—0.033- μ F disc ceramic capacitor



- C25—100- μ F, 12-volt electrolytic capacitor
 C26, C27—50- μ F, 15-volt electrolytic capacitor
 D1, D2—1N541, or matched pair 1N542
 I.1. L1-A, L2, L3—See text
 Q1, Q2, Q3, Q4—2N3663 transistor (Texas Instruments)
 R1, R6, R7, R13—1000 ohms
 R2, R5, R11—68,000 ohms
 R3, R12—220 ohms
 R4—680 ohms
 R8—4700 ohms
 R9—560 ohms
 R10—330 ohms
 R14, R15—10,000 ohms
 R16—68 ohms
 R17—50,000-ohm, $\frac{1}{2}$ -watt potentiometer, with s.p.s.t. switch (IRC Q11-123, with 76-1 switch)
 S1—S.p.s.t. switch (part of R17)
 T1, T2—10.7-MHz subminiature i.f. transformer (J.W. Miller 2071)
 T3—10.7-MHz subminiature ratio detector transformer (J.W. Miller 2073)
 TS1—Five-terminal tie lug strip (center ground)
 TS2—Three-terminal tie lug strip (center ground)

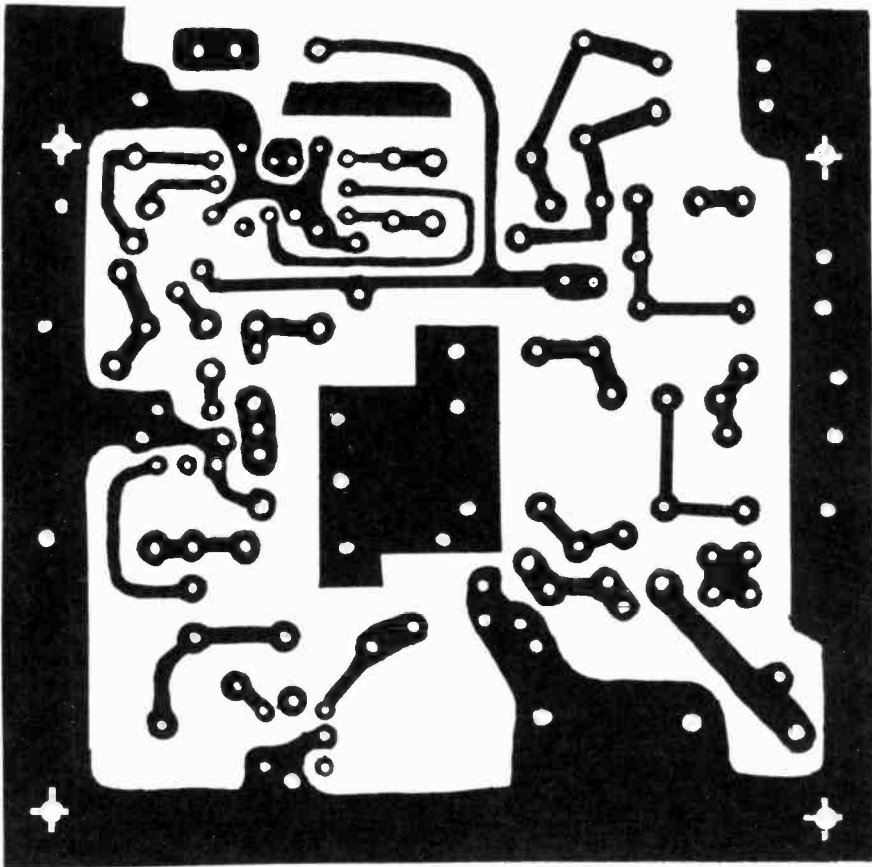
All resistors
 $\frac{1}{2}$ watt

- TS3—Antenna terminal strip (optional—see text)
 I—A.F. amplifier module (Lafayette 99 C 9042 or similar)
 1— $2\frac{1}{2}$ "-diameter permanent magnet speaker
 1—7" x 5" x 3" metal box (Bud CU-2108-A or similar)
 1—Printed circuit board for r.f. module*
 Misc.—Telescoping whip antenna (Lafayette 99 C 3114), $\frac{1}{4}$ " to $\frac{1}{4}$ " shaft coupler (H.H. Smith 120), $\frac{1}{4}$ "-o.d. x 1"-long brass spacer (H.H. Smith 2320), $\frac{1}{2}$ "-o.d. x $1\frac{1}{2}$ "-long ceramic spacer (H.H. Smith 2647), $\frac{1}{4}$ "-o.d., $\frac{1}{8}$ "-i.d. x $\frac{1}{2}$ "-long brass spacer (H.H. Smith 2100), 6-32 screws and nuts, 4-40 screws and nuts, $1\frac{1}{2}$ "-diameter knobs, battery hardware, ground lugs (3), antenna angle bracket—see text, rubber feet (4), perforated speaker grille, tin pointer, wire, solder, etc.

*An etched and drilled circuit board is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216 for \$3.00.

stages (Q3 and Q4) all operate in the common-base mode. Operating common-base pays dividends in this design, as it eliminates the need for tricky neutralization circuits and simplifies impedance-matching between stages. Moreover, the higher input and output impedances gained by using common-base circuitry

eliminate the need for tapped antenna, mixer and oscillator coils, and permit use of small coupling capacitors in the r.f. and converter stages which effectively reject unwanted i.f. signal "feed-through."
 Tuning of the receiver is also surprisingly simple, since only oscillator coil L3



is tuned, by single-section variable capacitor *C10*. This method of tuning was arrived at after experiments which proved that the small increase in gain obtainable by tuning antenna coil *L1* and mixer coil *L2* along with oscillator coil *L3* was more than offset by the bulk and expense of a three-gang variable capacitor. Consequently, a "broad-band" approach was adopted in the antenna and mixer resonant circuits. Antenna coil *L1* is resonated at about 168 MHz by fixed capacitor *C2* while mixer coil *L2* is resonated at about 158 MHz by trimmer capacitor *C5*. This tuning arrangement yields nearly uniform front-end gain across the entire 154-174 MHz spectrum and considerably eases the problems of cost and alignment.

The preassembled a.f. module cuts the construction time considerably, and helps to keep costs down. However, assembling the printed-circuit r.f. module and hooking up the two modules in the cabinet

still calls for a fair investment of time and effort.

The printed circuit board for the r.f. module is a must in a project like this one, as the very high frequencies at which the circuit operates demand strict control over parts layout, lead lengths, and grounding. You can make your own board using the full-size layout shown in Fig. 2, or you can obtain it ready-to-go (see Parts List).

Cabinet Details. Lay out the cabinet as shown in Fig. 3. Be sure to measure accurately before you drill. (Since antenna terminal strip *TS3* is optional, the holes are also optional; they can be drilled now if you intend to use the receiver with an outdoor antenna.) Drill and punch the required holes, removing burrs and ragged edges with a tapered reamer or file.

When metal work has been completed, make up a panel plate (Fig. 4) and ce-

Fig. 2. For best results, copy exactly the actual-size printed circuit board etching guide (on the opposite page).

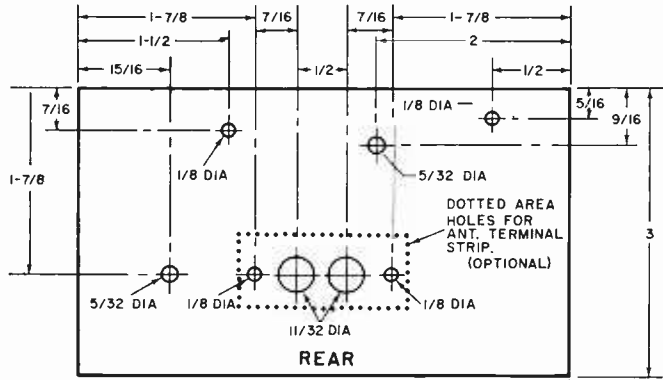
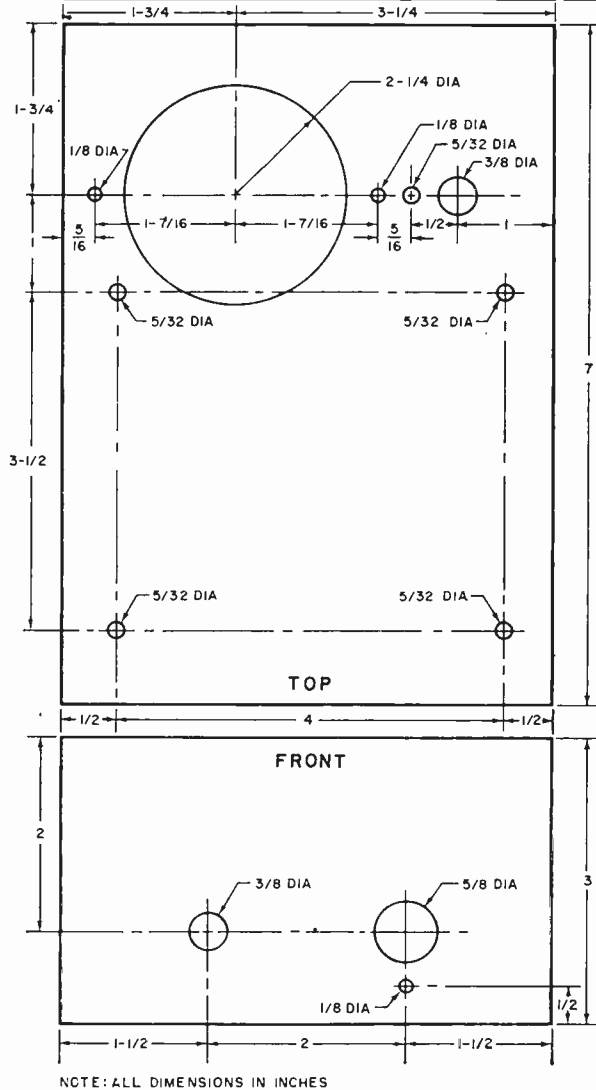


Fig. 3. To avoid unwanted interactions, mounting holes should be drilled to conform with dimensions and locations shown in the drawing (at right).



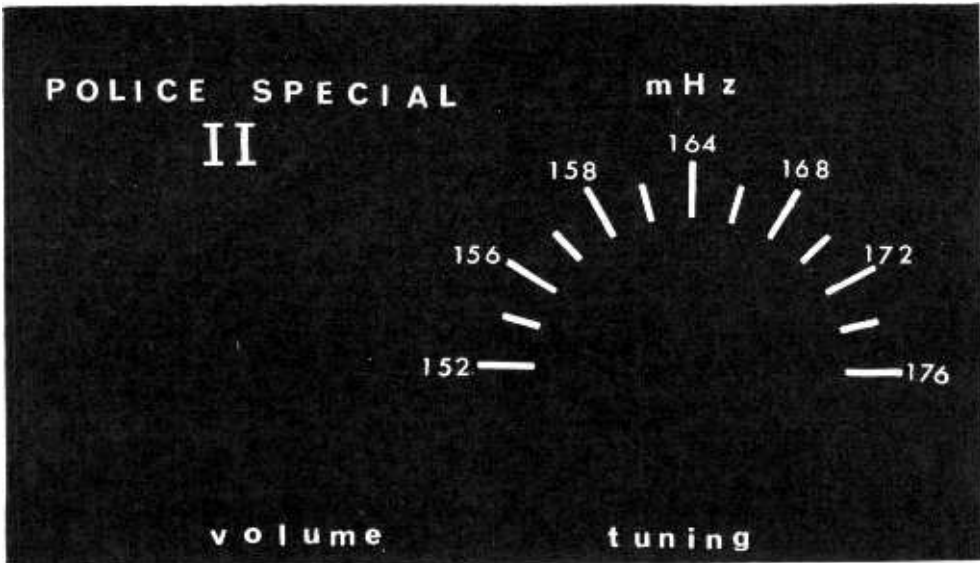


Fig. 4. Actual-size calibration guide can be copied or cut out and cemented directly on front panel.

ment it to the front panel of the cabinet using a good-quality adhesive cement. When the cement has dried, apply two coats of clear, acrylic spray to the panel plate to protect it from wear and tear. Allow the spray to dry, and cut out the panel plate portions covering the clearance holes for the tuning capacitor and volume control shafts, using a razor blade or sharp knife.

Install the six threaded metal spacers to support the r.f. module and a.f. amplifier module, and the threaded ceramic spacer to support the whip antenna (Fig.

5). Slip a ground lug under the spacer closest to the volume control. Insert a $\frac{3}{8}$ "-o.d. rubber grommet into the clearance hole for the whip antenna.

Cut a $2\frac{1}{2}$ "-diameter circular speaker grille from perforated sheet metal or phenolic material and paint it black to complement the gray hammertone finish of the cabinet. When dry, place the grille inside the cabinet, over the speaker mounting hole, with the speaker on top of it. Insert two 4-40 screws into the speaker mounting holes from the outside of the cabinet and slip a ground lug onto

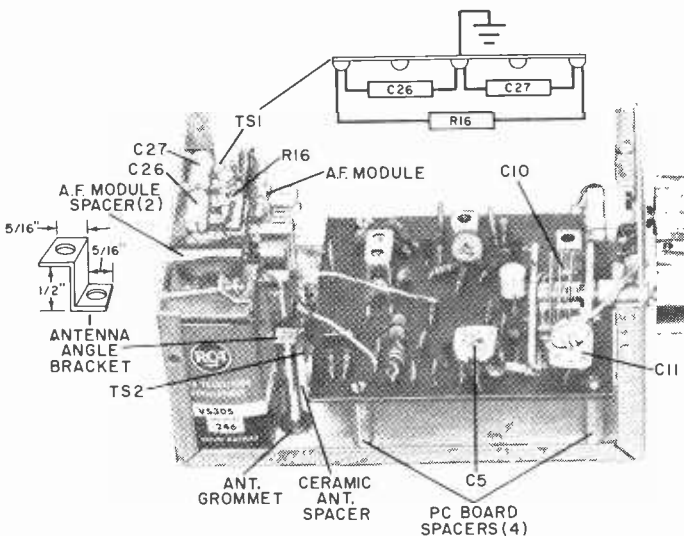


Fig. 5. Shown at left are construction details for the antenna mounting bracket and the parts arrangement on terminal strip TS1. Battery is held in place by a metal clamp.

each screw from inside the cabinet, placing each lug so that it bears against the mounting lip of the speaker. Fasten the lugs in this position with two 4-40 nuts, so that the speaker and grille are securely held against the cabinet.

Install volume control *R17* on the front panel, being careful not to tear the panel plate when tightening mounting hardware. Fasten terminal strip *TS1* to the rear panel of the cabinet and install resistor *R16* and capacitors *C26* and *C27* on it as shown in Figs. 5 and 6. Run two leads from the high side and center of the volume control to the two empty terminals of *TS1*, for later connection to the a.f. amplifier module. Connect the low side of the volume control to one contact of its on-off switch; then, con-

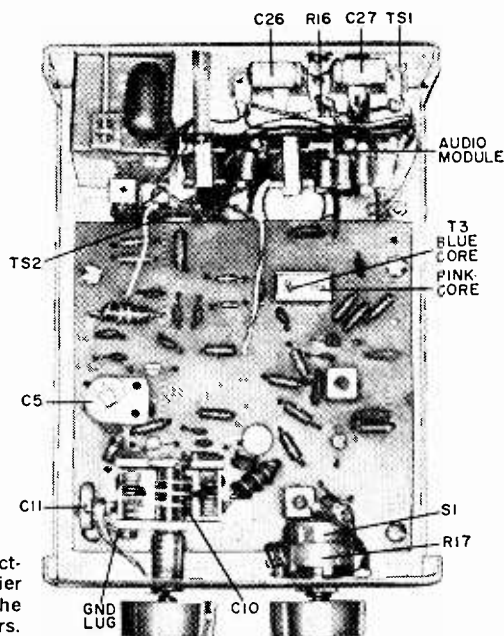


Fig. 6. Carefully orient detector transformer *T3* exactly as shown. Commercially available audio amplifier module should be mounted on the rear apron of the chassis using appropriate size hardware and spacers.

HOW IT WORKS

Signals intercepted by the self-contained whip antenna are capacitively coupled to antenna tuned circuit *L1* and *C2*. The desired signal induces a voltage across *L1-C2* which is coupled to the emitter of r.f. amplifier *Q1* by *C3*. The base of *Q1* is bypassed to ground by *C4*, with operative bias provided by *R2*, and emitter current stabilization furnished by *R1*. The minute signal current flowing into the emitter-base junction of *Q1* controls the flow of collector current through mixer tuned circuit *L2-C5*. The amplified signal voltage developed across this tuned circuit is coupled to the emitter of converter *Q2* by *C6*.

Converter *Q2* is an autodyne circuit; i.e., it is both an oscillator and a mixer. Oscillation is established by coil *L3* in series with the *Q2* collector (resonated by tuning capacitor *C10* and trimmer capacitor *C11*) feeding back a portion of the r.f. voltage to the emitter through *C9*. Since the feedback current is positive (in-phase), the circuit oscillates.

Frequency of oscillation is determined by the setting of *C10* and may be varied from 143.3 to 163.3 MHz. An incoming signal current appearing at the emitter of *Q2* mixes with the oscillator current, due to nonlinear detection in the emitter-base junction. This mixing process creates the familiar "sum" and "difference" signal frequencies. The important signal is the difference (or i.f.) signal, in this case, 10.7 MHz.

A portion of the primary of *T1* is resonated at 10.7 MHz by capacitor *C12*. Consequently, the 10.7-MHz energy in the collector current of *Q2* "sees" a high impedance across *T1-C12* and is induced into the secondary winding of *T1* and coupled to the emitter of i.f. amplifier *Q3* by *C13*. Transistor *Q3* amplifies the incoming i.f. signal, and applies its output across self-resonant i.f. transformer *T2*. The secondary of *T2* couples the amplified 10.7-MHz i.f. signal to the emitter of second i.f. amplifier *Q4*, which further amplifies

the signal, applying it to the primary of ratio detector transformer *T3* through "swamping" resistor *R12*. The effect of strong signals on the high primary inductance of *T3* is limited by *R12*, preventing "ringing" and oscillation in the circuit. The i.f. signal applied to the tuned primary of *T3* is induced into the tuned secondary through mutual coupling. Both the primary and secondary windings are resonant at 10.7 MHz, being tuned by *C18* and *C19* respectively.

Voltages across the primary and secondary tuned circuits of *T3* are 90° out-of-phase at resonance, but this phase difference changes as the frequency of the incoming i.f. signal varies. Therefore, the signal voltages applied to diodes *D1* and *D2* for peak detection also change, in step with the frequency variations of the incoming signal. Both diodes are placed "back-to-back," so that both conduct simultaneously during one-half of the signal frequency cycle. Thus, as the frequency of the i.f. signal varies, the diodes detect the peak voltage excursions, developing audio voltages in series across equal capacitors *C20* and *C21*. Capacitor *C23* bypasses residual i.f. voltages appearing in the audio signal after detection. Resistors *R14* and *R15* provide the d.c. load for the detector diodes. Capacitor *C22* prevents the diodes from responding to noise pulses or other amplitude-modulated interference by holding the rectified signal voltage constant across the load resistors. The audio recovered from the incoming signal is applied via *C24* to volume control *R17*.

The prefabricated a.f. amplifier module raises the audio signal to a comfortable listening level through two cascaded audio amplifier stages and a push-pull, Class-B output stage, delivering a maximum of 100 milliwatts of audio to the speaker. Operating power for both the r.f. and a.f. modules is supplied by 9-volt battery *B1*, bypassed by decoupling capacitor *C27*. Additional decoupling is furnished by *R16* and capacitors *C25* and *C26*, to prevent audio modulation of the d.c. voltage applied to the r.f. module.

nect this contact to the ground lug under the nearby spacer.

Install terminal strip *TS2* and the whip antenna angle bracket on the tapped ceramic antenna spacer, securing them with a 6-32 bolt. Position the angle bracket so that it lines up under the grommeted clearance hole.

Wire the "hot" contact of the on-off switch to the right-hand terminal of *TS2*, but don't solder until the battery clip is installed. Wire the left-hand terminal of *TS2* to the left-hand side of resistor *R16* on *TS1*, but don't solder at *TS2* until the battery clip is installed.

A.F. Module. The prefabricated audio amplifier module has four pre-drilled mounting holes in its printed circuit board. However, only two of these holes are used. Hold the board in position on the rear panel spacers to check alignment of the board holes with the two tapped spacers. Drill out the two mounting holes matching the spacer positions to accept 6-32 screws. Install the a.f. amplifier module on the spacers as shown.

Next, remove the battery clip from the a.f. amplifier module, cutting the red and black leads about halfway along their respective lengths. Strip the leads attached to the battery clip and connect the black (negative) lead to the left-hand terminal of *TS2* and the red (positive) lead to the right-hand terminal of *TS2*. Solder both connections. The color-coded leads of the a.f. amplifier module should then be connected as shown in Fig. 1. When you've completed these steps, check your wiring carefully.

Mount the battery as shown in Fig. 5, then connect the battery clip to the battery, switch the set on, and turn the volume control to maximum gain (fully-clockwise). Touch the center terminal of the volume control with your finger and note if an audible 60-Hz buzz comes from the speaker, indicating that the a.f. amplifier module is working properly. If nothing happens, check the wiring again, and the battery, or look for a defect in the volume control, a.f. amplifier module, or speaker.

R.F. Module. First install tuning capacitor *C10* on the non-foil side of the printed circuit board, using two #6 self-tapping screws inserted through the board

into the holes on the underside of the capacitor frame (see Fig. 7). Tighten the screws securely to prevent vibration of the capacitor and to make good ground contact with the printed pattern on the underside of the board.

Now attach a ground lug to the tapped hole at the far left on the front of the tuning capacitor frame, using a short 6-32 machine screw. Bend the ground lug

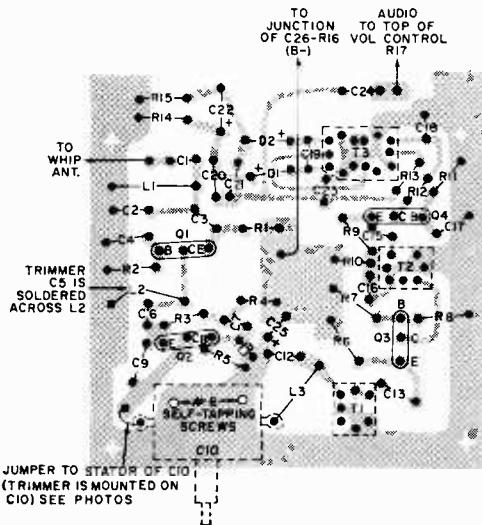


Fig. 7. When mounting capacitor *C10* on board, make good electrical contact between frame and foil.

around the left side of the capacitor. Remove the mounting clip from *C11* and solder rotor terminal to the new ground lug. From stator of *C10* feed a jumper of busbar down through the stator terminal of trimmer capacitor *C11* and through the printed circuit board, trimming off the excess busbar length after you are finished soldering.

Install i.f. and ratio detector transformers *T1*, *T2*, and *T3* in their respective locations on the printed circuit board (see Figs. 6 and 7), being careful not to bend the terminal pins in the process since you may break the micro-thin wire leads inside. The mounting tabs of each transformer should be bent flat and soldered to the foil ground conductor. Be careful to install ratio detector transformer *T3* properly. The blue core (output side) should be closest to diodes *D1*

and *D2*, and the pink core (input side) closest to transistor *Q4* (see Fig. 6).

Then install all resistors and capacitors on the board, as shown in Fig. 7.

When all components have been installed, check the parts layout and schematic to make sure that none were missed or installed in the wrong position. If everything checks out, install transistors *Q1* through *Q4*. Gently spread the leads of the transistors to fit the widely spaced mounting holes in the printed board, and be sure that the emitter and base leads are inserted into the proper holes. Bend leads flat against the printed conductor pattern and solder quickly to avoid heat damage. Clip off excess lead lengths when connections have cooled. Install diodes *D1* and *D2* (observing proper polarity), with the same care given the transistors.

Fabricate coils *L1*, *L2*, and *L3*, as shown in Fig. 8. The coil forms used in each case are standard 1-watt resistors. The exact values of resistance may be within $\pm 20\%$ of the specified values, as long as the diameter of the resistor body is the same. If you intend to use an outdoor antenna with the receiver, add coupling link *L1-A* to antenna coil *L1*, as shown in Fig. 8. Install the finished coils on the printed board as shown in Fig. 7.

Remove the mounting clip from trimmer capacitor *C5* and solder its rotor and stator terminals to the end leads of mixer coil *L2* as shown. Then install a 5" length of hookup wire lead to the B-minus conductor pattern of the board, a 7" length to the output end of *C24*, and a 2" length to the input end of *C1*. Cut a 2" length of shield braid and solder it to the ground lug on tuning capacitor *C10*. Attach and solder a ground lug to the free end of the shield braid.

The r.f. module is now complete and ready for installation in the cabinet. Do a final check on all wiring and soldered connections and clean up any excess flux or solder splashes on the conductor side of the board. Remember that this receiver is tuning the very-high frequencies where short leads are a prime requisite. Also make sure that there are no cold soldered connections and that all parts are rigidly mounted.

Slip the assembled module into the cabinet and align the board properly on the four spacers. Secure the board to the

spacers using short 6-32 screws. Don't tighten the screws too much or you will crack the board.

Next, slip a short 4-40 screw through the front panel and slip the ground lug connected to the shield braid onto it—secure it with a 4-40 nut to make a good, solid ground connection. Attach the 7" hookup wire lead from output capacitor *C24* to the high side of volume control *R17*, and connect the 5" hookup wire lead to the junction of resistor *R16* and capacitor *C26* on terminal strip *TS2*. The 2" antenna input lead connects to the center terminal of *TS2*.

Finishing Touches. Fabricate the pointer of the tuning dial as shown in Fig. 9. Sand the shaft coupling end to remove the plated finish. Then cut the pointer from sheet tin (a tin can is fine) and solder it to the sanded end of the shaft coupling. When the solder has cooled, apply a coat of white enamel to the pointer and allow it to dry.

The $\frac{1}{8}$ "-diameter flatted shaft of tuning capacitor *C10* can be adapted to fit standard $\frac{1}{4}$ " knobs by soldering a $\frac{1}{4}$ "-

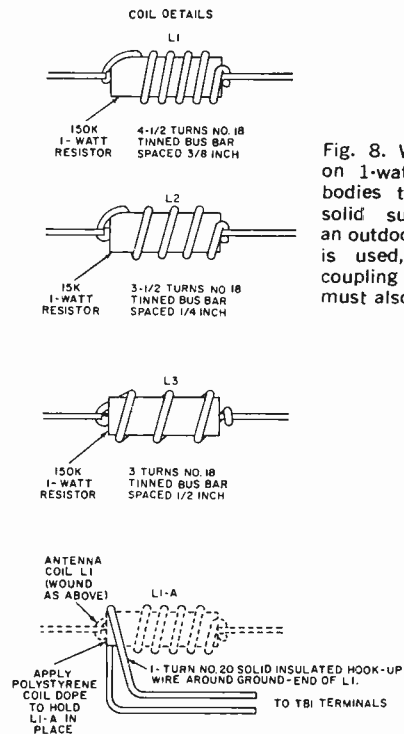


Fig. 8. Wind coils on 1-watt resistor bodies to provide solid support. If an outdoor antenna is used, antenna coupling coil *L1-A* must also be used.

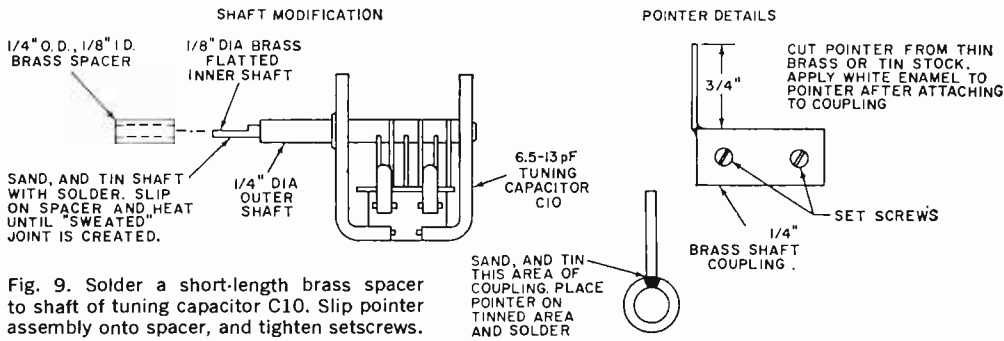


Fig. 9. Solder a short-length brass spacer to shaft of tuning capacitor C10. Slip pointer assembly onto spacer, and tighten setscrews.

o.d. x $\frac{1}{8}$ "-i.d. brass spacer to the existing shaft. Lightly sand the shaft and apply a thin coat of solder. Now slip the brass spacer onto the tinned shaft, heat the spacer until the solder on the shaft flows and allow the spacer-and-shaft-joint to cool.

Loosen the setscrews on the shaft coupling and slide the coupling onto C10's inner shaft, through the clearance hole in the front panel. Align the pointer with the rotor plates of the variable capacitor and tighten the rear setscrew to lock the shaft coupling to the outer shaft of the tuning capacitor. Install knobs on the adapted tuning capacitor inner shaft and the volume control shaft.

Install four rubber feet on the bottom half of the cabinet. For best results, use a good quality rubber or contact cement to attach the feet, rather than drilling holes and using hardware.

Alignment. Proper alignment of the completed receiver requires a fairly accurate signal generator, capable of producing tone-modulated 10.7-, 158-, and 168-MHz r.f. signals. To align the receiver, extend the antenna and rotate the volume control to the maximum position. Set the signal generator to 10.7 MHz, amplitude-modulated about 30%, and loosely couple the generator output to the receiver's antenna.

Then, using an insulated alignment tool, tune the slugs of T1, T2, and T3 for maximum output. When no further increase in output can be obtained, reset the signal generator to 158 MHz, amplitude-modulated about 30%, and place its output lead within six inches of the re-

ceiver's antenna. Set the tuning capacitor to a dial reading of 158 MHz and adjust oscillator trimmer capacitor C11, until the generator's signal is heard from the receiver speaker. Reduce the output of the generator to minimum and adjust mixer trimmer C5 for maximum output from the receiver. (You may have to readjust oscillator trimmer C11 to retune the receiver as the mixer trimmer is adjusted, since some interaction between the two adjustments is inevitable.)

When the receiver has been peaked at 158 MHz, retune the generator to 168 MHz, and tune in the signal on the receiver. Squeeze or stretch antenna coil L1 as necessary to peak the generator signal at this frequency. Check the tracking and tuning range of the receiver by setting the signal generator to 152 MHz and picking up the signal with the receiver. Tune progressively higher in the band in 2-MHz increments, to 176 MHz. If no parts substitutions were made and the coil specs were followed exactly, your receiver should easily tune from 152 to 176 MHz.

Now null the ratio detector for best reception of narrow-band FM signals. This adjustment can be performed on the bench and "touched-up" later using local Public Service signals. Tune the signal generator to 160 MHz, amplitude-modulated about 30%. Tune the receiver to the generator frequency, then adjust the blue core of ratio detector transformer T3 for a "null" in the received signal. As you make this adjustment, the signal should rise, drop off sharply, and rise again as the core is adjusted. The drop-off point is the correct null setting.

(Continued on page 152)



The "FERRET" Drags Them In

SINGLE-CONTROL PRESELECTOR
PEPS UP SHORT-WAVE
RECEPTION

BY GEORGE J. WHALEN, K2BIE

If you're an avid SWL or ham with a general-coverage receiver in the "under \$100 class," chances are you've discovered that the sensitivity of your receiver falls off rapidly as you tune above 14 MHz, especially if the receiver lacks an r.f. amplifier stage. What is worse, however, image rejection also drops off sharply with increasing frequency, making such a receiver highly susceptible to interference and annoying heterodynes.

Obviously, even the best antenna and a good Q-multiplier can't make up for deficiencies in the receiver's front-end. This is the job of an r.f. preselector, a unit combining high-gain r.f. amplification with a selective tuned circuit, inserted between the antenna and the receiver's antenna input terminals. It is the equivalent of adding a new front-end to your receiver, and the results can be astonishing.

The *Ferret* is such a unit. It is a high-gain, solid-state r.f. preselector designed to boost the sensitivity and selectivity of moderately priced short-wave receivers tuning the 7- to 30-MHz range. It consists of a two-stage amplifier, employing a high-frequency FET and a *npn* bipolar transistor, in combination with a high-Q tuned circuit which covers the 7- to 30-MHz range in a single sweep of the tuning dial.

The *Ferret* features a uniform gain of at least 30 dB throughout its tuning range and has a noise figure of better than 3 dB at 30 MHz. The high-Q coil in the *Ferret* input circuit and the universal input circuitry permit a good match to most antenna types, and the *Ferret* will even operate efficiently with an antenna made up of a dozen feet of hookup wire.

The prototype *Ferret* (see Fig. 1) is housed in a 5" x 4" x 3" gray-hammer-tone-finish aluminum box, with all major components mounted on a 3" x 3" printed circuit board. A single-section 10-365 pF variable capacitor mounted on the board and the on-off toggle switch secured to the front panel of the box are the only controls. Terminal strips on the rear wall of the box permit connection to any antenna type and to the receiver's input terminals.

Construction. Putting the *Ferret* together shouldn't take more than a few

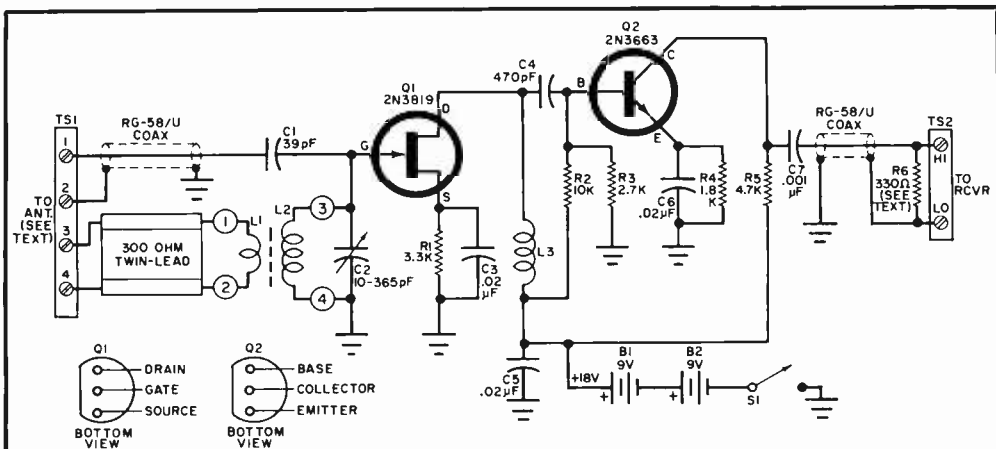
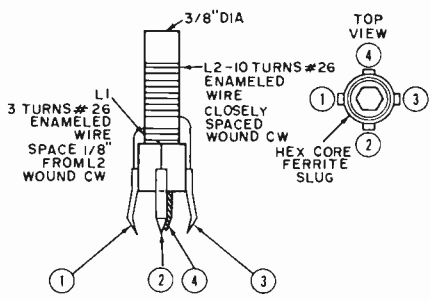


Fig. 1. The "Ferret" short-wave preselector has three optional inputs: one for single-wired antennas, a second for coax-fed antennas, and a third for any balanced input leadin.

The coil for the "Ferret" is hand-wound according to the plan detailed below. Carefully observe winding direction and connections to terminals. Coil is tuned by ferrite slug.



PARTS LIST

- B1, B2—9-volt battery (Burgess P6 or similar)
- C1—39-pF disc ceramic capacitor
- C2—10-365 pF variable capacitor (Lafayette 32 H 1103)
- C3, C5, C6—0.02-μF disc ceramic capacitor
- C4—470-pF disc ceramic capacitor
- C7—0.001-μF disc ceramic capacitor
- L1, L2—See coil drawing
- L3—55-μH r.f. choke (J. W. Miller 4629 or similar)
- Q1—2N3819 or TIS-34 FET
- Q2—2N3663 or 2N4254 transistor
- R1—3300-ohm, 1/2-watt resistor
- R2—10,000-ohm, 1/2-watt resistor
- R3—2700-ohm, 1/2-watt resistor
- R4—1800-ohm, 1/2-watt resistor
- R5—4700-ohm, 1/2-watt resistor
- R6—330-ohm, 1/2-watt resistor (optional—see text)
- S1—S.p.s.t. toggle switch
- TS1—4-point terminal board
- TS2—2-point terminal board
- Misc.—Printed circuit board*, battery holder, metal box, 1/2" spacers, RG-58/U coaxial cable, 300-ohm twin lead, hookup wire, solder, nuts, bolts

*An etched and drilled printed circuit board is available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216, for \$2, post-paid. Transistors, \$2; coil form 30c.

evenings' work, provided you use an exact duplication of the author's printed circuit board, wiring, and parts layout—which is especially important in high-gain r.f. circuitry. You can make the PC board yourself, using the actual-size layout in Fig. 2, or purchase it etched and drilled (see Parts List).

Before starting on the printed circuit board, lay out the box as shown in Fig. 3. Drill the required holes and remove burrs and ragged edges with a tapered reamer and warding file. Then install the dual battery-holder on the rear wall of the box using two short 4-40 screws and nuts. Mount terminal strips TS1 and

TS2 in their respective positions and check that each lug clears the edges of the mounting holes. Install toggle switch S1 on the front wall of the box as shown in the photographs. Solder a jumper between the top two terminals of the dual battery holder so that the holders are placed in series.

Next, connect a length of insulated hookup wire to the bottom left terminal of the dual battery holder and run it forward along the box surface to one terminal of toggle switch S1. Attach a solder lug to a short length of hookup wire and connect the free end to the other terminal of the toggle switch. Secure

Fig. 2. Actual-size foil pattern for the printed circuit board (right). If you don't want to make your own, you can buy an etched and drilled board from the supplier listed in the Parts List on facing page.

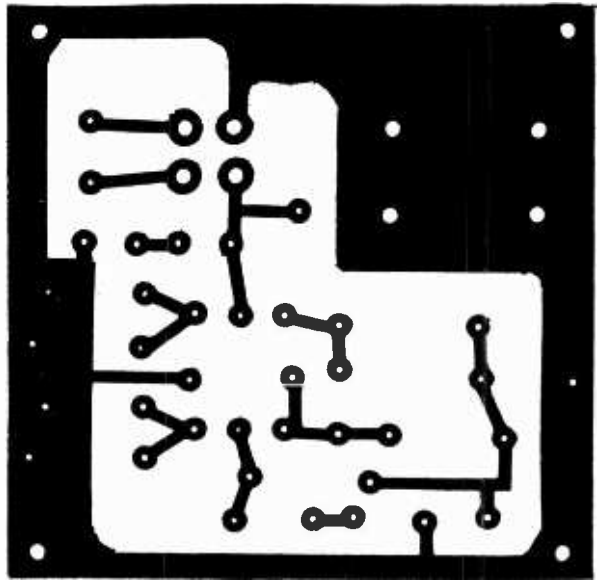
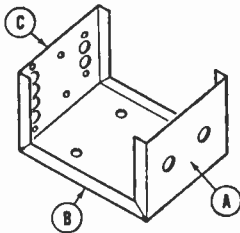
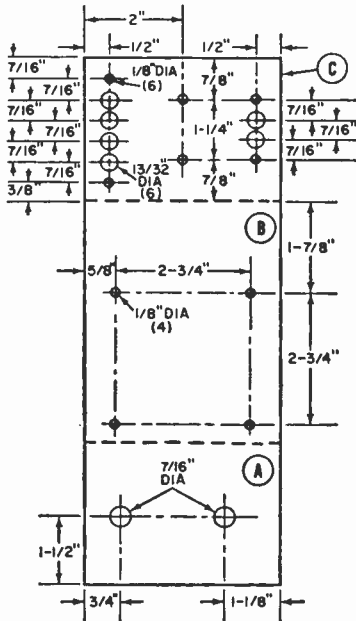


Fig. 3. If you build your "Ferret" in the same type box used by the author, follow the drilling and cutting plan below. Not shown on side B are holes for four mounting feet (holes are not really necessary since 3M adhesive bumpers can be used).



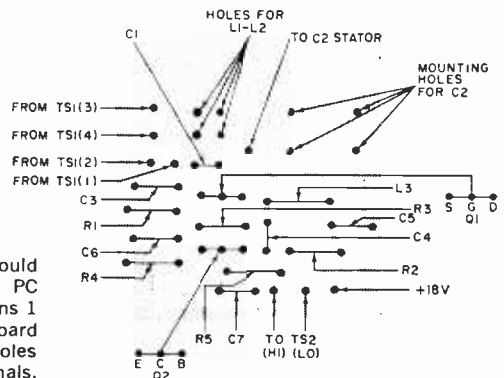
the solder lug to the box surface with a 4-40 screw and nut to make a solid ground connection to the box. Scribe a minus (-) sign near the bottom left

Fig. 4. This is how the components should appear as you look up through the PC board. Rotate coils L1-L2 so that coil pins 1 and 2 face the left-hand side of the board (looking up). The coil mounting holes must be enlarged to pass the terminals.

terminal of the battery holder and a plus (+) sign next to the bottom right terminal as a reminder to install batteries B1 and B2 correctly.

Begin assembly of the parts on the PC board by installing variable capacitor C2. First bend the four stator lugs up against the side of the capacitor to prevent interference when mounting. Then install C2 using four short 6-32 screws inserted through the board holes into the tapped holes in the underside of the capacitor frame. Tighten the screws sufficiently to make a good ground contact with the printed pattern on the underside of the board and to prevent vibration of the capacitor.

Now install the coil assembly on the board, being careful to insert the four



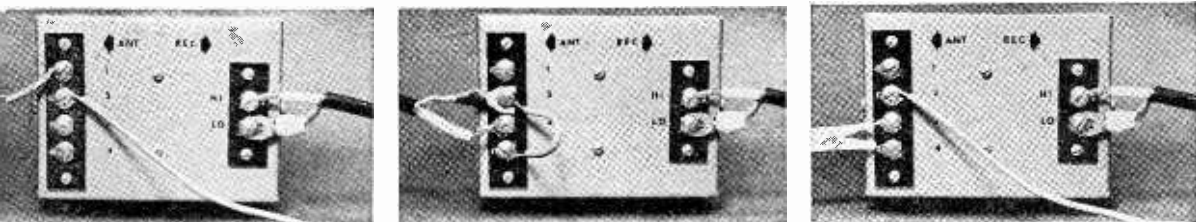
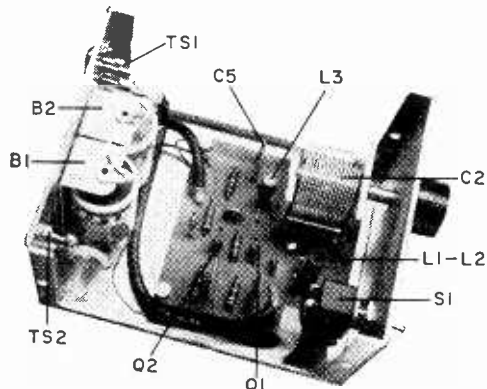
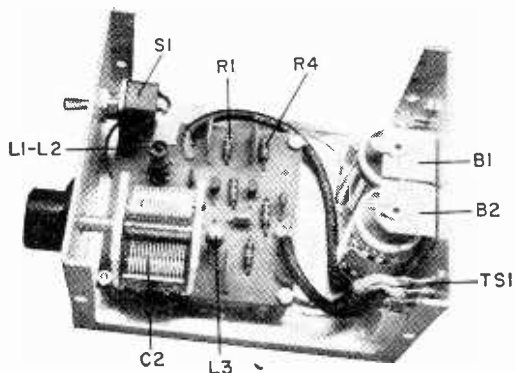


Fig. 5. The three methods of connecting an antenna to the preselector. At left, a single-wire lead-in is connected to ANT terminal 1 and a ground to terminal 2. In center photo, a coax-fed antenna is connected to terminal 3 and the shield connected to terminals 2 and 4. At right, a balanced 300-ohm twin-lead input is connected to terminals 3 and 4. A ground connection from terminal 2 is optional.



The "Ferret" fits snugly in metal box. You'll have to adjust the height of the metal spacers to permit the shaft of tuning capacitor C2 to clear hole.

terminals of the coil form into the proper holes in the board. Solder the terminals to their respective printed conductors, using just enough solder to make a good secure connection. Then proceed to install the remaining components shown in Fig. 4.



Although battery drain is small, it's a good idea to shut off the power when the "Ferret" is not in use. You should be able to build it in four hours.

HOW IT WORKS

In the *Ferret*, FET *Q1* operates in the common-source mode, and is biased by resistor *R1*, bypassed for r.f. by capacitor *C3*. Unlike the conventional bipolar transistor, the gate input impedance of *Q1* is substantially higher than a megohm, permitting tuned circuit *L2-C2* to be connected directly to the gate. Variable capacitor *C2* resonates *L2* at any frequency between 7 and 30 MHz.

Primary winding *L1* and capacitor *C1* each provide a path through which signal currents in the antenna may be introduced into tuned circuit *L2-C2*; capacitor *C1* provides a moderately high impedance path, while *L1* offers a fairly low impedance, inductively-coupled path into the tuned circuit. An amplified version of the signal appears across the 55- μ H r.f. choke (*L3*), which is self-resonant at a frequency below 7 MHz. Capacitor *C5* decouples the d.c. applied to the drain of *Q1* and supplies a return path for r.f. current, preventing feedback through the common impedance of series-connected batteries *B1* and *B2*.

The amplified r.f. output of *Q1* is coupled to the base of *Q2* through *C4*, which has no appreciable reactance at the signal frequency. Transistor *Q2* operates in the common-emitter mode to contribute best gain. Emitter current limiting is provided by *R4*, bypassed for r.f. by *C6*. The operating point of *Q2* is established by base-bias divider resistors *R2* and *R3*, with collector current maintained at 1.5 mA.

The output of *Q2* appears across *R5*. Capacitor *C7* couples the amplified signal to output terminal strip *TS2* through a short length of coaxial cable to prevent unwanted coupling between output and input circuits. The short-wave receiver's input circuitry provides the tuned circuit load for the *Ferret*. And resistor *R6* (nominally 300 ohms) shunts the output terminals of the preselector, providing a mutual terminating impedance for the preselector and receiver.

When the resistors and capacitors have been installed (except for *R6*), check the parts layout and schematic to make sure that none were missed or installed in the wrong position. If everything checks, install transistors *Q1* and *Q2*.

Then cut two 6-inch lengths of RG-58/U coaxial cable and one 6-inch length of 300-ohm twin lead. Strip both ends of all cables. Connect one of the lengths of coax to the board points provided near output capacitor *C7*. (The inner

conductor goes to *C7* and the outer conductor is connected to the board ground pattern.)

Finally, attach the length of 300-ohm twin lead to the board points provided adjacent to coil assembly *L1-L2*, and solder a 4-inch length of hookup wire to the *B+* point. The board is now complete, but should be given a final check for solder splashes before being installed in the box.

Finishing Touches. Insert four 4-40 screws (at least $\frac{3}{4}$ -inch in length) through the holes in the bottom of the box. Slip four $\frac{1}{2}$ -inch spacers over the screws. Then slip the assembled PC board into the box, guiding the shaft of variable capacitor *C2* through the hole in the front panel. Ease the board down until the screws pass through the board mounting holes and the board rests on the four spacers. Secure the board in this position by tightening four 4-40 nuts on the four mounting screws.

Next, attach the cables from the printed circuit board to the input and output terminal strips (*TS1* and *TS2*).

As the final wiring step, connect the length of hookup wire from the *B+* point of the board to the (+) terminal of the dual battery holder. Apply decals to the front panel to give your *Ferret* a more finished appearance. It is also a good idea to install four rubber feet on the bottom of the box since, sooner or later, the *Ferret* will wind up sitting atop your short-wave receiver.

Alignment. Connect a length of RG-58/U coaxial cable to the output terminal strip (*TS2*) of the *Ferret*. The inner conductor attaches to the *H1* terminal and the outer conductor (shield) attaches to the *LO* terminal. Attach the other end of the cable to the input terminals of your receiver.

Using Fig. 5 as a guide, attach your antenna to the input terminals of the *Ferret*. Install batteries *B1* and *B2* in the dual battery holder, observing proper polarity. Then turn on your short-wave receiver and allow it to warm up for a few minutes.

Tune your receiver to exactly 7 MHz and set toggle switch *S1* on the *Ferret* to the "ON" position. Rotate the tuning control of the *Ferret* to fully mesh the

plates of tuning capacitor *C2*. At this point, you should hear a slight increase in noise in your receiver, or an increase in level if you happen to be tuned to a signal. Using an insulated hex alignment tool, adjust the core of coil assembly *L1-L2* until peak output is obtained at 7 MHz.

Next, tune your receiver to 30 MHz and rotate the tuning knob of the *Ferret* to fully open the plates of tuning capacitor *C2*. Using an insulated screwdriver, adjust the trimmer capacitor on the side of *C2* until the noise or signal output of the receiver peaks up. Then tune down from 30 MHz in 2-mHz steps, peaking the *Ferret* tuning knob to maximum receiver output at each step. You should notice a substantial improvement in the performance and sensitivity of your receiver.

In some instances, the *Ferret* may perform erratically due to lack of impedance matching between the output of the *Ferret* and the input of your receiver. To cure this problem, solder a 300-ohm resistor (*R6*) across the terminals of *TS2*. This resistor will present a common impedance to the two circuits.

Another cure for instability is to try a really short lead between the case ground of the *Ferret* and the chassis of your receiver. This would be in addition to the grounding provided by the shield braid of the coax cable.

On The Air. A few minutes of use will teach you all there is to know about operating the *Ferret*. With the tuning knob peaked to a specific frequency, you will be able to tune about 300 kHz up or down the band without changing its setting. This latitude should prove ample under most conditions, since it will permit you to tune through just about any short-wave broadcast band, ham band, or the Citizens Band without undue knob twisting.

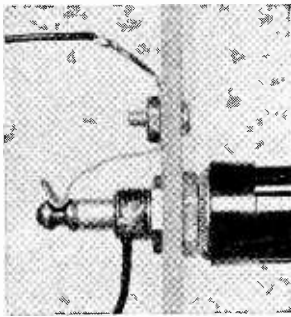
The antenna you choose will depend upon the portion of the 7-to-30 MHz spectrum you're interested in. A random length of wire will give fairly good performance throughout the tuning range of the *Ferret*. However, you can multiply the extra punch delivered by the *Ferret* by using a dipole, vertical, quad, or beam cut to the frequencies you want to tune in.

-30-

THE BEST OF TIPS & TECHNIQUES

MAKE-IT-YOURSELF PHONE JACK FROM SCRAP PARTS

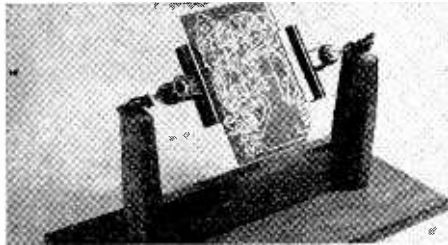
For those who like to home-brew everything for a project, here's a simple and reliable phone jack that can be added to the list. It's made from a short length of threaded iron or brass pipe, a pair of hex nuts, and a length of springy brass. The actual length of the threaded pipe depends on the thickness of the panel on which the jack is to be mounted; the thicker the panel, the longer the pipe (about $\frac{3}{4}$ " long for a $\frac{1}{4}$ "-thick panel). After the pipe is cut, secure it



to the panel with the hex nuts as shown in the photo. Solder hookup wire directly to the pipe, or to a solder lug placed under the hex nut. Now bend a $\frac{3}{8}$ " wide by 2"-long (approx.) piece of springy brass strip as shown, and drill a hole in it for mounting on the panel. Then solder another piece of wire to the brass strip. If you mount the newly made jack on a metal panel, be sure to insulate the brass strip from the chassis by using one extruded and one flat fiber washer. —Art Trauffer

PAPER-CLIP JIG HOLDS PRINTED CIRCUIT BOARD

Two large paper clips mounted on a suitable bracket can be used to support a printed circuit board and small components. Both sides of the printed circuit board are accessible for work at the flip of the clips. There's less chance of damaging the components and you can place a work light behind the board to help you trace out a circuit. The jig shown in

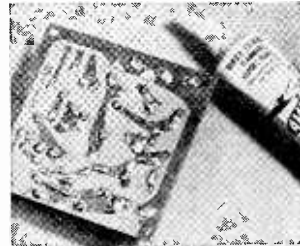


the photo can be duplicated for about \$2.00. The upright supports can be either wood or metal and, with a little ingenuity, can be

made to adjust the height of the work. Slip wide rubber bands over the jaws of the clips to cushion the board. Here, each clip is bolted to an eye bolt which is held in place with a small compression spring. However, almost any other mechanically secure arrangement can be used. —David A. Reid

MODEL AIRPLANE CEMENT REDUCES CORROSION AND SHOCK HAZARD

For use in space, military and industrial electronics, printed circuit boards are often encapsulated in a tough epoxy plastic to protect them from moisture, dirt, grease, etc. While your printed circuit boards are not likely to be subjected to space, marine and corrosive atmospheres, they are susceptible to moisture and dirt and can be a potential shock hazard. After all components have been installed and all soldered



connections checked, you can protect your boards against damage and yourself against shock by coating the boards with a film of clear plastic model airplane cement. Apply a coat to one side of the board, let it set, then repeat the process for the other side of the board. Two or more coats may be necessary for boards used in high-voltage circuits. —Michael Evangelist

USE PERMANENT MARKER PEN TO LAY OUT ETCH PATTERN

The most time-consuming part of building a project that incorporates a printed circuit board is the laying down of the resist pattern. You've probably struggled along with messy liquid resist or resist tape, strips, and dots. An easier way to lay out the etch pattern is to use a felt- or nylon-tipped permanent marker. (The ink in such markers has the properties of regular etch resist solutions.) The marked tips can be shaped with a knife for the desired foil pattern width. Draw the resist pattern directly on the foil side of the board, making large dots where holes are to be drilled. Two or more coats of ink are generally needed for good resistance to the etching solution. To etch the board, immerse it in a concentrated solution of hot ferric chloride (without additives). —Bert Thiel

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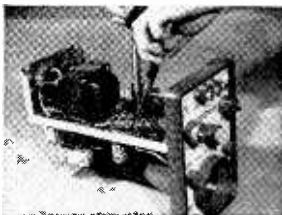
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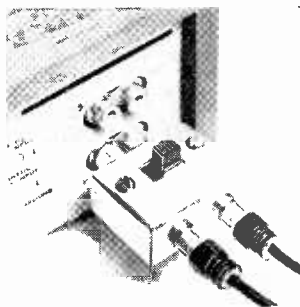


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CANCEL MONO NOISE ON STEREO RECORDS

Rumble and record surface noise are common problems when mono records are played on a stereo record player. You can reduce or even



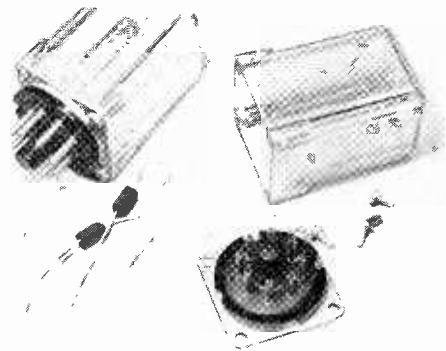
eliminate this noise if the two "signal" conductors from the phono pickup are shorted together. This can be quickly accomplished with a simple switching arrangement at the amplifier input. Mount a miniature

s.p.s.t. slide switch in a small metal case. Then mount two phono jacks on one side of the case and two phono plugs on the other side, using the case as a common ground for the four parts. Wire the jacks, plugs and switch so that in one position the switch is open and provides normal stereo channel separation and in the other position both channels are combined. Plug the switch box into the inputs of your amplifier and the phono pickup cables into the switch box as shown in the photo. When playing mono records, just switch to the "combine" position.

—Art Trauffer

PLUG-IN DUST COVER MAKES MODIFICATIONS SAFE AND EASY

When updating a power supply from tubes to silicon rectifiers, you can use a plug-in relay dust cover (similar to the Potter and Brumfield 35D070) to house the parts and protect

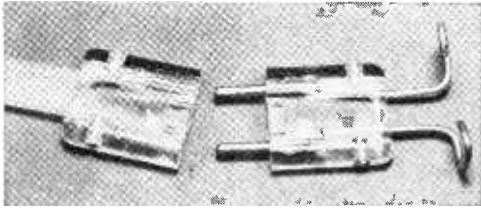


against high voltage hazards. After removing the plastic case from the octal base as shown in the photo, solder the silicon rectifiers to the correct base pins. Then drill a few small holes in the plastic cover to allow for heat dissipation when the rectifiers are in operation, and replace the cover. This same type of dust cover can be used for housing small projects and other circuit modifications not associated with power supplies.

—Fred H. Horan

**CABLE CONNECTORS
SAVE TIME AND EFFORT**

Still fumbling with a screwdriver to disconnect the antennas from your TV set and FM and short-wave receivers whenever the sets have to be moved? If so, you can save a lot of time and effort with a couple of twin-line antenna cable connectors. These Mosley 301 and 311 connectors can be fitted between the set's antenna input terminals and the 300-ohm twin-line cable in short order. Connect

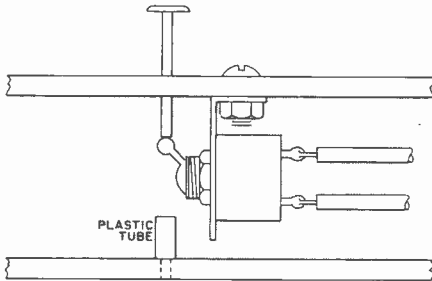


the lead-in cable to the female connector as needed. Then fit a pair of heavy bare wires into the male connector and bend the wires as shown in the photo. Finally, mount the male connector—via the bent wires—to the antenna input terminals on your set, and snap the two sections of the connector together. When you have to remove the antenna for any reason, simply reach behind the set and unplug it—total time, about 2 seconds.

—Steven Koons

**HIDDEN SWITCH PREVENTS
UNAUTHORIZED USE OF ELECTRONIC DEVICES**

If you are bothered by unauthorized people turning on your equipment, here is a way to hide the power switch so that it cannot be readily switched on. As shown in the drawing, mount the switch inside the device you want



it to control the power to, and position the toggle (or slide) between two holes, one in the chassis cover and one in the chassis. A piece of plastic rod protrudes through the cover hole and rests on the toggle. To turn on the switch, insert another plastic rod through the hole in the chassis and the plastic tube and press until the switch clicks on; then remove this rod. The switch is easily turned off by depressing the permanently mounted plastic rod on the chassis cover. Because this rod only touches the switch toggle, it cannot be used to reactivate the switch.—Richard Rylander

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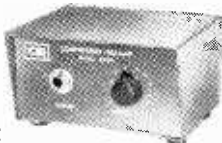
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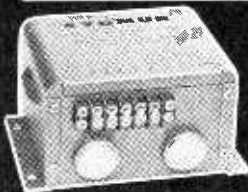


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STRIPPED SCREW HOLES CAN BE BEEFED UP BY "STAKING"

Because of the stripping action of overtightened self-tapping screws, getting them to hold firmly in soft aluminum after they have been removed and replaced a few times can become a problem. You can use a larger screw, but this would necessitate using an even larger screw subsequently. However, there is a simple solution to the problem—at least temporarily.

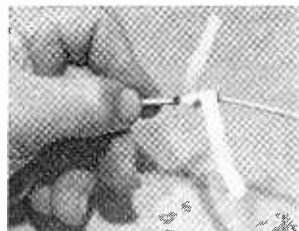


"Stake" the edges of the screw hole with a broad-bladed screwdriver or small dull chisel. All it takes is a few light taps with a hammer.

—Henry R. Rosenblatt

OLD TRICK KEEPS TAPE FROM UNWINDING

Here's how to make electrical tape stick to small round surfaces without unwinding: cut



off a short length from the roll and wrap two turns tightly around the area being covered. Tear the piece that remains lengthwise down the middle and inter-

lace the split ends until the surface is covered. Bet the tape won't slip while you are putting it on or ever afterwards.—Glen F. Stillwell

PLUG-IN LOOP ADAPTER FOR CLAMP-ON AMMETERS

Here's an easy way to wrap a clamp-on ammeter around one side of the a.c. power line without breaking into the line, and without disconnecting the unit under test. Secure a plastic light flasher (such as the "Snapit" by Cable Electric Products, Inc.) and carefully drill out the center retaining rivet. Break away the wire-wound flasher element,

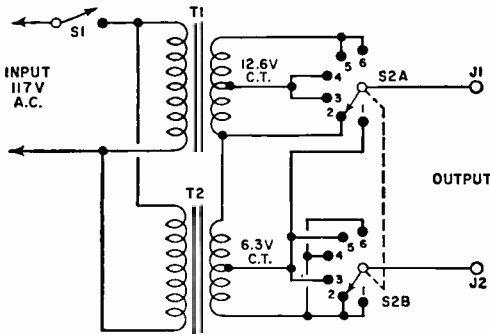


and connect a 1½"-diameter loop of 14 AWG stranded wire in place of it. Cut a notch in one of the walls of the case to clear the loop of wire. Use a 4-40 nut and bolt in place of the rivet.

—Vincent F. Allen

**SELECT—DON'T SETTLE—
FROM TWO FILAMENT TRANSFORMERS**

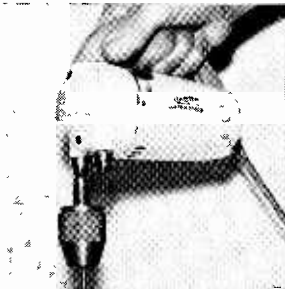
No experimenter's workbench is complete without a low-voltage a.c. power supply, but it's not necessary that the supply be continuously variable from 0 to its top voltage. A few of the most commonly used low voltages will usually be enough. With two low-cost filament transformers and a simple switching arrangement as shown in the schematic, you can obtain 3, 6, 9, 12, 15, and 18 volts (positions 1 through 6 of S2, respectively). Build the circuit in any convenient size case. Then plug it into a 117-volt a.c. source, turn the power on, set S2 to position 6, and measure the voltage from J1 to J2. If the meter reading is approximately 6 volts (it should be about 18 volts),



T1 and T2 are improperly phased. For correct phasing, simply reverse the primary connections of only one of the transformers. When d.c. voltages are required, the output at J1 and J2 can be connected to a rectifier and d.c. filter network.
—Frank H. Tooker

**ELECTRIC FOOD MIXER
DOUBLES AS LIGHT-DUTY DRILL**

If you have an old electric food mixer that still has a usable motor, don't sell it to a junk dealer. It can be converted into an electric drill for light-duty work. In most cases it is necessary only to insert an adapter chuck into one of the mixer sockets and tighten a setscrew. However, some mixers do not have setscrews; so you'll have to exercise a little ingenuity in such a case. An adapter chuck that allows larger drills to be used with 1/4" drills is the most convenient and inexpensive type. Many hardware stores sell imported chucks for about 98 cents. The mixer-cum-drill can then be used to drill holes in metal chassis or woodwork. You can also take advantage of the variable speeds available on this type of mixer.
—Art Trauffer



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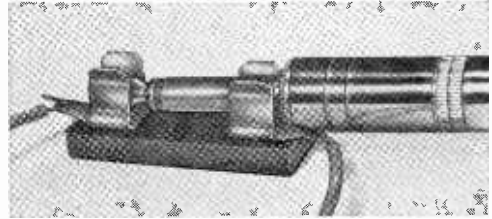
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FUSE HOLDER
DOUBLES AS PHONE JACK

A snap-in type fuse holder can come in handy when you need a phone jack in a hurry and can't find one in your spare parts box. These fuse holders will accommodate almost any conventional 1/4"-diameter phone plug, as shown in the photo. All you need do is solder a pair of wires or shielded audio cable



to the lugs on the holder and clip in the phono plug. Then connect the wires or cable from the fuse holder into the circuit where it is to be used. If necessary, bolt the fuse holder to your workbench or to the case of the device.

—Dave Edlund

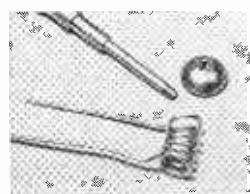
USE TWO ISOLATION TRANSFORMERS
TO ELIMINATE SHOCK HAZARD

One isolation transformer eliminates much of the shock hazard so far as the electrical chassis ground in a given electrical device is concerned. But if two transformerless devices are plugged into the same outlet, the chassis of one can be 117 volts "hot" with respect to the other. This is true whether or not an isolation transformer is connected between the devices and the outlet. To completely eliminate electrical shock hazards between two transformerless devices that are plugged into the same outlet, each device should be powered by its own isolation transformer.

—Frank H. Tooker

TELESCOPING ANTENNA
DOUBLES AS MULTIPLE COIL FORM

The next time you have to wind a coil and need a coil form, try using one of the sections of a telescoping antenna. Most telescoping antennas are made up of three or more concentrically fitted parts, or sections, each of which provides a different diameter. Select the section that has the most suitable diameter for the coil, and begin winding.

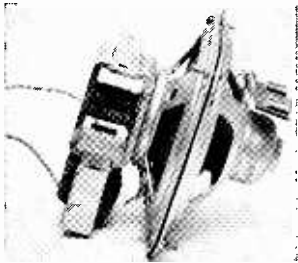


When the job is done, unscrew the plastic or metal cap from the antenna end as shown in the photo, remove the coil, and replace the cap on the antenna. Almost any type of TV "rabbit ears," short-wave receiver, walkie-talkie, etc., antenna can be used in this manner.

—David N. Bascom

BOLT SPEAKERS TOGETHER TO PREVENT CONE DAMAGE

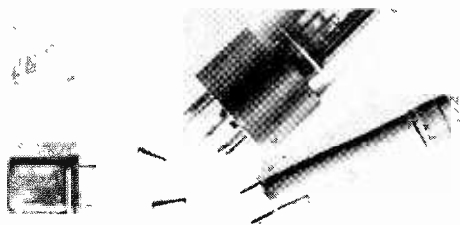
Loudspeakers are perhaps the most fragile and easily damaged "spare parts" to store. A punctured or torn cone can mean the total loss of a speaker. You could box each speaker individually, but this might present a space problem. Two same-size speakers can be bolted together as shown in the photo to protect the cones from damage. Take care not to overtighten the bolts, or you might bend the speaker baskets out of shape.



—James E. Arconati

SALVAGED TUBE PINS ADAPT CRYSTALS AND COILS TO TUBE SOCKETS

A substitute part can present a problem if it has small wire-type connector pins and the



socket into which it is supposed to be plugged is designed to accept larger pins. Instead of changing the socket, simply modify the terminals on the part. The pins on an old octal tube will usually do the trick. After carefully breaking away the tube's Bakelite base, cut the connecting wire flush with the tops of the pins. Then slip the pins onto the component's terminals and solder them in place if necessary. This simple modification will work for coils, plug-in relays, crystals, and most other types of components.

—James S. Green

FUSE BOTH SIDES OF THE A.C. POWER LINE

Even if the manufacturer of an electronic device that employs a transformerless power supply does not specify it, there should be a fuse in both sides of the incoming a.c. line. A careful check of a one-fuse circuit will show that if the power line is plugged into an a.c. outlet so that the fuse is in the ground side of the line, a short circuit between the "hot" side and ground will simply bypass the fuse. This can result in extensive damage to the electronic device. The only way to effectively avoid such a situation is to put a fuse in both sides of the line.—B. W. Blachford

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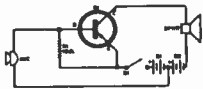
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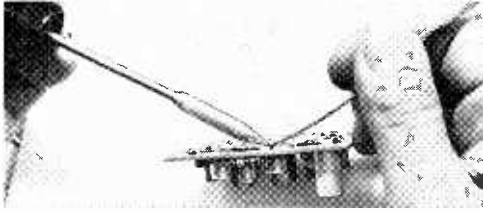
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CABLE SHIELD SPEEDS AND SIMPLIFIES DESOLDERING

If you've ever soldered shielded cable into a circuit, you are aware of the fact that the shield absorbs quite a bit of solder before the job is done. This ability of the shield to soak up solder comes in handy when you're desoldering components from a printed circuit board, solder lugs, etc. When placed over the



connection to be desoldered and heated with a soldering iron or gun, the shield will usually soak up all but a thin film of the solder. The residue of solder left on the connection will not hamper easy removal of the component.

—Donald E. Hammack

SIMPLE JIG IMPROVES APPEARANCE OF PROJECTS

When wiring several small parts to closely spaced terminals, you can give your project a neat, factory-wired appearance by bending component leads to a uniform shape. A simple jig, consisting of a block of wood and a few headless nails, is all you need.

Before driving the nails into the block of wood, bend the leads of a small component to the desired shape, then set the component on the block of wood, and drive the nails in at the bends as shown in the photo. For different size components, you may need several of these easy-to-make jigs. With the aid of a jig, you can speed assembly time, eliminate "kinked" and broken component leads, and reduce the possibility of unwanted short circuits.

—Frank H. Tooker

MAKE YOUR OWN MINIATURE MERCURY SWITCH

If you have an old thermometer and a miniature NE-2 neon lamp, you have the makings of a mercury switch for compact projects. The glass tip of the lamp must first be carefully ground down until you have about a

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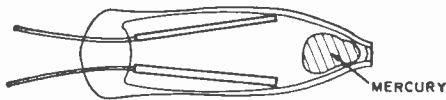
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1/32" diameter hole in the envelope. Insert a sewing needle through this hole and bend the electrodes as far apart as possible (see drawing). Break the thermometer in half, and heat the bulb end to extract a 1/10" to 1/8" bead of mercury. Use a medicine dropper to force the bead of mercury through the hole in the lamp's envelope. Now check the make-and-break action of your home-made mercury switch using a continuity checker; inter-



mittent "make" action means that more mercury must be added, and improper "break" action indicates that some of the mercury must be removed. Finally, seal the hole in the lamp's envelope with plastic cement.

—Frederic W. Chesson

COLOR-CODING SAVES TIME WHEN YOU'RE LOOKING FOR A SPECIFIC TOOL

Nutdrivers and screwdrivers often have similar sizes and shapes; so locating the correct tool for a given piece of hardware can be time-consuming. However, a simple color-code system, similar to that found on some nutdriver sets, will speed things up. All you need are several different colors of enamel paint. Select the tools that have been giving you trouble, dip their handles into different color paints, remove and let dry. Two or more color bands can be used to identify special features; one to identify the type of tool, another to identify its size, and a third to tell whether or not the tool is magnetized. Each successive band of color is produced by dipping the tool handle into the paints and varying the depths by about 1/4". If three bands are desired, the first band would extend about 1" from the end of the handle, the second about 3/4", and the third about 1/2" from the end.



—Jerome B. Koons

FLASHLIGHT CELLS PROTECTED AND DATED

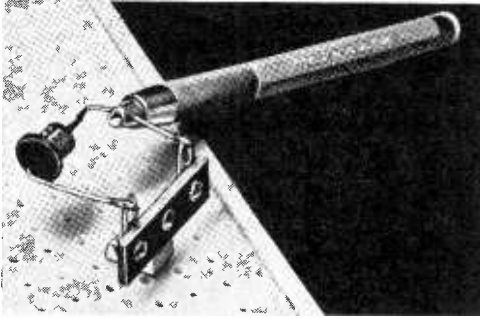
When flashlight cells are to be stored away for future use, or when they are taken along on camping or fishing trips, they will be protected from water or moisture and quick deterioration if they are kept in readily available plastic pill containers. Some pill containers come with adjustable reminder dials. These can be used to note the time of the year you bought the cells. For example, if you bought the cells in the middle of Septem-

ELECTRONIC EXPERIMENTER'S HANDBOOK

ber, you could set the pointer halfway between 9 and 10.
—Art Trauffer

MECHANICAL DRAFTING PENCIL LEND A THIRD HAND

A mechanical drafting pencil can be as useful a "tool" in electronics as it is on a drafting table. It will serve as a heat sink, a vise for small parts, or as a grasping tool for picking



up things. To use the "pencil," simply depress the plunger at the top, and when the gripper jaws extend, clamp them over the part to be heat-sunked or picked up. Then release the plunger. After the work is done, depress the plunger again to release the jaws. You'll find that this "tool" is a real time-saver when you're working on circuits that look like they

should be handled with jeweler's tools and under a magnifying glass.
—Mike Rocha

COLOR INDICATOR LAMPS AND LENSES WITH MODELER'S PAINT

In projects where several different color indicator lamps are used to indicate the unit's various functions or modes of operation, the glass envelopes of the bulbs can be colored to save time and money. A metal flake type of paint, used for painting model cars, is available in several colors (each costing about 15 cents) and makes an ideal coloring agent. Before you use the paint, however, let it stand undisturbed for a day or two to allow the metal flakes to settle to the bottom. Then all you need do is dip the envelope of the bulb into the upper layer of clear lacquer, being careful not to disturb the metal flakes. Let the first coat dry, and dip the bulb into the lacquer again. Two coats will suffice in most cases. If you prefer, you can paint the inside of clear lenses to obtain the same effect.
—Frank G. Palesh III



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POLICE RECEIVER

(Continued from page 130)

On-the-air "touch-up" of the receiver's alignment requires patience and a steady hand. The adjustment calls for a slight de-tuning of the blue core of the ratio detector transformer to narrow the response for improved NBFM detection. To complete the "touch-up," tune across the band until you hear a Public Service station of medium signal strength. While the station is transmitting, adjust the blue core of transformer *T3* a fraction of a turn in each direction from null, "rocking" the tuning capacitor slightly across the signal frequency. Leave the blue core set at the position which yields maximum audio output.

Antennas. If you live in a fairly well-populated city or town, chances are the whip antenna will be all you'll need for good local reception (up to 10 miles) of VHF Public Service stations. However, if you're out in the country, you may need an outdoor antenna to boost reception. A roof-mounted TV antenna will give excellent results, expanding the pickup range by a fair margin. -30-

TECHNICIAN SHORTAGE

(Continued from page 78)

the psychological tests given by a few companies valid or do they work against experienced personnel? Just how important is fluent English, especially in bilingual areas of the country?

Judicious relaxation of some of these regulations and prejudices could put a large number of technicians to work at all levels, not only ameliorating the technician shortage but reducing the relief rolls. In addition, company policies leading to upgrading of technical personnel would lessen the shortage at the upper levels, where it is reported to be most acute. A few manufacturers subsidize further study and profit by it in many instances. Company training programs also help in many cases.

There is, however, one "stinker" in the whole situation. Many of those who can become good technicians do so, but also have the ability to become good engineers, and do that too. The net result is that the economy has gained an engineer but lost a competent technician! —50—

LOW VOLTAGE SUPPLY

(Continued from page 116)

change in the output voltage. In the latter respect, it does its job so well that it even opposes, for the moment, changes in the output voltage produced by alterations in the setting of R_4 . If the response to changes in the setting of the output control is found to be too slow for the majority of your applications, the value of capacitor C_2 may be reduced to as low as 25- μ F without serious deterioration in the performance of the supply.

Turn R_4 back to its maximum counter-clockwise position and set S_1 at its 20V position. The meter needle should deflect upscale to about 4 (indicating about 8 volts output with multiplier resistor R_7 now in the circuit). The tolerance of D_1 's zener potential will produce some variation in this reading from one unit to another, but this is of no consequence. Rotate R_4 to its maximum clockwise position, and advance R_6 slowly until the meter reads exactly full scale (20 volts output).

With S_1 at either 10V or 20V, and R_4 set for maximum output, allow the instrument to idle for about half an hour or so—then check full-scale output on both ranges. Some slight readjustment of R_5 and R_6 may be needed as a result of the forming of C_2 . —50—

SPEED CONTROLLER

(Continued from page 16)

the circuit touches the metal case. A metal case is used so that Q_3 will have a built-in heat sink. Use a mica insulator and insulated mounting hardware to secure Q_3 in position. If desired, a light

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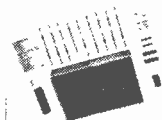
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EXPERIMENTAL REED SWITCH KIT



Many hobbyists like to experiment with a new electronic device before they proceed to design a circuit in which it might be used. The Wabash "Engineering Design Kit" (No. 67-001) was assembled for those who want to practice using dry reed switches without spending a lot of money in the process.

The kit contains fifteen dry reed switches, three solenoids—one of which is a logic coil, four permanent magnets, and a "how" and "why" instruction booklet. The switches come in two sizes and three sensitivities, to give you a well-rounded idea of the versatility of reed switch-type relays and proximity switching devices.

With this kit, you can test and evaluate proximity and position detectors, demonstrate sensitivity, latching relays, logic circuits, and matrix or crosspoint latches. The particular reed switches supplied are said to respond to a frequency of up to 2000 counts per second. That's about an average 0.5-millisecond open-close response time.

You can obtain your experimental reed switch kit by sending \$10 to New Product Engineering, Incorporated, Wabash Magnetics, 812 Manchester Ave., Wabash, Ind. 46992.

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coat of silicone transistor grease on both sides of the mica insulator will assist in dissipating any heat developed. The speed-control potentiometer can be mounted as desired, making sure that its metal cover does not touch the circuit at any point. Use a rubber grommet to pass the insulated positive and negative pow-

HOW IT WORKS

Transistors $Q1$ and $Q2$ form a free-running multivibrator with the "on" time of $Q2$ determined by the setting of potentiometer $R3$. Rotating this control to one extreme produces a short "on" time, while rotating to the other extreme produces a lengthy "on" time. Resistor $R2$ acts as a limit resistor to establish the maximum "on" to "off" time of $Q2$. The selected ratio of $R3$ to $R2$ limits the maximum "on" to about 90% of the multivibrator's time interval.

The d.c. voltage for the motor being controlled passes through switching power transistor $Q3$. The transistor specified for this circuit can handle about 10 amperes, but $R5$ is included to limit current to about 2.5 amperes. Since $Q3$ is operating in a switching mode, it is always saturated when "on" and therefore dissipates very little heat even with a multi-ampere load. Of course, when it is "off," it has no dissipation. Therefore, it always operates relatively cool and a large heat sink is not required.

In operation, $Q3$ is alternately switched "on" and "off" by the action of the multivibrator. This switching action permits full power to be applied to the motor in pulses, with the result that when the motor is slowed down, it does not lose any torque and develops full power even when rotating slowly. The power pulses are integrated by the mass of the motor-driven device so that a smooth flow of torque exists. As the power pulses are made wider, the motor receives more power and rotates faster. Conversely, as the pulses are made narrower (more "off" than "on" time of $Q3$), the motor slows down.

Diode $D1$ is used to prevent the back-e.m.f. generated by the rapidly rotating motor from damaging $Q3$. This diode also acts as a brake, because when power is removed from the motor, the diode absorbs the motor-generated voltage and this rapidly slows the motor to a stop. Diode $D2$ protects transistors $Q1$ and $Q2$ in the event that the d.c. voltage input is applied incorrectly.

er leads through the side of the metal case. Use a red-colored lead for the positive, and a black-colored lead for the negative.

Operation. As shown in the schematic, you must remove both the positive and negative leads from the motor being controlled and connect them to the controller with the polarity shown. Then connect the two motor leads to the terminals of $TS1$. Turn on the d.c. power, then control the speed of the motor by adjusting $R3$. This control can be calibrated in terms of speed for the particular motor being used.

-30-

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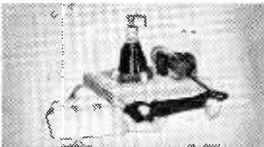


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READER SERVICE NO. ADVERTISER PAGE NO.

1	Allied Radio	103, 104
2	Burstein-Applebee Co	150
4	Caringella Electronics	142
3	Cleveland Institute of Electronics 157, 158, THIRD COVER	
6	Datak Corporation, The	144
7	Delta Products, Inc'	143
5	EICO Electronic Instrument Co., Inc FOURTH COVER	
8	Edmund Scientific Co	156
9	Electro-Voice, Inc	141
10	Heath Company	69, 70, 71
11	IMC Magnetics Corp	145
12	International Crystal Mfg. Co., Inc	6
13	Johnson Company, E.F.	10
14	Lafayette Radio Electronics	35, 36
15	McGee Radio Co	144
16	Meshna Jr., John	152
18	Multicore	SECOND COVER
	National Radio Institute	1, 2, 3
17	New Products Engineering, Incorporated	154
19	Olson Electronics Incorporated	152
20	Petersen Radio Co. Inc	151
21	Port Arthur College	150
22	RCA Electronic Components & Devices	8
	RCA Institutes, Inc	137, 138, 139
23	Radio Shack	4
24	Schober Organ Corp., The	149
25	Sydmer Electronic Specialties	142
26	United Audio Products, Inc	140
27	Xcelite, Inc	153
	CLASSIFIED ADVERTISING	155

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ELECTRONIC EXPERIMENTER'S HANDBOOK

More than 5 million two-way transmitters have skyrocketed the demand for service men and field, system, and R & D engineers. Topnotch licensed experts can earn \$12,000 a year or more. You can be your own boss, build your own company. And you don't need a college education to break in.

HOW WOULD YOU LIKE to earn \$5 to \$7 an hour...\$200 to \$300 a week ... \$10,000 to \$15,000 a year? One of your best chances today, especially if you don't have a college education, is in the field of two-way radio.

Two-way radio is booming. Today there are more than five million two-way transmitters for police cars, fire trucks, taxis, planes, etc. and Citizen's Band uses—and the number is growing at the rate of 80,000 new transmitters per month.

This wildfire boom presents a solid gold opportunity for trained two-way radio service experts. Most of them are earning \$5,000 to \$10,000 a year more than the average radio-TV repair man.

Why You'll Earn Top Pay

One reason is that the U.S. doesn't permit anyone to service two-way radio systems unless he is licensed by the FCC (Federal Communications Commission). And there aren't enough licensed experts to go around.

Another reason two-way radio men earn so much more than radio-TV service men is that they are needed more often and more desperately. A two-way radio user *must* keep those transmitters operating at all times, and *must* have them checked at regular intervals by licensed personnel to meet FCC requirements.

This means that the available li-

censed expert can "write his own ticket" when it comes to earnings. Some work by the hour and usually charge at least \$5.00 per hour, \$7.50 on evenings and Sundays, plus travel expenses. Others charge each customer a monthly retainer fee, such as \$20 a month for a base station and \$7.50 for each mobile station. A survey showed that one man can easily maintain at least 15 base stations and 85 mobiles. This would add up to at least \$12,000 a year.

How to Get Started

How do you break into the ranks of the big-money earners in two-way radio? This is probably the best way:

1. Without quitting your present job, learn enough about electronics fundamentals to pass the Government FCC License. Then get a job in a two-way radio service shop and "learn the ropes" of the business.

2. As soon as you've earned a reputation as an expert, there are several ways you can go. You can move out, and start signing up your own customers. You might become a franchised service representative of a big manufacturer and then start getting into two-way radio sales, where one sales contract might net you \$5,000. Or you may be invited to move up into a high-prestige salaried job with one of the same manufacturers.

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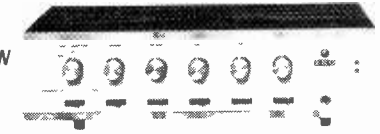
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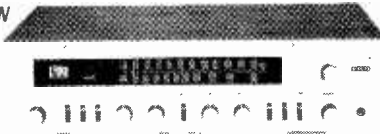
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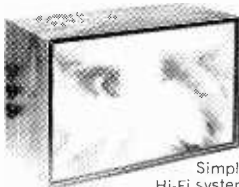
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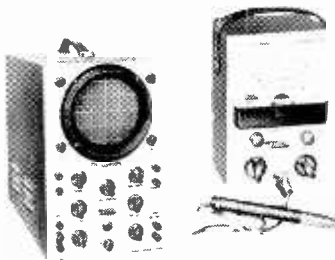
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