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(see page 72)
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ELECTRONIC EXPERIMENTER'S HANDBOOK
REVERB FOR YOUR CAR—ULTRASONIC OMNI-ALARM—TIME-SIGNAL-ONLY RECEIVER—UPDATE TO SOLID STATE—STATIC-FREE THERMISTORIZED AQUARIUM HEATER—DWELL METER ADAPTER—SOLID-STATE TACHOMETER FOR CD OR TRANSISTOR IGNITION SYSTEMS—HANDFUL OF POWER—TRANSISTORIZED AUTO-LIGHT MINDER—$2 INTRUSION ALARM

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MUSSETTE COLOR ORGAN—STEREO HEADPHONE CONTROL UNIT—PUT AN AIR BRAKE ON YOUR WOOFER—TAPE RECORDER ECHO CHAMBER—LONG-TAILED PHASE INVERTER—SOLID-STATE STEREO RECORD PLAYER—INTERSTATION HISS SUPPRESSOR FOR FM TUNERS

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LISTEN IN ON THE SUN—THE MODBOX—SURE-SHOT Q5’ER HOOKUP—POWERHOUSE 2-TUBE SHORT-WAVE RECEIVER—BC-454 GOES MARITIME

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PULSE GENERATOR—SOLID-STATE SCOPE CALIBRATOR—COMBINATION RC SUBSTITUTION BOX—INTEGRATED CIRCUIT AMPLIFIER—ETERNAL VTVM “C” CELL

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CROWD STOPPER—MEET THE MINI-ORGAN—ELECTRIC DOZEN GAME—SUPERCHARGED SALT SHAKER—LI’L ATLAS DEFIES GRAVITY—THE TICKLE STICK—REFLEXOMETER

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CHAPTER

To provide a desirable “mix” of projects for this chapter of the ELECTRONIC EXPERIMENTER’S HANDBOOK, your editors screened 70 eligible articles and settled on the 10 projects listed below. All of these projects have been carefully double-checked by the individual authors and the editorial staff. You can build any one of them with complete assurance that if you follow the instructions the project will work “first time out.”

Due to the continued interest in automotive electronics, four of the articles in this chapter pertain to improving the operation of your car, or increasing your driving enjoyment on long trips. The reverberation article (page 8) is a very desirable construction project—one that has been satisfactorily duplicated by hundreds of electronics hobbyists. The “Auto-Light Minder” (page 41) is another favorite and needs to work only once to repay its construction cost.

Two different theft alarm systems are described—one essentially for home or travel (page 44) and one for business or office (page 13). The time-signal receiver (page 19) is a project that was developed for POPULAR ELECTRONICS and is now in use in many laboratories and offices, as well as ham shacks and workshops.

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13 ULTRASONIC OMNI-ALARM ...................................................... Daniel Meyer
19 TIME-SIGNAL-ONLY RECEIVER ................................................. Charles Caringella, W6NJV
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44 $2 INTRUSION ALARM ............................................................... R. L. Winklepleck
Reverb for your car
Concert hall on wheels

HAVE you ever noticed the difference between the sound of music indoors and the sound of music out in the open air? This difference is due to the presence and absence, respectively, of reverberation. In an enclosed space, we hear the direct sounds from the performing instruments, and the sounds that are reflected from the walls, ceiling, floor, furniture, and other surfaces.

These reflected sounds reach our ears later and slightly weaker than the direct sound because they have traveled a greater distance. The larger the room, the greater the reverb time, and the greater the decay. If the direct sound is loud enough, it will usually cause more than one reflection... each subsequent reflection arriving with greater delay and greater decay.

Reverberation time, as small as it might be, is quite critical. If it is too long, there is a severe echo effect, and if it is too short, the music will sound flat and lifeless, as it would normally sound in a very small room. So important is this reverb time that some concert halls have added electronic reverberation to optimize the natural reverberation characteristics of the auditorium.

For less than $20 plus a little time, you can assemble the reverberation set-
up to be described here for your car radio or your hi-fi set at home. With it, you will be able to electronically enlarge your listening area to concert-hall proportions.

**How It Works.** A patented Hammond organ reverberation unit, an electromechanical device, is used to delay and decay a portion of the sound. A transducer at one end of the reverberation unit acts like a speaker. It picks up the audio signal from the output transformer in a car radio, converts this electrical energy into mechanical energy, and "excites" a couple of sets of springs which are attached to it. (See Fig. 1.)

The signal, now in mechanical form, travels along the springs and energizes an output transducer attached to the other end of the springs. The output transducer acts like a microphone and reconverts the mechanical energy back into electrical energy. It takes approximately 25 milliseconds for the sound to travel down the springs, but not all of the signal gets past the output transducer the first time. Some of the signal "bounces" back and forth from transducer to transducer, through the springs, one or more times. (This feature is purposely designed into the springs to simulate multiple reflections in a room.) The delay line has approximately 40 to 50 db insertion loss and so the reverb signal must be amplified to bring its output signal level back up to the original input level.

Almost any audio amplifier could be used to beef up the output of the reverberation unit and feed the signal to the rear-seat speaker in a car, or to a second speaker in the home. But you can build the amplifier shown here and mount it and the reverb unit in a 5" x 9½" x 2" case.

In the transformerless amplifier in Fig. 2, the signal from the reverberation unit is applied between the base of Q1 and the sliding contact on potentiometer R4, which acts as a stabilizing emitter resistor and level control. This unby-passed resistance introduces degenerative feedback to reduce distortion. Distortion is less than 1% at 3 watts output.

The amplified signal from the collector of Q1 is capacitively coupled to the base of Q2. Transistor Q2 amplifies the signal and feeds it to the complementary driver transistors (Q3 and Q4). Transistor Q3 conducts on positive half cycles, and Q4 conducts on negative half cycles, and drives output transistors Q5 and Q6 in a push-pull manner. The voltage drop across D1 and D2 forward-biases the driver transistors slightly to prevent

---

**Fig. 1.** Audio delay line simulates delay and decay characteristics of a large concert hall, in your home or car. Amplifier boosts sound just enough to compensate for insertion loss of the delay line.
Fig. 2. Signal from the delay line is applied to points A and B, then amplified and fed out to a speaker connected to C and D. Level control R4 is adjusted to obtain equal levels of direct and indirect signals. Amplifier distortion is less than 1% at 3 watts output. Class B operation accounts for high efficiency.

crossover distortion. The diodes also provide temperature compensation.

When reverb is desired, S1 switches in the second speaker and the fader control (R18) controls the percentage or mix of direct and "reflected" sound. When S1 is in the normal position, the fader control feeds more or less direct signal to either speaker as desired.

Silicon transistors in all but the output stages make the amplifier temperature-stable. The specified output transistors should be used if at all possible; they are inexpensive and have superior leakage and frequency response characteristics.

Fig. 3. Non-conductive paint is used on component side of printed circuit board to show location of parts.
PARTS LIST

C1, C3—10-µf., 15-volt electrolytic capacitor
C2, C4—5-µf., 15-volt electrolytic capacitor
C5—200-µf., 6-volt electrolytic capacitor
C6—500-µf., 25-volt electrolytic capacitor
C7—100-µf., 15-volt electrolytic capacitor
C8—1000-µf., 25-volt electrolytic capacitor
D1, D3—1N456 silicon diode
D2—1N1692 diode
Q1, Q2, Q4—2N3638 transistor
Q3—2N3706 transistor
Q5, Q6—2N3611 transistor
R1, R3, R7, R10—4700-ohm, 1/4-watt resistor
R2, R6—22,000-ohm, 1/4-watt resistor
R4—1000-ohm printed circuit board type trimmer resistor
R5, R11, R12, R13—1000-ohm, 1/4-watt resistor
R8—25,000-ohm, printed circuit board type trimmer resistor
R9—100-ohm, 1/4-watt resistor
R14, R15—1/2-ohm, 1/2-watt resistor—see text
R16—33,000-ohm, 1/2-watt resistor
R17—220-ohm resistor
R18—20-ohm potentiometer
R19—10-ohm, 1/2-watt resistor
R20—10-ohm, 1/2-watt resistor
S1—D.p.d.t. switch
T1—Low-voltage rectifier transformer; 117-volt primary, 20-volt secondary with CT (Allied 64 U 713, or equivalent)
T2—Reverberation unit; 8 ohms input, 2000 ohms output (Gibbs Type 5G)*
1—Printed circuit board, or other suitable wiring board
2—5" x 9 1/2" x 2" aluminum case (Bud AC-403 or equivalent)
Misc.—Terminal strip, 1/2" standoffs, nuts, bolts, wire, solder, etc.

*The following parts can be purchased from DEMCO, Box 16297, San Antonio, Texas 78216: reverberation unit, $7; epoxy fiberglass printed circuit board, $2.50; kit, including reverberation unit, printed circuit board and all components for amplifier, except case and external a.c. power supply, $15.00.

Fig. 4. Bottom view. Reverberation unit (audio delay line) is shock-mounted and hangs from four small springs when the chassis is top side up. Chassis can be mounted under dashboard near the driver.

Fig. 5. For use in the home, a 12-volt power source is needed. If it is not available from existing equipment, you can build this full-wave power supply.
Since the power amplifier operates class B, standby or low-level operation causes little power drain. Only at full output is the maximum 0.5 to 1.0 ampere of current required. For use in installations other than in cars, the a.c. supply shown in Fig. 3 can be used to power the amplifier. It is best to build the power supply in a separate case to avoid hum pickup.

**Construction.** To simplify matters, a printed circuit board is used for the amplifier, as shown in Fig. 6. It is shown actual size in case you decide to make your own.

Note the lead arrangement for Q3 (the 2N3706). If bent properly and installed as shown, the flat side of the case will face resistor R12. If you cannot locate any proper size 0.5-ohm resistors for R14 and R15, you can make them by winding 15 inches of #36 magnet wire on a resistor body and soldering the ends of the wire to the resistor leads; use at least a 1000-ohm resistor.

The delay line assembly must be shock-mounted to prevent car movements and road bumps from activating the springs. To do this, suspend the reverberation unit from the top of the case with four springs, one in each corner. Allow sufficient clearance between the unit and the case to prevent contact even when you hit the brakes hard.

To mount the springs, drill two small (#60) holes about 3/8" apart for each spring. Start from the inside of the chassis and thread the end of the spring through one of the holes, and then back through the other hole into the case. Do not shorten the leads from the reverberation unit; they must be long enough to allow free movement.

Mount the unit in the case, the open side facing in, as shown in Fig. 4. Dress all the leads from the unit to extend past the output end. The output end of the delay line is the end with the shielded transducer.

**Installation.** In automotive installations, the fader control and switch can be mounted on a separate panel and located within easy reach of the driver. The leads can then be run to the reverberation amplifier, which can be mounted in the trunk or other convenient place.

Disconnect the speaker from the car radio's output transformer and connect it to the fader control. Then install a rear-seat speaker and connect it to the fader control. This will allow you to select either direct output to both front and rear speakers, or direct output to the front speaker and reverberation output to the rear speaker. Of course, if your car is already equipped with a fader control and a front and rear speaker setup, you're that much ahead of the game—all you need add is the d.p.d.t. switch (S1).

To adjust the amplifier for proper operation, connect it to a 12-volt power supply. It's a good idea to install a 1-ampere fuse in the + lead. Measure the voltage at the collector of Q5 (it can normally range from 4 to 8 volts) and adjust trimmer resistor R8 to obtain a 6-volt reading. The purpose of this adjustment is to obtain symmetrical operation.

After you install the amplifier, tune in your favorite program—and enjoy your concert hall on wheels.

**Using the Reverb At Home.** The reverberation amplifier can be used on a stereo system in your home by feeding a combined signal to the input transducer. Only one reverberation system is needed since there is no such thing as stereo separation in reflected sounds.

The combined signal can be obtained by connecting 22- to 47-ohm, 1-watt resistors from the signal lead of each speaker to the input of the reverb unit. Start with 47-ohm resistors and reduce the value if the volume output is insufficient. But do NOT use the fader (R18) or the load resistor (R19) in your home installation—drive the reverb directly from the combined signal takeoff point.

A wide-range speaker is not required on the reverb channel since the frequency response of the reverb channel is about 100 to 5000 hertz. The amplifier in the diagram will put out more power (to a 4-ohm speaker) if the input voltage is raised from 12 to 18 volts. The output would then be about 6 watts.

The author is working on the design of a new reverb unit using one of the miniature (?) delay line assemblies, a project scheduled for spring publication in **Popular Electronics.**
YOU CAN'T hear it; you can't see it; you can't feel it; you can't smell it; and you can't taste it; but you can make it work for you. It really isn't mysterious; it just seems that way. What is "it"? The beam in the Ultrasonic Omni-Alarm, an all-purpose, all-sensing, always-ready alarm system. The system can be used as an intruder alarm, fire alarm, or as a counter or controller in an industrial process or production line. It can also be employed to demonstrate the use of ultrasonic sound, and should make a good science project.

The alarm consists of a transmitter that broadcasts an inaudible ultrasonic beam of "sound" and a receiver on the
The photocell similar about same chassis R2 M1-0-15 L1-15-R3, R19 R1, R4, R6 Q2, Q3, Q4, Q5 Q1, K2, K1-Printed-circuit-type neon D3, D1, C12, C13, C14-0.003-µf., 5% polystyrene capacitor C6, C8, C10-0.01-µf., 50-volt ceramic disc capacitor C12, C13, C14-5-µf., 15-volt electrolytic capacitor D1, D2-1N34 germanium diode (or equivalent) D3, D4-50-volt PIV, 750-µa. silicon rectifier I1-Neon pilot light with built-in resistor K1-Printed-circuit-type d.p.d.t. relay (Price Electric 206-14P or equivalent)* K2, K3-Relay—see text L1-15- to 25-mh., variable inductor with 10% top (DEMCO 3E-027-1)* M1-0-15 volt d.c. voltmeter (Lafayette 99 G 5047 or equivalent) Q1, Q6-2N3706 transistor (Texas Instruments, or equivalent)* Q2, Q3, Q4, Q5-2N3708 transistor (Texas Instruments, or equivalent)* R1, R4, R6-470-ohm, 5/8-watt resistor R2-47,000-ohm, 5/8-watt resistor R3, R19-4700-ohm, 1/2-watt resistor R5, R18-1000-ohm, 1/2-watt resistor R7, R11, R13-100,000-ohm, 1/2-watt resistor R8, R16-10,000-ohm, 1/2-watt resistor R9, R13-27,000-ohm, 1/2-watt resistor R10, R14-2500-ohm, 1/2-watt resistor R12-10,000-ohm trimmer resistor (CTS X-201 or equivalent)* R17-15,000-ohm, 1/2-watt resistor* R20-Resistor—see text S1, S2-Miniature s.p.s.t. toggle switch SO1-2-brong socket (optional) T1-Low-voltage transformer: 110- to 120-volt primary; 20-volt CT secondary (Stancor TP-2 or equivalent) 2-Chassis (Bud CIU-465 or equivalent) Circuit board (DEMCO #129)* 2-25-kc. ultrasonic transducers (DEMCO E-25)* Misc.-Wire, solder, nuts, bolts, connectors, spacers, etc. NOTE: Most of the parts listed above are standard and should be available from your local dealer. If you have any difficulty in obtaining them, you can contact DEMCO, Box 16297, San Antonio, Texas 78216 for the following: a kit of all the parts marked with an asterisk for $20; an etched and drilled fiberglass circuit board like that shown in the photo for $3.50; any of the parts used—price list available from DEMCO on request.

![Diagram](image-url)

**Fig. 1.** One-transistor oscillator, Q1, generates an ultrasonic signal which is beamed through the air and back to the receiver, Q2 to Q6. Alarm sounds when beam is interrupted.
mitter and one from the receiver, can be placed up to 50 feet apart to protect a large area. Any interruption of the beam causes an alarm. Even a fire in the area between the transducers can create enough air turbulence to set off the system.

How It Works. The transmitter portion is nothing more than a single transistor oscillator circuit (Q1) which directly drives the output transducer connected to terminals A and B (Fig. 1). Coil L1 and capacitor C4 make up a resonant tank tuned to 25 kc. Feedback from the coil to the base of Q1 through C3 helps sustain the oscillations. Resistor R5 isolates the transducer from the tuned circuit and prevents variations in the transducer and its cable capacitance from affecting oscillator operation too much.

The receiver, consisting of transistor circuits Q2 through Q6, picks up the signal from the input transducer, amplifies it, and energizes relay K1. Transistors Q3, and Q4 are conventional common emitter amplifier stages. Potentiometer R12 acts as a level and sensitivity control. Transistor Q5 is used as an emitter follower and provides the low output impedance needed to drive the half-wave voltage-doubler rectifier consisting of D1, D2, C12 and C13. The resulting d.c. voltage is used to turn Q6 "on." Transistor Q6 drives the alarm relay.

The circuit is arranged so that the relay is held in at all times when there is a signal present. A drop or absence of signal causes the relay to open, and the
alarm to sound, or a counter to operate, etc. This is a type of "fail safe" operation, in that a defect in the system, power failure, transducer failure, circuit failure, etc., will cause the alarm to sound. The circuit is compromised if the same power source is used to activate

the external alarm. However, this condition can be easily remedied, as described in the installation instructions.

Switch S2 must be placed in the Reset position (closed) before the system will operate. With the switch in this position, the relay will kick in and out every time the sound beam is on and then broken. For counting or other activities requiring self-resetting, the switch should be left in the Reset position. But for alarm purposes, the switch should be placed in the Reset position only long enough for the relay to kick in.

Once the relay is "on," move the switch to the Operate position; relay contacts J and H will continue to complete the relay circuit and hold the relay "on" until the beam is interrupted. When the beam is broken, the relay opens. The relay will not close even if the beam is restored, and the alarm will sound continuously until the switch is manually

Fig. 4. By locating the receiver and transmitter output and input connectors on the rear cover, the entire package takes on a clean professional look.

Fig. 5. If vibration of hardware in the transmitting transducer creates an audible sound, carefully open case and insert small piece of foam plastic.

ELECTRONIC EXPERIMENTER'S HANDBOOK
the parts in any manner more convenient for you. If you do change the layout, avoid stray coupling between the transmitter and receiver sections, but in any event observe polarity of electrolytic capacitors and diodes.

After all the parts are mounted on the circuit board, connect wires to points A through M. These should be about 8 inches long. Twist together leads A and B; C and D; E, F and G; K, L and M; and J, H and N.

Mount the switches and meter on the front panel, and the transducer connectors and alarm connector on the back panel, as shown in the photos. Use shielded microphone cable and appropriate connectors for the transducers. For a 50-foot spread, each cable need be only 25 feet long. A phono plug connects the transducer to the cable. Any type of cabinet can be used to house the circuit.

Adjustment. Mount the transducers about 20 feet apart. Turn the sensitivity control fully clockwise (viewed from the knob side) and turn on the power. Place S2 in the Reset position and advance gain control R12. As the control is turned counterclockwise, the meter reading should increase; and at approximately 8 volts, the relay should be heard to click in. If the relay does not close—or if the reading doesn’t reach 10 volts—at the full counterclockwise position of the gain control, the slug in L1 should be adjusted.

Use a nonmetallic alignment tool to turn the slug about halfway into the coil form. Now slowly turn the slug out of the form and watch the meter reading. When the reading reaches 10 volts, reduce sensitivity and keep adjusting until a peak or maximum reading is obtained. Turn the alarm off and back on to be sure that the adjustment is stable. If the meter reading does not return to the same place or is zero, tune for the second highest reading.

If you find that the best transmitter adjustment causes the transmitting transducer to make audible sounds, damp the transducer. The high drive level can cause the crystal or internal parts of the transducer to "sing" at an audible frequency. Carefully open the transducer case by straightening the crimped edge.
on the back of the transducer to remove the cover. Then carefully insert a piece of foam plastic (not rubber) under the crystal as shown in Fig. 5. The pad should be approximately \( \frac{\sqrt{2}}{2} \)" square by \( \frac{\sqrt{2}}{2} \)" thick. Replace the cover and seal the seam with rubber cement to prevent the transducer case from rattling.

If everything seems to be in working order, set the sensitivity control to obtain a 10-volt reading and have someone take a walk to break the path between the transducers. The meter reading should drop to zero and the relay should drop out.

**Installation.** You can mount the transducers for direct or for reflected beam operation as shown in Fig. 6. Direct-type operation is more effective over greater distances. With the reflected-type setup, both transducers can be mounted on the same wall to cover hallways and small rooms. Do not use more cable than necessary for the receiving transducer; the longer the cable, the more capacitance it has; and the greater the capacitance, the greater the loss in signal to the receiver. If the system is to be used as an intruder alarm, mount the transducers high enough and in such a way that a cat or a dog will not break the beam and cause a false alarm—unless you would like to know about the uninvited four-legged visitor.

Keep the beam as far away from heating or air conditioning ducts as possible. Although this system will tolerate some air motion, violent or turbulent motion can set it off. The Omni-Alarm cannot normally be used outside, especially in a windy place—the "sound" beam can be blown away enough to cause the alarm to trip.

Any type of alarm device that can be activated by a switching action can be connected to the relay contacts. Perhaps the simplest arrangement is that of a bell or light connected to points \( E \) and \( F \) as shown in Fig. 7. But while this hookup will work fine, it can be put out of commission simply by cutting the wires.

If you want to make the installation tamperproof, you can enclose the external alarm and its circuitry in a locked steel box, mounted high above ground level. The alarm will sound if an intruder breaks the beam, cuts or shorts the wires, or if there is a power failure. Two identical relays are used as shown in Fig. 8. All relays have a higher pull-in than drop-out current, and you can take advantage of this characteristic. Resistor \( R20 \), installed in the alarm control unit, is selected to allow a small current to flow through \( K2 \) and \( K3 \), which is too small to pull in the relays, but large enough to hold them in. Set the alarm and manually close the contacts of \( K2 \). Now, if anyone cuts the wires or breaks the beam to open \( K1 \), \( K2 \) will open and sound the alarm. If someone shorts the wires, \( R20 \) is bypassed and \( K2 \) closes, and sounds the alarm.

If you want to be real "mean," you can put a Microswitch in the bottom of the case. Then the alarm will sound if the case is picked up. An added safety feature inherent in this type of circuit is that the alarm will sound when the batteries approach their end life.

To obtain pinpoint control in a production line setup, you can insert one or both of the transducers into one end of a 1"-diameter plastic tube. This reduces the range. Distances of one to three feet can be monitored without feedback problems.
BUILD a portable time-signal receiver and you can tune in on standard time broadcasts from your living room, picnic table, boat, car, or even from a private plane. This miniature receiver is a complete superhet circuit with crystal-controlled local oscillator, prepackaged pretuned i.f. module, and transformerless audio amplifier. A printed circuit board makes it easy to build and only a screwdriver (no test equipment) is needed for alignment!

Standard time signals can be heard in almost every country in the world. In the United States, radio stations of the National Bureau of Standards (all having the call-sign WWV) continuously transmit time signals on a number of frequencies. Besides accurate time-signal information, the transmissions also provide: standard radio frequencies, standard audio frequencies, standard musical pitch, standard time intervals, radio propagation forecasts, and geophysical alerts. This receiver can be used to monitor WWV on a frequency of 10 MHz or 15 MHz.

You can also use the time-signal receiver to tune in CHU, Ottawa, Canada, on a frequency of 7335 kHz, or on 14.670...
MHz. The CHU time-signal broadcasts are very popular because of their voice-time announcements each minute. A short tone or “beep” is broadcast each second.

The model of the WWV-CHU receiver shown on page 19 (a portable, crystal-controlled, 8-transistor receiver) can be built for a little more than thirty dollars. It has an r.f. amplifier, a mixer, a pre-aligned J. W. Miller i.f. amplifier, and a push-pull Class B audio output. Powered by an ordinary transistor radio battery, the receiver has a low power consumption and battery life is quite good.

The WWV-CHU receiver is portable and can be used anywhere. A telescoping, built-in whip antenna can be extended to 52 inches for increased signal pickup. The audio stage drives a built-in speaker. In a noisy environment, or for private listening, an earphone can be plugged into the jack provided for that purpose. Since the receiver is crystal-controlled, there is no need to tune for the station.

Sensitivity is excellent, being better than one microvolt for a S/N ratio of 10 dB, which compares favorably with the large multi-tube communications receivers. Although the circuit is fairly complex, the receiver is easy to build. There are no coils to be wound since prewound, molded r.f. chokes are used. The receiver is even easier to align. The only piece of “equipment” needed for alignment is a screwdriver.

**How It Works.** The r.f. front end uses several new, low-cost, encapsulated, npn silicon transistors. Transistor Q1 is the r.f. amplifier, and transistor Q2 is the mixer. Coils L1 and L2 are prewound iron-core r.f. chokes and are specified as being either 10 µH or 5.6 µH. If 10-µH chokes are used, then CHU on 7335 kHz or WWV on 10 MHz can be tuned. The 5.6-µH chokes will enable the receiver to be tuned to three time-signal stations: WWV on 10 MHz, CHU on 14.670 MHz, or WWV on 15 MHz. Midget trimmer capacitors C2 and C6 tune or resonate the chokes to the respective frequencies. Transistor Q3 is the local oscillator, which is crystal-controlled and “untuned.” Fundamental crystals are used in this circuit.

The miniature i.f. module eliminates the need to build a separate i.f. amplifier. Within the module are two transistors, three i.f. 455-kHz transformers, a crystal diode detector stage, and miscellaneous decoupling capacitors.

The volume control is potentiometer R13. There are no transformers in the audio amplifier section so that cost and receiver weight are kept down. The audio preamplifier is Q4, a npn germanium transistor. Transistors Q5 and Q6 operate push-pull Class B in a complementary-
The edge-view drawing of the printed circuit board shows special preparation of the C2 and C6 soldering tabs. Shown in photo at left is method employed to obtain socket clips to hold the crystal. Use an expendable 9-pin socket.

This i.f. amplifier contains two transistors, three i.f. transformers, and crystal diode detector. Be sure to get the J. W. Miller Model 8902-B specified and not the older-style Model 8902 with outboard i.f. transformer.

If you purchase an LMB aluminum box No. 139, you can duplicate construction of the receiver shown on the cover using these dimensions.
This is the schematic diagram of the complete CHU-WWV time-signal receiver. The oscillator is crystal-controlled and the circuit is simply peaked up through adjustment of capacitors C2 and C6. The i.f. amplifier is prepackaged and prealigned, and is also peaked up once the receiver is in operation.

Use the layout of the top side of the printed circuit board shown below to spot the positions for the components in the wiring diagram above. Holes for the loudspeaker apply only if a Quam 2 1/4'' PM speaker is installed in the space provided.

Compare photo below with board layout at left. Speaker is now fastened to printed circuit board and the chassis cover with speaker cutout slips over U-shaped back cover seen in this photo.
symmetry configuration. A 100-ohm speaker is fed from the audio output stage through closed-circuit phone jack J1. When headphones are plugged into the phone jack, the speaker is automatically disabled. Any impedance headphone can be used. The audio output stage delivers over 50 milliwatts of power.

Construction. The entire time-signal receiver circuit is constructed on a printed circuit board measuring only 3¾" x 2¼" in size. A glass epoxy circuit board, etched and drilled, is available from the author (see Parts List).

Component mounting should follow that shown in the photo at left. All resistors are mounted vertically and all capacitors mounted as close to the printed circuit board as possible. Prior to mounting the miniature trimmer capacitors, C2 and C6, cut the soldering tabs as shown on page 21.

Space limitations will not permit the use of a crystal socket on the printed circuit board. Instead, two socket pins salvaged from a 7- or 9-pin tube socket are soldered directly to the board. Once these have been soldered in place, also as shown on page 21, they serve as the "socket" for the crystal.

All of the transistors should be mounted approximately ¾" away from the circuit board. Carefully observe correct placement of the "flat" side of transistors Q1, Q2 and Q3. As usual in soldering transistors, keep the heat applied to the leads to a minimum, but consistent with a good connection.

The connecting leads to the circuit board (from B1, J1, R12 and S1) should be approximately 2" long. These will be cut to the proper length once the circuit board has been installed in the chassis box. The speaker mounts directly on the printed circuit board where the holes are provided—it is installed last. Two 4-40 screws secure the speaker to the printed circuit board.

Prepare the metal box by drilling the holes in the back cover and making the 2" cutout in the front cover (see drawing on p. 21). Cement a 2½" x 2½" piece of perforated sheet aluminum in back of the 2" cutout. Use epoxy cement for this step. If you wish, you can paint the perforated sheet before cementing it in place.
Mount the telescoping whip antenna through a ½” rubber grommet in the hole in the top of the back cover. The bottom of the whip is held by a steatite insulator. The solder lug, provided with the antenna, should be installed between the bottom of the antenna and the top of the insulator. Next, install the volume control, R12, and the phone jack, J1.

The completed circuit board, with speaker installed, is mounted last. If you follow the layout provided in the drawings, the speaker will automatically line up directly behind the 2½” opening when the front cover is installed.

Place a solder lug under the 4-40 nut in the lower left-hand corner of the circuit board. The solder lug will thus serve as the ground point for the negative lead of the battery. Run the battery’s positive lead along the underside of the circuit board and solder the end to switch S1.

Alignment and Operation. The completed receiver can be aligned with an “on the air” signal from WWV or CHU. Since the receiver’s local oscillator is crystal-controlled, there is no need to “hunt” for the station.

Assuming propagation conditions will permit reception of the desired station at the time you select (see box entitled “Time Signal Broadcasts”), simply tune C2 and C6 for maximum station volume or background noise. Also, a slight “tweaking” of the input transformer in the i.f. strip might be necessary. A hole in the top of the i.f. module enclosure allows access to the input transformer tuning slug.

In most cases, the built-in antenna is all that is needed. However, it is possible to improve reception with a “long wire” antenna. An external antenna can be clipped to the top of the whip. The

(Continued on page 148)
Unlike the proverbial "tempest in a teapot," this solid-state phonograph amplifier really kicks up a storm. Featuring push-pull output amplification for more power, less distortion, and truer fidelity, the unit has been designed to satisfy the need for an inexpensive, easy-to-build phonograph amplifier that will operate satisfactorily with most high-level, low-cost ceramic or crystal cartridges.

Whether you'd like to update that old discarded record player or assemble a new one around the solid-state amplifier design, this four-transistor unit is sure to please all but the most discriminating listener.

By Louis E. Garner, Jr.
Featuring a high-impedance input, the phono amplifier works fine with any high level (1-2 volt) ceramic or crystal pickup cartridge. Best results are usually obtained with a 16-ohm speaker, but an 8-ohm speaker will do.

How It Works. The amplifier input from a phono cartridge is applied to the base of emitter follower Q1 (as shown in the schematic diagram, above) through volume control R1, limiter resistor R2, and coupling capacitor C1. With Q1 serving as an impedance-matching device, this transistor provides a high input impedance to the source and a low output impedance to driver Q2.

Transistor Q1's output, developed across R4, is applied to the base of Q2 through C3. Bias for this stage is provided through R3. The output of Q2 is then direct-coupled to push-pull amplifiers Q3 and Q4. The R7-R8 divider combination, together with R9 and C5, provide a compensated base bias for Q2.

A common output from the push-pull amplifiers is developed across emitter resistors R17 and R18 and coupled through C9 to the speaker voice coil. Resistors R12, R13, and R14, together with C8, provide the base bias voltage for Q3 and Q4.

A special type of feedback equalization network in the tone control circuit provides low-frequency roll-off compensation whenever the volume control is turned up fully. The network components consist of C4, R5, R10, C6, R15, C7, R11 and R17. Potentiometer R16 is the tone control. The main advantage of this equalization arrangement is that it improves tonal quality without introducing excessive losses. The amplifier can be powered directly by a 12-volt battery. However, since the attached record changer will usually be a.c.-operated, it will be advantageous to employ either a 12-volt filament transformer, or make a direct connection to the 12-volt auxiliary winding on the phonograph motor. Diode D1 and capacitor C10 provide a
PARTS LIST

C1—0.02-µF, 50-volt disc ceramic capacitor
C2, C5, C8, C9—100-µF, 15-volt electrolytic capacitor
C3—50-µF, 50-volt disc ceramic capacitor
C4—390-pF disc or tubular ceramic capacitor
C6—470-pF disc or tubular ceramic capacitor
C7—4.7-pF disc or tubular ceramic capacitor
C10—500-µF, 25-volt electrolytic capacitor
D1—50-volt PIV diode (RCA 1N3754 or equivalent)
Q1—RCA 40395 transistor
Q2—RCA 40234 transistor
Q3—RCA 40396N transistor (see text)
Q4—RCA 40396P transistor (see text)
R1—2-megohm potentiometer, audio taper (with s.p.s.t. switch S1)
R2—180,000-ohm resistor
R3—1-megohm resistor
R4, R6—1000-ohm resistor
R5—3.3-megohm resistor
R7, R9—1500-ohm resistor
R8—330-ohm resistor
R10, R15—270,000-ohm resistor
R11—22,000-ohm resistor
R12, R13—220-ohm resistor
R14—18-ohm resistor
R16—3-megohm potentiometer, audio taper
R17, R18—1-ohm resistor
S1—S.p.s.t. switch (on R1)
1—3½" x 2¾" x 3" (approx.) L-shaped aluminum chassis/panel
2—Heat sink clips (RCA SA2100)
Misc.—Knobs (2); ½"-long standoff spacers (4); screws, nuts, lock washers, solder, etc.

NOTE: A complete kit of parts, including an etched circuit board, is available from DEMCO, 219 W. Rhapsody, San Antonio, Texas 78216, for $9.50 postpaid.

rectified d.c. output to operate the unit. For battery-powered motors, or when you want to use a battery supply for the amplifier, D1 serves to protect the circuit from an accidental battery polarity reversal.

Construction. The amplifier can be assembled on the 3¼" x 2¾" x 3" L-shaped aluminum chassis, or on any other convenient-sized chassis. If you are doing a conversion job, investigate the possibility of using the existing chassis; in most cases, it will be quite adequate. You may even be able to use your old volume and tone controls—if these are of the proper resistance. But bear in mind that a metal chassis must be used to provide adequate heat-sinking for output transistors Q3 and Q4. These transistors (RCA 40396N and 40396P) are matched pairs, and must be purchased as such.

It is far more convenient to mount the components on a printed circuit board or simply on a perforated phenolic board than to wire them directly to the chassis. The size board required will be determined essentially by available spacing, but a 3" x 3" board is usually suitable. If you prefer to use a printed circuit board, or want to work from a kit, these are available from DEMCO (see Parts List).

Except for Q3 and Q4, which are mounted underneath the circuit board, all components are visible.
It is recommended that the builder employ point-to-point wiring on the phenolic circuit board because of the simplicity of the circuit. Besides, you will get a greater feeling of accomplishment when the job is completed.

Transistors Q3 and Q4 are mounted directly on the chassis in any convenient location. The other transistors, Q1 and Q2, can be mounted on the circuit board. As shown in the illustrations, both the volume and tone controls are panel-mounted.

The circuit board is mounted on spacers as shown, although this arrangement can be varied to suit any preferred installation. Connect the external wires from the pickup cartridge to the un-grounded side of the volume control, and connect the ground shield to a good chassis ground. (Cartridges such as the Sonotone 2TA-S and Astatic 70-TS, 74-TS or 76-TSB can be used.) Connect the loudspeaker voice coil to the “C” and “E” terminals (see schematic).

If an auxiliary motor winding or a filament transformer is used as a power source, connect one lead of the 12.6-volt winding to diode D1’s anode, and the other lead to ground. If a battery is being used instead, connect the positive lead through a s.p.s.t. switch installed on the volume control (R1) to the anode terminal of D1. In this case, motor power is controlled by a separate switch.

After double-checking your work, apply power—and enjoy good listening.
WHETHER YOU'RE an amateur ichthyologist or just a fellow with a few tropical fish, you'll want to build this transistorized thermistor-controlled aquarium heater, and get rid of that annoying radio interference that your present bimetallic thermostat produces. What's more, you'll be able to maintain precise temperature control to within ± 0.5-degree of setting.

When equipped with a standard 75-watt submersible heater, the unit will operate satisfactorily in small tanks—up to 20 gallons—and maintain the desired tank temperature within a differential of up to 10 degrees F above ambient. For larger aquariums, or where greater temperature differentials exist, a larger heater can be employed or a full-wave rectifier substituted for the single rectifying diode used.

How It Works. As shown in Fig. 1, Q1 functions as part of the sensing circuit while Q2 acts as a triggering device to turn on SCR1. Thermistor TH1 and R1 form a voltage divider that provides a variable base bias for Q1. Potentiometer R3 in Q1's emitter establishes the operating range of the transistor, and thus serves as the temperature control adjustment.

In operation, if the tank temperature is below normal, the relatively large voltage drop across TH1—due to its high resistance at low temperatures—places a high reverse base bias on Q1, cutting off the transistor.

With Q1 at cutoff, the forward bias developed across R4 drives Q2 in a high state of conduction and the zener or avalanche breakdown voltage of D1 is exceeded. Thus, the emitter voltage across R5 is applied to the gate of SCR1 to turn on the device which energizes the heater in its anode circuit.

As the water temperature increases, causing the thermistor resistance to go down, Q1 becomes forward-biased and conducts. The output at the collector overcomes Q2's forward base bias, and this transistor is driven into cutoff. This turns off SCR1 and the heater is deenergized.

Diode D2 is a voltage regulator that maintains the d.c. at the cathode of rectifier D3 at a constant 18-volt level. Neon lamp II, in series with R7, is a test device used during initial adjustment of the unit.

Construction. To assure maximum operating safety, the thermostat's electronic circuitry is housed in a plastic freezer container rather than in a metallic box. Begin construction by preparing the aluminum panel shown in Fig. 2. It is made from a 1⅛” x 2¾” by ⅛”-thick aluminum plate laid out and drilled to the dimensions given, and
Fig. 1. Water temperature is constantly monitored by thermistor TH1, which controls the bias on Q1. Heater is turned on by the SCR when Q2 conducts.

```
I1VAC

D1 D3

R6 3.3 k 4W

R7 56 k

Z1

75W HEATER

TH1

2N697

Q1

Q2

2N697

D1 D2

SCR1

C1 1µF

E

I

PARTS LIST

C1—0.01µF, 110-volt ceramic disc capacitor
D1—24X6L2 silicon zener diode (GE)
D2—Z4XL18 silicon zener diode (GE)
D3—1N3755 silicon diode (RCA)
F1—3-ampere fuses (and fuse holder)
I1—NE-2 neon lamp
Q1, Q2—2N697 transistor
R1—75,000-ohm, 1/2-watt resistor
R2—10,000-ohm, 1/2-watt resistor
R3—1000-ohm, 1/2-watt miniature molded composition potentiometer
R4—10,000-ohm, 1/2-watt resistor
R5—470-ohm, 1/2-watt resistor
R6—3300-ohm, 4-watt resistor
R7—56,000-ohm, 1/2-watt resistor
SCR1—2N3228 silicon-controlled rectifier
TH1—Thermistor (Voco 51A1 from Newto Electronics, or Pescial Electronics EMC4 from Allied Radio)
1—75-watt submersible aquarium heater
1—3/4" x 3/4" x 2 1/2" plastic freezer container with cover
1—2" x 7" piece of 1/2"-thick plexiglass
1—2 3/4" x 2 3/4" perforated phenolic board
1—1/2" x 2 1/2" piece of 11/16"-thick aluminum plate
6—1/4"-d. x 1 1/8"-long standoff
Misc.—6-32 x 1"-long screws with four flat washers and nuts (2); small plastic clamps (3); 6-32 x 3/4"-long screws with nuts (4)
```

then made into an L-shaped bracket. Not shown are two small holes that must be drilled to mount the bracket.

Secure the bracket to the circuit board (see Fig. 3) using two 6-32 x 3/4" screws inserted from the bracket side of the board through two 9/32"-o.d. x 1/2"-long standoff and nuts. Do not install the remaining two standoffs at this time.

Mount the fuse holder where shown, then install and wire up the remaining parts. In the model shown here resistor R6 consists of three 10,000-ohm, 2-watt resistors in parallel. This combination was used for no other reason than the fact that they were readily available. However, it is more convenient to use a single 3300-ohm, 4-watt resistor instead.

Also, if desired, Q1 and Q2 may be wired directly into the circuit, eliminating the transistor sockets. Be sure to use a low-wattage iron when soldering transistors and diodes, and avoid overheating these devices. And be sure to observe diode polarities.

When installing the SCR mounting kit, apply a little silicon grease between the aluminum panel and the mica washer to improve heat conduction. The thermistor must be mounted in a glass tube and the wires run through a small plastic air hose that you can get from an aquarium supply store. To seal the thermistor glass tube at one end, use a Bernz-O-Matic type torch to heat the tube until it is red-hot, and then draw

Fig. 2. Mounting bracket is made from 1/16"-thick aluminum plate cut to dimensions given. It acts as a heat sink for SCR1 and as a support for R3.
Fig. 4. Mount formed plexiglass on plastic container cover using standoff supports and screws indicated. Use a flat washer on either side of the cover to prevent premature rupture of the plastic. Thermistor glass tube shield is secured under clamp.

Fig. 5. A full-wave bridge rectifier in the line circuit causes the SCR to conduct on both half cycles, resulting in a doubling of the heater power.

Testing. After carefully checking out your wiring, give the circuit a dry run—outside of the aquarium. Plug in the unit and adjust temperature control potentiometer R3 until the neon light comes on, indicating that the heater is working.

Now place the thermistor glass tube in the palm of your hand and squeeze the tube gently to apply a little heat. If the light goes out, the indication is that all is working well. If the light stays on, try readjusting R3 slightly until it goes out.

Caution: Do not operate the heater out of water for any extended period of

(Continued on page 145)
DWELL METER ADAPTER

Use your voltmeter to adjust your ignition points with precision

By DAVID H. BOZARTH

To obtain the hottest possible spark under most operating conditions in a conventional ignition system, the dwell angle of the ignition points should be adjusted in accordance with the manufacturer's specifications in most cases. If the need for a dwell meter does not justify the cost of purchasing one, you can build this voltmeter adapter to enable your meter to read out dwell angle. By using parts from the surplus market, you should be able to hold the total cost below $2.00.

Construction is straightforward and—except for observing polarity—assembly, wiring, and parts layout are not critical. The adapter can be made to plug directly into a voltmeter as shown, or be connected to the voltmeter with a pair of leads. The meter “averages” the pulses and gives a voltage reading which is essentially proportional to the percent of time the points are closed. This percentage may be related to degrees by use of the dwell angle conversion chart on page 147.

To calibrate the adapter, attach lead B to the negative side of the battery and adjust R2 to obtain a full-scale reading on the meter. Use the 5-volt d.c. scale if your meter has one, otherwise the nearest one to it but below the 6.8-volt limit imposed by the zener diode. A full-scale reading would then be an indication of essentially 100% dwell time (points always closed).

To use the adapter, remove lead B from the battery and attach it to the terminal on the distributor going to the primary winding of the ignition coil. (It may be easier to attach the lead to the coil.) On an 8-cylinder engine, for example, if you obtain a 3-volt reading on a 5-volt scale, simply multiply 3 volts by 9 (9° per volt) and you’ll arrive at a dwell-angle indication of 27°.

(Continued on page 147)

Connect both leads to the battery and adjust R2 for full-scale reading. Meter face can be calibrated directly or dwell angle determined from chart.

All parts, including banana plugs, are mounted on a piece of fiberboard shaped to conform to the meter.

Only two leads are needed to complete hookup to positive side of battery and ignition points.
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CIRCLE NO. 19 ON READER SERVICE CARD
ABSENCE of inductive kick across the ignition points in a capacitor discharge (CD) or transistor ignition system prevents many commercially available tachometers from operating properly. Some of these tachs use a vibrator type of chopper and batteries; others use diodes and transistors which are not fast enough to give a true rpm indication. Still others, especially those with inductive input components, tend to load down the ignition system, depriving it of a significant amount of high voltage.

Here's a tach that requires very few parts and no batteries, is easy to build, and won't steal any high voltage from your spark plugs.

The entire works including the meter can be put into one package, or as is commonly done, divided into two units—the meter, as one unit, acting as a receiver, and the other components in another unit acting as a sender. The receiver can be mounted on the dash or steering column within view of the driver; the sending unit can be located in any convenient place, including the engine compartment—but keep it away from the hot engine.

How It Works. In a negative-ground CD or transistor ignition system, the battery voltage appears across the points as a positive-going rectangular pulse when the points open and close. The pulse is applied across D1 and R1. Zener diode D1, a 1N3017, limits the pulse peak applied across the remainder of the circuit to 7.5 volts. Since this is well below the lowest battery voltage in a 12-volt system, the meter readings will not wander with fluctuating battery voltage.

Capacitor C1 takes on a charge through the meter and resistors R2 and R3 and through D3 when the points are open and the battery voltage is across the points. If the points were to remain open all the time, C1 would charge up at a decreasing rate until it was essentially fully charged. Current through the meter would fall off accordingly. Initially the meter needle would start out very high on the scale and fall off to practically zero, if the needle could respond fast enough. But the engine doesn’t stand still and the points keep opening and closing.

When the points close, C1 discharges through D2, the closed points, and R1, and is ready to take on the next surge of current when the points open again. If D2 and D3 respond fast enough, then the average current through the meter will depend more upon the number of
or TRANSISTOR IGNITION SYSTEMS

pulses in a given time (frequency) than upon the width or shape of the pulse. The faster the circuit responds, the greater its ability to "track" the leading edge of the pulse.

Another benefit of this type of current monitoring is that the dwell time of the ignition points becomes less of an error factor and the meter reading takes on another dimension of accuracy to more perfectly reflect engine rpm. The trick then is to use a pair of diodes that have a high-speed switching action characteristic.

Since we have minimized—if not eliminated—pulse amplitude, pulse width, and pulse shape as meter-response factors, and have "forced" the meter to respond to the leading edge of the pulse, this circuit can be relied upon for extremely accurate readings, and to surpass many commercially available products. As the meter readings are directly proportional to the pulse frequency and since pulse frequency is in direct proportion to engine rpm, the meter can be calibrated to read out rpm.

Resistors R3 and R3 are used to calibrate the meter. Resistor R4 is optional and need not be installed, unless you intend to monitor the waveform across the points with a scope. Not shown is a 0.005-µf. capacitor which can be put across R2 to act as an r.f. bypass to prevent the tach from causing radio interference.

Construction. All parts except the meter are enclosed in a 2½" x 4" x 2½" box. Two small L-brackets are attached to the sides of the box to facilitate mounting. Parts layout is not critical, and a larger or smaller box can be used if desired.

The size of the meter does not matter, either, but the meter movement should be 0-1 ma. for a 10,000-rpm full-scale reading, or 0-500 µa. to obtain full-scale deflection at 5000 rpm. You could then use the existing scale and multiply by 1000 to determine rpm. (A reading of

Current through the meter is a function of pulse frequency; pulse frequency is a function of engine rpm. Fast-acting diodes (SD-2) enable the circuit to respond to the leading edge of the pulses to minimize significance of pulse shape and width. Zener diode D1 regulates voltage peaks to make the readings independent of battery voltage fluctuations.
3.5 ma. would indicate 3500 rpm.) When other commercial rpm meters are used, R3 may have to be jumped, as some of them incorporate 0-2 ma. movements. Regardless of scale markings or meter movements used, you should calibrate the tach before you install it in your car.

Diodes D2 and D3 are fast-acting avalanche types, and are available in matched pairs to within 5% for forward conduction, rise time, and linearity. (See Parts List.) These diodes (Module SD-2) are encapsulated in a compound to keep them both at the same temperature. Maximum variation in the rpm reading due to temperature change is less than 1%. You can substitute other fast acting diodes for this purpose, such as 1N645, but you are more likely to do better with the SD-2 module. By all means observe po-

### PARTS LIST

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>12-volt battery</td>
</tr>
<tr>
<td>C1</td>
<td>1-µF, 100-volt capacitor (for 6-volt systems or 2-cycle engines, use 2 µF)</td>
</tr>
<tr>
<td>C2</td>
<td>2-µF, 100-volt capacitor</td>
</tr>
<tr>
<td>D1</td>
<td>1N3017 zener diode (for 6-volt systems, use a 1N3824)</td>
</tr>
<tr>
<td>D2, D3</td>
<td>SYDMUR SD-2 module* (1N645 or equivalent)</td>
</tr>
<tr>
<td>D4</td>
<td>1N91 diode</td>
</tr>
<tr>
<td>D5, D6</td>
<td>1N34 diode or equivalent</td>
</tr>
<tr>
<td>M1</td>
<td>0-1 ma. meter for direct calibration to 10,000 rpm (for 5000-rpm maximum reading, use 0-500 µa. meter)</td>
</tr>
<tr>
<td>Q1</td>
<td>2N173 transistor</td>
</tr>
<tr>
<td>R1</td>
<td>100-ohm, 1-watt resistor</td>
</tr>
<tr>
<td>R2</td>
<td>100-ohm carbon, lock-shaft potentiometer</td>
</tr>
<tr>
<td>R3</td>
<td>270-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>R4</td>
<td>100-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>R5</td>
<td>150-ohm, 2-watt resistor (use 47-ohm, 2-watt resistor for capacitor-discharge ignition systems)</td>
</tr>
<tr>
<td>R6</td>
<td>6800-ohm, 1-watt resistor</td>
</tr>
<tr>
<td>S1, S2</td>
<td>S.p.s.t. switch</td>
</tr>
<tr>
<td>T1</td>
<td>Low-voltage rectifier transformer; 117-volt primary, 24-volt center-tapped secondary</td>
</tr>
<tr>
<td>Misc.</td>
<td>Terminal strips (2), L brackets (2), machine screws and nuts, wire, etc.</td>
</tr>
</tbody>
</table>

*Available from SYDMUR, P.O. Box 25A, Midwood Station, Brooklyn, N.Y., for $3.50.

Parts layout of sending unit is not critical. Fast-acting diodes are encapsulated to keep them both at the same operating temperature for minimum error.
Either a signal generator or a power supply having a 60- and 120-hertz ripple can be used to calibrate the tachometer. The transistor circuit is used to obtain square waves from the sinusoidal waveforms.

To determine the significance of test signal frequency, consider an 8-cylinder, 4-cycle automobile engine. There are four power strokes, four sparks, and four pulses every revolution. At 900 rpm, there would be 3600 pulses per minute or 60 pulses per second. Therefore, a test signal of 60 hertz is equivalent to 900 rpm. By the same token, a test signal of 120 hertz simulates 1800 rpm.

For maximum meter accuracy, select a check point as close as possible to the engine speeds you are most likely to attain most of the time. Since circuit action is essentially linear, all you need is a single test point. Refer to the calibration and conversion chart to find out what test signals you can use for 4-, 6-, and 8-cylinder, 2- and 4-cycle engines.

Special Considerations. For 2-cycle engines, capacitor C1 should be a 2-µf. unit. For 6-volt ignition systems, D1 should be a 1N3824 zener diode (4.3 volts), R1 a 39-ohm, 1-watt resistor, and C1 a 2-µf. capacitor. For positive ground systems, simply reverse the leads going to the distributor from the tachometer. Happy motoring.

<table>
<thead>
<tr>
<th>Cylinders</th>
<th>K</th>
<th>2-cycle engine</th>
<th>4-cycle engine</th>
<th>fK (4-cycle engine) = rpm</th>
<th>R3 (approx. ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td>30</td>
<td>1800</td>
<td>3600</td>
<td>6000</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>20</td>
<td>1200</td>
<td>2400</td>
<td>4000</td>
</tr>
<tr>
<td>8</td>
<td>7.5</td>
<td>15</td>
<td>900</td>
<td>1800</td>
<td>3000</td>
</tr>
</tbody>
</table>

CALIBRATION AND CONVERSION DATA CHART

1967 Spring Edition
BUILD A
HANDFUL OF POWER

TINY MODULAR
RECTIFIER CIRCUITS
SIMPLIFY
CONSTRUCTION OF
A.C.-OPERATED
D.C. POWER SUPPLIES

By EDWARD M. LONG

A NEW generation of pre-packaged full-wave bridge rectifiers for a.c.-operated low-voltage d.c. power supplies has recently appeared on the horizon. Made of matched diffused-junction silicon rectifiers encased in epoxy, these units can be used with any filament transformer to provide a "handful" of d.c. power for operating transistorized circuits, low-voltage d.c.-operated equipment, or for test purposes.

These prepackaged rectifiers are currently being produced by a number of firms, and are being marketed through electronic parts distributors. The Mallory FW-50 unit, rated at 1.5 amperes, 50 PIV, was selected for illustrative purposes. It can be used with either a 12-volt or 24-volt miniaturized filament transformer.

The power supply in the photo shows the rectifier module mounted on the transformer (Olson Electronics T-290) and connected through a terminal strip. Both the rectifier and the terminal strip are fastened on the transformer with epoxy. The extra lugs on the terminal strip can be used for mounting a filter circuit, if one is desired.

As shown in the diagram, the a.c. input leads are connected to the center legs while the d.c. output leads are connected to the outer legs. If it is desired to improve the d.c. regulation of the power supply, a bleeder resistor can be connected across the d.c. output terminals. The value of the bleeder will depend on the load requirements.

Hardly bigger than a thumbnail, the new prepackaged bridge rectifiers offer numerous advantages to the circuit designer as well as to the experimenter.
HAVE YOU EVER left your car in a parking lot and returned several hours later to find that you forgot to turn your lights off and that your battery has run down? Join the club. This kind of negligence seems to be most prevalent on rainy, overcast days or at dusk when many people have their lights on. For only $7, and a few hours of your time, you can build the “Auto-Light Minder” and eliminate the problem forever.

When you install the Auto-Light Minder in your car, it will sound an alarm if you leave your lights on after you turn off the ignition. Turn the lights off, and the alarm will stop. It’s that simple. And there is a circuit for every car, whether it has a 6- or 12-volt positive or negative ground system.

The Auto-Light Minder also has a reverse mode of operation, which lets you intentionally leave your lights on when the ignition switch is off . . . without sounding the alarm. But when you turn on the ignition switch, the alarm sounds off to remind you that you are trying to start your car at the same time your lights are on, and also to alert you to the fact that the alarm is not set to work in a forward mode. The Auto-Light Minder is foolproof, and it never “forgets.”
How It Works. The Auto-Light Minder is essentially a one-transistor oscillator circuit that works when battery voltage is applied only to the emitter of Q1. Battery voltage is fed to the unit from two possible places in the car: the ignition system and the light system. Sometimes this voltage comes from either one of these places and sometimes it comes from both places.

In the forward mode of operation, battery voltage from the ignition system is connected to the collector, and battery voltage from the light system is connected to the emitter; if the ignition switch is on, and the lights are on, both the collector and the emitter of Q1 are at the same potential. Under these conditions, the circuit will not oscillate, and the alarm will not sound. If the ignition is turned off, and the lights are left on, the collector is returned to ground through part of T1, R2 and C2, and develops the bias voltage necessary for the circuit to oscillate. If you turn the lights off, the supply voltage is removed from the emitter and the circuit ceases to oscillate. Diode D1 protects the transistor against a reverse battery voltage.

In the reverse mode of operation—you merely flip S1 to obtain either the forward or the reverse mode—the voltage from the light system is completely disconnected from the Auto-Light Minder, and the lights can be turned on without triggering the alarm. However, when the ignition is turned on, it will place the necessary voltage on the emitter of Q1 and cause the alarm to sound. To shut off the alarm, throw S1 into the forward position and you won't be bothered again unless you shut off your engine and leave your lights on.

The negative ground Auto-Light Mind-
shown is easily adapted to a positive ground system, with only three minor—but very important—differences in the wiring: (1) a 2N647 npn transistor is used for Q1; (2) the positive side of electrolytic capacitor C2 is connected to the ground lug of the terminal strip; and (3) the anode of diode D1 is connected to the emitter of Q1, and the cathode goes to S1. The instrument can be operated in either 6- or 12-volt systems without any circuit changes.

**Construction.** All components are mounted in a small metal box. Begin construction by drilling holes to mount the tiny speaker, switch, terminal strip, and grommet. The approximate location of the components is shown in the photograph. Drill several small holes for the speaker grille and insert a piece of grille cloth or wire mesh between the speaker and the box to prevent possible damage to the speaker.

One side of the transformer can be held in place with one of the speaker mounting screws, and the other side with the same screw that is used to mount the terminal strip. All the small components are connected either to the terminal strip or to the switch. Be sure to use a heat sink when soldering the diode and transistor leads.

The wires going from S1 to the ignition switch and to the light switch should be well insulated and flexible to withstand vibration. These leads should be sufficiently long to avoid strain and should be marked to insure correct connections to the ignition and light systems.

**Installation.** A location near the driver’s seat is desirable in order to keep S1 within easy reach. Do not block the speaker opening. In most cases, under the dash near the steering column is the best place for the unit. A couple of self-tap screws will hold the box in place. Before drilling holes in the dash for the screws, make sure that your drill or screws will not damage any wires or instruments behind the dash.

The lead to the ignition system should be connected to the ignition switch terminal which is connected to the ignition coil. If you have difficulty in getting to the ignition switch, you can make this connection at the ignition coil; but be sure to make it on the top side of the primary winding of the coil, and not the side going to the distributor.

Connection to the light system should be made at the light switch terminal which is connected to the taillights. Since the taillights go on when the parking or driving lights are on, the “Auto-Light Minder” will work on the high and low beams, and when the parking lights are on.

Be careful not to create a short circuit while you are installing the unit. Disconnect one side of the battery to be on the safe side. An accidental short with a screwdriver or wrench will cause sparks to fly and possibly destroy or fuse the points of contact.

To check for correct operation, set S1 in the forward position with the ignition switch off, and turn on the lights. The alarm should sound. Turn on the ignition switch, and the alarm will stop (it should not be necessary to start the car). Now flip S1 to the reverse position, and the alarm should sound. Turn the ignition off (S1 still in the reverse position and the lights still on), and the alarm will stop. Return S1 to its forward position, turn your lights off, and then forget about forgetting to turn off your lights.
$2 INTRUSION ALARM

BLAST OF SOUND
GREETS ANY UNWELCOME VISITORS

This innocent-looking thingumajig is a burglar alarm. Knock it over and it emits a raucous, honking noise. Secret of the alarm is a mercury switch.

The author used a metal strap attached to the horn and battery holder to mount the mercury switch. The cardboard ring, which permits the alarm to roll, is simply press-fitted to the tubular container.

THAT'S RIGHT! For a two-dollar bill you can build a portable, dependable, effective alarm. It gives forth with a strident honk whenever a door or window to which it is connected is opened or moved.

The heart of this warning device is the innards from one of those cheap (79¢) bicycle horns seen in auto supply and novelty stores. These horns consist of a very loud honker, a single "D" cell holder, and a push button. While you're in the auto supply store, also purchase one of those tubular cans of tire patching material.

Cut a ½” hole in the metal lid of the tubular can and solder the horn-battery unit to the inside of the lid. Then substitute for the horn button a glass tube mercury switch which is available from most electrical supply houses.* Attach the switch to the battery holder in such a position that the mercury closes the contacts and blows the horn when the unit is tilted from a vertical position.

When you place the alarm upright against a door (in the direction it opens), opening the door will knock the alarm over and sound a warning. If the door opens in the opposite direction, a length of string looped from doorknob to alarm will pull the alarm over. Similarly, a length of string from the alarm to a window will pull it over when the window is opened.

You can also attach the alarm to the door of a cabinet, the lid of a storage chest, a power tool you don't want moved, or anything of this kind. Its small size makes it very handy to take on trips (remove the battery first) for use on those poorly secured hotel and motel doors. And you'll probably think of many other uses for this two-buck alarm.

—R. L. Winklepleck

*Mercury switches are also available from Poly-Paks at about three for a dollar.
If you are a regular reader of the ELECTRONIC EXPERIMENTER'S HANDBOOK, you will not be surprised to find that Dave Weems has provided us with a couple more speaker system enclosure stories. This makes it nine Handbooks in a row that have featured Dave's hi-fi designs. In this issue of EEH, there are two entirely different enclosure ideas—one with “acoustic resistance” (page 61) and one with a labyrinth (page 56). If you're handy with woodworking tools, we're sure you'll find either one of these enclosures a satisfactory addition to your hi-fi outfit.

Several low- and medium-power color organs have been published in previous editions of EEH. At the request of many readers, we asked Don Lancaster to build a color organ that had “power”—and he came up with the “Musette”—750 watts of colorful illumination (page 46). The design is relatively simple and the power-handling capabilities make this one of the most attractive (no pun) projects we've published.

Chuck Caringella's stereo headset adapter (page 53) may—at first glance—seem like a lot of useless nonsense, but look at it closely and then look at your stereo amp. Can you balance, vary, and switch the sound from your easy chair? If you can't—this project is for you.
BUILD THE
MUSETTE

A true high-fidelity multichannel musical kaleidoscope for home entertainment

By DONALD E. LANCASTER

MORE COLORFUL than a performance of Swan Lake by Disney's spectacular dancing waters ... more vibrant than any Discotéque party you've seen ... "Musette," the color organ par excellence, swings and sways as it interprets your favorite tunes in delightful kaleidoscopic animation.

Unlike most low-cost, low-power, photocell-operated color organs (see article in Popular Electronics, March 1965, p. 43), Musette is truly a high-fidelity, high-power instrument. It separates the applied audio from your hi-fi amplifier, AM, FM, or FM stereo receiver into component frequency bands (hereafter called channels). Five such channel separations are provided to cover the full frequency range (see Fig. 1).

The output from each of the five channels can operate up to a 150-watt color purity spotlight to put on a spectacular dancing performance indoors on your wall or ceiling, or outdoors on a special display. For, Musette plays tunes in lights—instead of sounds—by translating the pitch, rhythm, and loudness of speech or music to corresponding variations of color, hue, and brightness.

As a five-channel spotlight control center, Musette can be used for dance hall or patio decoration, as stage lighting for the "Little Playhouse," or as an advertising and sales attraction.

If you are willing—and able—to tackle a really advanced project, and can afford to lay out the 80-odd-bucks for materials alone, the building of Musette should prove to be a rewarding experience. If, on the other hand, you can't swallow

---

Fig. 1. These frequency-response curves show the relative attenuation of each band of frequencies in the audio spectrum.
the high price tag in one gulp, you can still bite off, build, and use the unit one channel at a time, adding more channels when money and time permit.

For maximum utilization of the organ while building, you should start with the high and medium frequency channels. These channels cover a relatively wide range of instruments. Then you can tackle the medium high, medium low, and low channel, in that order.

Simplified Circuit To understand the inner workings of Musette first consider the simplified lamp control circuit of Fig. 2. A lamp in series with a silicon-controlled rectifier (SCR1) makes up the load across the output of a full-wave rectifier (D1 through D4).

The SCR that controls the lamp is triggered by a pulsing circuit consisting of avalanche breakdown (trigger) diode D5, a capacitor charging circuit (C1-R1) and biasing resistor R2.

When the charge on C1 reaches 30 volts, trigger diode D5, interposed between the charging capacitor (C1) and the SCR gate, switches on, causing the capacitor to discharge and trigger the SCR. The ratio of on period to off period, and thus the average brightness of the lamp, is determined by the adjustment of R1, which establishes the charging time of C1. Thus, if D5 turns on the SCR at the start of each half cycle, the lamp will stay on longer than if the SCR is turned on later in that half cycle.

Now if a negative voltage is applied to the cathode side of D5, the effect will be to pre-bias the diode so that it conducts and triggers the SCR earlier during each half cycle. The greater the negative bias, the earlier the SCR will be turned on, and the longer will be the on cycle that applies power through the lamp. Initially, potentiometer R1 is adjusted to set the lamp at a minimum brightness level. Then, any varying negative voltage across R2 will produce a corresponding variation in brightness levels.

Fig. 2. Simplified schematic shows how an SCR can be made to fire in synchronism with the a.c. line frequency.
Fig. 3. Overall circuit of five-channel color organ is made up of five basic circuits easily identified by individual input transformers (T1 through T5). Each circuit operates its own display lamp.
In practice, this negative voltage is obtained from a rectified and filtered audio signal by an action similar to that which produces the a.v.c. voltage in an AM receiver.

**Actual Circuit.** Now, let's look at the overall schematic of the five-channel color organ (Fig. 3). Each channel is identified by a separate input transformer (T1 through T5).

Except for the fact that each channel responds to a different portion of the audio spectrum, and thus each colored light represents a specific band of frequencies, all the channels operate in the same manner. Therefore, it will suffice to explain how a single channel operates. To make matters easy, let's discuss the channel at the top of Fig. 3. This happens to be the high channel.

Potentiometer R13, in the primary of input transformer T1, is used to adjust the sensitivity of the channel. Capacitor C7, together with the inductance provided by the secondary of T1, forms a parallel resonant bandpass filter. The audio across T1 is rectified by D1 and filtered by C2 and R8, a changing negative voltage that is applied across R8 to prefire D16 and vary the brightness of the spotlight in the anode circuit of SCR1. Diode D6 and capacitor C17 isolate the negative voltage from the SCR's gate. All other components operate as described for Fig. 2.

Operating power is obtained from the a.c. line, and rectified by the diodes forming the full-wave bridge rectifier. Pilot lamps 16 through 19 provide illumination for the special translucent knobs used in the project. The display lamps (11 through 15) are connected in series with their respective SCR's through plug P1 and socket SO1.

If you are an old pro and can wire directly from a schematic diagram, you may—but need not—use a printed circuit board for component layout. Actually, the only advantage you get from a printed circuit board is the elimination of point-to-point wiring which usually requires more layout space. However, in special instances like this color organ, the use of a printed circuit is almost an absolute necessity. First, the layout has been arranged to minimize and/or eliminate the chance possibility of feedback. Secondly, the printed circuit board affords the best means to mount wave bridge rectifier assembly (Motorola MDA 062-3 at $4.35—no heat sink required) SCR1-SCR5—2N3528 silicon-controlled rectifier (RCA), 1.6 amperes, 200 volts. 

**SO1—6-prong, high-current socket (Cinch Jones S-306-AB)**

SI—S.p.s.t., slide switch, 6 amperes, 110 volts; T1-T5—Thorderson 2454 audio output transformer: primary, 15-20,000 ohms; secondary, 3.5 ohms, 5 watts (do not substitute); available from Newark Electronics, No. 5F2004, for $1.25 each in lots of 5, plus shipping. 1—8 1/2 x 4 3/4 x 2 3/4 cabinet (LEM CB-R, available in grey or brown or black)

1-Set of Tenite translucent knobs (10 knobs colored red, yellow, green, blue, and milky white)—optional

1—6 1/2 x 2 3/4 x 3/4" printed circuit board**

1—7 1/4 x 3 1/2 x 3/4" aluminun sheet (for bracket)

4—Bayonet pilot light sockets (Lecraft—7-11)

Misc.—1/4"-high spacers (4), 3/8"-high spacers (8), #6 hardware, pop rivets, line cord (minimum 6-amp. rating), Heyco strain relief, wire, solder, display cable (Belden 8467), swivel-type outdoor sockets for display lamps, plywood base and junction box, display materials, reflectors or diffusors, 6-amp. fuses (do not eliminate)

6-Bayonet, 250-volt, 11-prong, high-current socket (RCA), 1.6 amperes, 200 volts. 

**Etched and drilled fiberglass circuit board (less parts) available for $3.50 postpaid from DEMCO, Box 16397, San Antonio, Texas 78216; a special kit of major components is $40.00.**
your SCR's. Thus, whether you buy or etch your own—use a PC board.

If the author's design is followed, you will come up with a presentable unit that will work just as well as it looks. But you can vary the packaging, as preferred, without loss of performance.

Whatever you do, don't substitute any other type of input transformer for T1 through T5, and be sure to use the exact value of capacitors specified for C1 through C7. The reason is that each transformer and its corresponding tank capacitor comprise a parallel resonant circuit which determines the frequency bandpass of each channel.

Construction. You can start construction with the circuit board, which should be etched and drilled as shown in Fig. 4. If you prefer, you can buy this PC board (see Parts List). Mount the components on the PC board as shown in the layout guide (Fig. 5), and then put the board aside temporarily.

Cut and form an aluminum mounting bracket for the controls and pilot lamps as shown in Fig. 6. Both the dimensions of the bracket and the spacing for the mounting holes are determined by the chassis enclosure selected.

After mounting the controls and the pilot lamps on the bracket, install the bracket on the chassis, following the spacing shown in Fig. 7. Carefully measure the shaft positions, and drill or punch out the front panel holes to accommodate the potentiometer shafts. If
you plan to use the recommended Tenite translucent knobs, bear in mind that each hole should be slightly larger than the knob diameter.

To avoid costly errors when drilling the front panel holes, make a cardboard template to use as a drill guide once you have verified all the dimensions. If you decide not to use the special knobs, make the front panel holes just large enough for the shafts. (In this case, the pilot lamps may be unnecessary.)

Finally, drill the mounting holes for the power switch in the front panel. If you don’t have a rectangular punch, you can make the rectangular switch cut-out by first drilling a large enough hole, and then filing the hole into a rectangular shape as required.

Now turn to the rear panel and determine a suitable layout for the input and output connectors (J1 and S01), the fuse holder, and the line cord strain relief. From Figs. 8 and 9 you can determine the best place to mount the full-wave bridge rectifier, as well as resistors R3 through R7 which are installed on the inside of the rear panel. Observe the mounting position of the terminal strip.

Install the circuit board on the chassis (see Fig. 8) using four spacers. The transformers are secured to the top surface of the chassis, between the front
panel and the circuit board, with #6 hardware.

After all the parts are installed, you can begin the point-to-point wiring. Start with the power circuit by completing the connections on the rear panel. Then wire up the four pilot lamps in series as shown in Fig. 3. Wire the transformer and potentiometer leads next. After you have made all connections shown in the schematic, start testing out the instrument.

Testing. With the power switch set to the off position, connect an audio line from the output of your amplifier (across the speaker voice coil or the 16-ohm speaker terminals) to the input jack (J1) on the rear panel.

Measure the voltage, in turn, across capacitors C2 through C6. Depending on the input voltage from the audio amplifier, and the setting of the respective SENSITIVITY potentiometers (R13 through R17), the voltage across each capacitor should be somewhere in the range between -1 and -16 volts.

Best operation is usually obtained with the sensitivity control set approximately 1/3 of the way up from minimum resistance. In any case, avoid turning any of the pots all the way up as this will only overdrive the channel.

After testing and adjusting the sensitivity of each channel, disconnect the audio input. Finally, connect a 25-watt incandescent test lamp from the hot lead going from output receptacle SO2 to the anode of one of the SCR's. Apply input power and vary the corresponding BACKGROUND potentiometer (R18 through R22) to check the operation of the channel under test. The lamp should glow smoothly from minimum brightness to full brightness. Then set the potentiometer for minimum brightness. Check each of the remaining channels in the same manner.

Preparing a Display. A typical display arrangement is shown in Fig. 10. It is made up of five swivel-type outdoor spotlights mounted on a sheet of 13" x 27" x 3/4"-thick plywood. The size of the board can be varied to suit specific applications. If the lamps are to perform inside a display, you can use either diffused (Continued on page 139)
CERTAIN solid-state hi-fi/stereo amplifiers require special consideration when stereo headphones are to be used. If you own one of these amplifiers, here is "how-to-build-it" information on a universal speaker/headphone control unit—which, incidentally, can also be employed with any conventional tube-type stereo amplifier. With this control unit, you can remotely select speaker or headphone operation—and adjust headphone volume level—without leaving your easy chair.

Stereo headphones offer the hi-fi enthusiast the optimum in stereo realism—in complete privacy—without having to sit in a fixed listening location. The stereo listener is not bothered by the usual household sounds, and conversely, others can read or watch television undisturbed.

Some stereo amplifiers incorporate a built-in, standard, 3-conductor phone jack for stereo headphones, while in several of the new solid-state stereo amplifiers a special circuit for stereo headphones must be devised. A typical example of the latter is the Heath Model AA-21 or AA-21C.

BUILD A Stereo Headphone Control Unit

Ideal companion for transistorized amplifiers combines safety from burnouts with maximum convenience

By CHARLES CARINGELLA
No Common Grounds. The Heath AA-21 requires that the speaker “common” line in the left channel be completely isolated from the “common” line in the right channel. The “common” terminal in the output of each channel is electrically above chassis ground. Each “common” line is returned to ground within the amplifier through a 0.18-ohm resistor. Both resistors are part of networks which provide a form of current feedback. Therefore, the common-terminals cannot be tied together with one “common” line into a 3-wire stereo headphone circuit, nor can the common lines be grounded to the AA-21 chassis. This means that two wires must be run to each speaker. You cannot run one “hot” wire to each speaker and use a single “common” return.

Conventional stereo headphones are sold wired to a 3-conductor phone plug. One conductor is connected to the left-channel earphone and another conductor to the right-channel earphone. The “common” return leads for both earphones are tied together to the third conductor, which also serves as the grounding sleeve, in the phone plug.

Obviously, such stereo headphones cannot be used directly with the amplifier described above since the “common” leads are tied together. The stereo headphone control unit shown in the schematic diagram allows headphones to be used with such an amplifier, without modifications to the amplifier or to the headphones. The control unit adapts the “4-wire” output of the amplifier to the “3-wire” headphone set.

How It Works. Complete isolation between channels is made possible by using two transformers, T1 and T2. The primary of T1 is connected to the output of the amplifier left channel and the primary of T2 goes to the right channel.

PARTS LIST

| J1—3-conductor, open-circuit, standard phone jack (Switchcraft 12B or equivalent) |
| R1a/R1b—Dual 100-ohm potentiometer with concentric shafts (R1a—Centralab “Fastatch” F1-100, R1b—Centralab FFS012, ¾”-long sleeve shaft; Centralab RFS012, ⅜”-long inner shaft) |
| R2, R3—4-ohm, 10-watt wire-wound resistor |
| S1—D.p.d.t. toggle switch |
| T1, T2—Transformer output transformer; primary impedance, 32 ohms, CT; secondary impedance, 4, 8, and 16 ohms (Merit A-2745 or equivalent) |
| 1—Length of 8-conductor cable—as required (Belden 8448 or equivalent) |
| 2—6-lug terminal strips (Cinch-Jones 2006 or equivalent) |
| 1—Angle bracket, made from ⅛”-thick sheet aluminum |
| 1—5” x 6½” panel, made from ⅛”-thick sheet aluminum |
| 1—6-13/16” x 3-9/32” x 2-5/32” black molded plastic instrument case (Harry Davies 260 or equivalent) |
| 1—Set of dual concentric knobs |
| 1—Plastic cable clamp for ¼”-diameter cable |
The author made a simple aluminum bracket to mount the two transformers back to back. Remainder of internal wiring is obvious from this rear view.

The secondary windings of T1 and T2 drive the stereo headphones. The secondary “common” leads are tied together and connected to ground. Concentric potentiometers R1a and R1b serve as the volume level controls. Dual knobs are attached to the concentric shaft and it is possible to adjust the two volume controls individually or simultaneously. Switch S1 selects either speaker or headphone operation.

An 8-conductor cable connects the headphone control unit to the amplifier. Almost any length of cable can be used. It is possible to run the cable across an average-size room (25-30 feet) without noticeable high frequency loss.

Resistors R2 and R3 are connected in series with the primaries of T1 and T2 for amplifier protection against overload at low frequencies. The Heath AA-21 is designed to operate into a minimum of 4 ohms resistive load. Since the d.c. resistance of the primaries is quite low, resistors R2 and R3 must be used in series with the windings. You can omit R2 and R3 if the control unit is used in conjunction with some of the other stereo amplifiers.

Construction. The completed control unit is housed in a molded plastic instrument case as shown in the photos. A 5" x 6½" front panel is made from ⅛"-thick sheet aluminum. After all the necessary holes have been drilled, the panel can be sprayed with lacquer of a suitable color. Instrument decals can be added for a finished “professional” appearance.

An inside view, showing the location of all components, can be seen on this page. Parts layout is not critical. Transformers T1 and T2 are mounted on an L-shaped bracket also fabricated from ⅛"-thick sheet aluminum.

The multi-conductor connecting cable has an outside diameter of approximately ¼". A suitable hole should be drilled in the top side of the instrument case to allow the cable to pass through.

Using the Control Unit. Only one adjustment is necessary, and that is, properly phasing the left and right channels. For proper operation, the two earphones should be “in phase.” This means that the diaphragms in the earphones should move in and out at the same time when they are driven by identical signals.

If you own a Heath AA-21, you have probably “phased” the speakers properly by following the procedure outlined in the instruction manual. The AA-21 is (Continued on page 142)
PUT AN AIR BRAKE ON YOUR WOOFER

How to get good bass response out of a $5.95 speaker without boom

By DAVID B. WEEMS

An interesting development in the evolution of the bass reflex enclosure was "friction loading" as used by Goodmans of England, wherein an "acoustic resistance unit" (A.R.U.) is placed across the open port to reduce the boom effect. While it really worked, it was criticized by some audio designers as a waste of power—the audio equivalent of driving a car with the brakes on—but the concept is ever with us and is gaining more advocates.

Actually, the speaker itself undergoes a kind of braking action to reduce overshoot and distortion. In the case of expensive speakers, the braking action is enhanced by a powerful magnetic field through which the voice coil travels. Low-cost speakers are more likely to suffer from "hangover" due to weak magnets; poor suspensions don't help either. Because the magnets are costly, their weight alone is sometimes a fairly good indication of speaker quality, particularly within a brand line. However, consideration of weight alone can be quite misleading, as different magnet materials have different magnetic strengths per ounce. When it comes to magnets for speakers, the larger the magnetic strength (gauss), the better.

But if the speaker is completely enclosed and vented to provide just enough resistance to the air flow, the restoring force to the cone is quite similar to that obtained from the magnetic field surrounding the voice coil. Therefore, instead of trading dollars for magnets to put on the brakes, when you build an enclosure, you can incorporate the A.R.U. feature.

Air brakes and large magnets are fine, but there is more to a good speaker. In the case of a woofer and its low frequency response characteristic, the lower the cone resonant frequency the
better. The $5.95 speaker used here checked out unusually well in this respect; resonance in "free air" was on the order of 35 to 40 hertz. A separate small tweeter and an L-pad is used to handle and balance the upper portion of the audio spectrum.

Experiments With a $5.95 Woofer. The first experiment saw the woofer mounted in a 1 cu. ft. box similar to the "Cinderella" enclosure (October, 1965). Performance was fairly good, but the 35- to 40-hertz bass resonance of the speaker—when enclosed in the box—moved up to 75 hertz, and so some potential bass response was lost. Turning up the bass control on the amplifier helped, but the overall effect was that of a woofer with a mild case of claustrophobia. The sound was not as satisfying as that produced by the small woofers in the Cinderella system. Evidently, a larger box was in order.

Next, continuing with the infinite baffle concept, a larger enclosure was used. In the new sealed box, the bass resonance dropped to 55 hertz, and the bass response was much better than you would expect from a low-priced woofer—sound was good but not spectacular. Indications were that the size of the enclosure was right, and the time had arrived for the addition of the A.R.U. feature.

Then the tedious part of the experiments began—drilling holes by installments and testing the results of each additional set of holes. The tests clearly demonstrated the inadvisability of just putting any old speaker in any kind of box. So, if you want to adapt this idea to other speakers, and make your own tests, you'll have to use an audio generator and a VTVM connected as shown in the diagram of the test setup.

The first batch of holes was drilled in the bottom of the box, converting the system from a sealed enclosure to a bass reflex type. With each series of holes, the voltage across the speaker voice coil was checked as the audio generator signal was varied from 200 hertz down to 20 hertz. The first sweep showed a voltage peak at 70 hertz and another at 25 hertz. Since these peaks were not even close to equal distance from the original peak of 35-40 hertz, it was obvious that the box was mistuned. Going back over the frequency run again showed that the peaks were also greatly unbalanced in amplitude, the lower peak being about twice as high as the upper peak.

Unfortunately, too many holes had been drilled. Tacking two layers of 1/2-inch polyurethane foam plastic over the holes brought the upper peak down to 60 hertz and lowered the amplitude of the lower peak, which proved that you can tune a bass reflex enclosure with an A.R.U.

After closing some of the bottom holes to obtain better matching, work was begun on the enclosure interior. After all, the original purpose of the box was to try the air brake idea with a resistive compartment around the woofer. Next, 165 1/4-inch holes were drilled into the triangular side piece (M) and the sloping back panel (L) until the remaining voltage peaks at 54 hertz and 21 hertz were insignificant. That point was reached with 170 holes in the sloping panel. A further frequency run showed dips in sound output at some points—apparently internal reflections were...
Except for the front, all inside surfaces of the woofer cage are covered with foam plastic. Loosely pack the woofer cage with a sheet of fiberglass.

**BILL OF MATERIALS**

A—18" x 22" x ¾" plywood for front and rear (3 required)
B—17½" x 19½" x ¾" plywood for top and bottom (2 required)
C—17½" x 22" x ¾" plywood for sides (2 required)
D—16¼" x ¾" x ¾" cleat (4 required)
E—22" x ¾" x ¾" cleat (4 required)
F—11" x ¾" x ¾" cleat
G—11¾" x ¾" x ¾" cleat
H—10½" x ¾" x 1½" cleat
I—11" x ¾" x 1½" cleat (1 side faced 45°)
J—1" x 2" diagonal brace for top, back, and both sides (about 96" required)
L—17½" x 12½" x ¾" plywood
M—11¾" x 19¼" x ¾" plywood (cut diagonally)

1—3-sq. ft. sheet of polyurethane foam plastic
1—3-sq. ft. sheet of fiberglass
1—2-yd. piece of cheesecloth
1—24" x 28" piece of grille cloth
4—4" legs (optional)
1—CTS-10WF 10" woofer*
1—TS-5051 3½" tweeter*
C1—5-μF, 25-volt capacitor
R1—8-ohm 1-padd (Calrad LP-8 or equivalent)*
Misc.—1½" x 8 flat-head wood screws (1 box), 2½" x 8 flat-head wood screws (6), glue, plastic, wæter, or stain and varnish, molding, etc.

* Available from McGee Radio Co., 1901 McGee St., Kansas City 8, Mo. (Woofer, $5.95; tweeter, $2.95. 1-padd, $1.49. Shipping cost extra.)

**NOTE:** Cleats and braces can be made from pine; all other lumber is at least 5-ply wood.

causeing cancellations. Foam plastic was stretched over the drilled panels, and the compartment was filled with fiberglass to alleviate this problem.

Compared to earlier listening tests, the sound quality was significantly improved. The bass response appeared to be smooth and extended further downward in range from the former limits. However, there was one criticism offered by careful listeners; the low end seemed to be too well damped. Several more sets of holes were drilled in the sloping panel, bringing the total up to 250. This change produced a fuller bass, but still not boomy. However, the lack of boom produced a slight imbalance in favor of the tweeter, and so a tweeter control (R1) was added as a further refinement.

**Construction.** You can cut costs by using the cheapest grade of construction plywood available; such material is satisfactory from a performance standpoint, but for good appearance must be covered. However, a good furniture finish calls for a good grade of lumber.

Except for the diagonal braces (K) which are used to stabilize the large unsupported surfaces, and the cage around the woofer, construction of the enclosure is quite ordinary. Strips of ¾" x ¾" pine (D, E, F, and G) are screwed and glued to the front panel, and cleat H is fastened to the side panel in a similar manner, to simplify construction of the woofer compartment. The drilled triangular side panel of the cage (M) is fastened to the bottom and front with glue and with six 2½" x 8 flat-head screws fed into front and bottom of cabinet from outside, and by ½" screws through piece L.

(Continued on page 141)
...and enjoy a new dimension in sound

By STEPHEN E. AUYER

DO YOU HAVE an inexpensive tape recorder and about ten bucks to spare? Why not build an echo chamber for the tape recorder and really enjoy a new dimension in sound effects? Few devices can add as much pleasure and enjoyment to tape recording as an echo chamber. And as a family fun-maker and entertainer, it has no peer.

Actually, an echo chamber is a very simple device. It takes a recorded sound, delays it, and then sends it on to follow the original sound. The delayed sound is heard as an echo, and produces a very pleasant effect.

How It Works. An additional pickup head is installed on the tape recorder about two inches away—in the direction of tape travel—from the recording head (for tape speeds of 3/4 ips). A signal is recorded on the magnetic tape as it passes the original head. As the tape moves on, the same signal is picked up by the new head (Fig. 1), amplified by Q1, and re-recorded as an echo a short time later. The setting of R5 determines how much of the signal is fed back and re-recorded to produce a strong or weak echo as desired; distance between heads determines echo separation.

The echo chamber preamplifier circuit is shown in Fig. 2. Transistor Q1 in a common emitter configuration provides sufficient gain to the delayed signal. Base bias is achieved by the voltage divider action of R1 and R2. The collector voltage is developed across R4.

Capacitor C2 bypasses emitter resistor R3 to eliminate degeneration, while C3 serves to block d.c. from across R5. Capacitor C5 couples the audio to the recorder amplifier.

Fig. 1. This simplified functional diagram shows a modified tape recorder with new head, echo preamplifier, and echo control R5.
During operation, the echo control (1) is turned up just enough to produce the desired echo level. If greater echo separation is desired, move new head (2) further away from the main recording head.

**PARTS LIST**

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1, C2, C3, C5</td>
<td>10-μF, 20-volt electrolytic capacitor</td>
</tr>
<tr>
<td>C4</td>
<td>5-μF, 10-volt electrolytic capacitor</td>
</tr>
<tr>
<td>Q1</td>
<td>2N1274 transistor (or any general-purpose audio type)</td>
</tr>
<tr>
<td>R1</td>
<td>47,000-ohm, 1/2-watt resistor</td>
</tr>
<tr>
<td>R2</td>
<td>10,000-ohm, 1/2-watt resistor</td>
</tr>
<tr>
<td>R3, R6</td>
<td>1000-ohm, 1/2-watt resistor</td>
</tr>
<tr>
<td>R4</td>
<td>4700-ohm, 1/2-watt resistor</td>
</tr>
<tr>
<td>R5</td>
<td>50,000-ohm potentiometer (with switch S1)</td>
</tr>
<tr>
<td>S1</td>
<td>S.p.s.t. switch (mounted on R5)</td>
</tr>
<tr>
<td>S2</td>
<td>Tape head (Midland 25-735 or Lafayette 90 R 6194)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Small piece of perforated phenolic board, knob, mounting hardware</td>
</tr>
</tbody>
</table>

**Construction.** The preamplifier can be assembled on a 2" x 3" piece of perforated phenolic board, using push-in Vector terminals for the connections. If there is a space problem, you can use a smaller board and simply utilize both sides of the board. Mount the assembled board in any convenient spot in the recorder using stand-off spacers or two right-angle brackets which you can make from a thin piece of aluminum cut to the proper size.

Install the echo control (R5) at any convenient spot on the tape recorder deck. Then connect the + (plus) side of C3 to the echo control (see Fig. 2). Now wire the plus side of C5 to the center lug of R5, and the other side of the capacitor to the output terminal of the tape recorder volume control. And be sure to establish a good common ground between preamplifier and recorder.

Mount the second tape head approximately two inches away from the first head, in the direction of tape travel. A word of caution: in many of the lower priced units, all parts of the tape do not make uniform contact with the head as the tape passes over it. For best results, you must therefore make certain that the second head covers the same part of the tape as the original head.

It may be necessary to install additional tape guides to keep the tape properly aligned. These can be made from a 1/2"-long, 1/8"-o.d. brass spacer, and can be secured to the deck with 3/4"-long #4 hardware. Use shielded cable when connecting the new head to its preamplifier.

**Operation.** Set up your recorder for normal recording. While monitoring the signal being recorded, increase the setting of the echo control (R5) until the desired amount of echo is produced. If the echo control is advanced too far, you will get an annoying feedback.

If your recorded sound comes out too "brassy," chances are the recording heads are not properly aligned. To correct this condition, loosen the screws that mount the second head, and rock the head slightly from side to side until the best response is obtained.

You can get an interesting effect by connecting the tape recorder monitor output to your hi-fi system, while the recorder is set to the record position. Then, as you talk into the microphone, your voice—plus its echo—will be heard.

For an extra-special sound effect, try connecting the output of an audio oscillator to the echo chamber. Then vary the frequency of the oscillator while recording.
IF THERE'S one thing most audio experts seem to agree on, it's that the battle over the relative merits—or demerits—of different speaker enclosure designs rages on unabated.

Advocates of the labyrinth-type enclosure have long attested to its superior reproduction qualities at the lower limits of the speaker's frequency range. They also claim better transient response and less obvious effects of any mismatch.

Proponents of the bass reflex type enclosure counter by noting that one can easily correct a mismatch in a bass reflex cabinet without resorting to major surgery. They will even admit to superior low-frequency response in horns or pipes while claiming that the latter tend to impede reproduction in the midrange.

Many authorities have downgraded the bass reflex enclosure by stating flatly that if critics call the labyrinth a resonant pipe, then the bass reflex is nothing more than a resonant box.

But even the most fanatic partisan will admit, privately, that not even his own pet speaker system is perfect. That being the case, any new speaker or enclosure design always evokes a great deal of interest—and suspicion.

A New Design. From England comes a new speaker enclosure design which has been dubbed an *acoustical transmission line* by its designer, A. R. Bailey, of the Bradford Institute of Technology. At first glance, it looks somewhat like a labyrinth enclosure, except that the length of the pipe—eight feet—suggests a departure from labyrinth design.

An unusual feature is that the cabinet is filled with long-fiber wool, in contrast to the common practice of just lining the wall surfaces of an enclosure. In all
probability, Bailey got his name for the enclosure from a theory for electrical transmission lines, which states that if a line of finite length is terminated in a resistance equal to the characteristic impedance of the line, disturbances along the line are not reflected back to the source, and such a line will behave as though it were of infinite length. The fiber wool acts as the terminating resistance in an acoustical transmission line.

But the more you look at Bailey's enclosure, the more it looks like a modified labyrinth. Recall that labyrinths provide maximum damping at one-quarter wavelength while maximum sound output is obtained at one-half wavelength. The 8’ length specified by Bailey corresponds to a quarter-wavelength at 35 Hz—just about the resonant frequency specified for the woofer.

In reality, Bailey's contribution seems to be mainly the long-fiber wool which damps resonant frequencies and produces an ultra-low-pass filter that eliminates midrange interference. Also, with this design, speaker mismatch is difficult to detect.

Bailey's speaker enclosure design employs an oval-shaped British speaker that is not generally available. It has, therefore, been modified slightly by the author to accommodate an American-made low-resonance 12" speaker—the Allied Radio KN-888HC. Also, since long-fiber wool is not generally available, kapok has been substituted.

The enclosure presented here performs well in the 50 to 60 Hz range and has excellent transient response. But this doesn't mean that everybody will like it; after all, not everybody likes lobster, either.

Incidentally, this version of Bailey's enclosure is called the long-tailed phase inverter simply because it has an extra-long curled tube which reverses the phase of the low-frequency rear wave coming from the speaker to reinforce—rather than cancel—the sound coming from the front of the cone.

Construction. An important design feature of any speaker enclosure is its rigidity. And although labyrinths are not subject to unduly high pressures, every precaution must be taken during construction to insure the utmost in rigidity.

This means that screws should be closely spaced and in tight, and that all joints should be glued in place.

Your first task, of course, will be to cut the plywood and pine cleats to the sizes specified in the Table Of Dimensions. One important rule of thumb is to measure twice, cut once. Also, a note of caution: when cutting out the 18" slot in panel K, be careful to make the slot just wide enough to accommodate panel J snugly.

Overall dimensions for the enclosure, including measurements for panel mounting, are given in Fig. 1. Additional construction details appear in Fig. 2. Note that panel H is first cut at 45° so that one side has a width of 5¼" while the other is only 5½" wide. Then the longer side is trimmed down so that the thickness of the tapered edge is ¾".

After sanding down all the panels, and before assembly, draw a guide line through the middle of panels G, H, I, and

---

**Table of Dimensions**

<table>
<thead>
<tr>
<th>IDENTIFICATION</th>
<th>SIZE</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>plywood 3/4&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, B 22 1/2&quot; x 37 1/2&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>C, D 18&quot; x 37 1/2&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>E, F 18&quot; x 24&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>G 22 1/2&quot; x 14 1/2&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>H 22 1/2&quot; x 6 1/4&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>I 22 1/4&quot; x 6&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>J 22 1/4&quot; x 18&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K 9 3/4&quot; x 23&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>clear pine 3/4&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front (lower sides) 3/4&quot; x 23&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Front (bottom) 3/4&quot; x 10&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Front (top) 3/4&quot; x 22 1/2&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Front (upper sides) 3/4&quot; x 13 1/2&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Rear (sides) &amp; diagonal brace for back 1 1/2&quot; x 36&quot;</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Rear (top &amp; bottom) 1 1/2&quot; x 22 1/4&quot;</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 1. Overall dimensions are provided in front view drawing of phase inverter enclosure (above). Location and mounting dimensions of interior panels are shown in the side view. At upper right, finished cabinet is packed with kapok, while interior surfaces are lined with a thin layer of cotton or wool batting.

Fig. 2. The slot in panel K (below) must be cut to close tolerances to insure a tight fit during assembly. Panel H is first cut at a 45° angle and then the points are cut off.

After fitting panel J tightly into K, secure the cleat at the joint with both screws and glue.

Photo at right shows location of each panel in the enclosure. All contacting surfaces of G, H, and I should be glued before screwing them to K.
After cutting and fitting the cleats, apply a little glue to the contacting surfaces, and nail them in place temporarily with small nails. Then secure them permanently with #8 x 1 1/4” flathead screws.

J where they will be attached to panel K. After panel J has been pushed into position, attach a 3/4" x 3/4" x 18” cleat to panels J and K (see photo) using glue and screws.

All contacting surfaces of panels G, H, and I should be liberally glued and then screwed to panel K. Screws should go diagonally through H into I and G (see Fig. 2).

Next, you can mount the previously assembled panels on the bottom piece, E, after which you add the sides, C, and D, and the top, F. Incidentally, you will find it a lot easier to add cleats to these parts before assembly. Note from the illustrations that the partitions are recessed 3/4” in from the front and sides of the baseboard in order to accommodate the front and side panels.

Apply glue to the edges of the partitions and then nail the front and side panels to the partitions. Then add a few 2”-long screws to give extra strength to the joints.

This is a good time to pack the middle section of the labyrinth with kapok. (Long-fiber wool is preferred, of course, if you can get it.) However, because kapok tends to settle, you should tack a single layer of cheesecloth from the bottom of panel G to the back of panel J (see Fig. 1).

After half-filling the partitions, make a pillow of loose kapok wrapped in cheesecloth and drape it over the top of J to fill the upper middle section as well as the front tube. Now you can attach the front panel using both glue and screws to secure it in place. Turn the cabinet upside down and finish filling the front tube with kapok right up to the level of the port. Tack another cheesecloth partition across from the top edge of the port to the front of panel J. Then fill the area behind the port with kapok.

Finishing Touches. Paint the side and front of the labyrinth with flat black paint and allow it to dry thoroughly before adding the grille cloth. It is advisable to cover the port with a piece of open-weave black cloth.

Because grille cloth is available only in 36” widths, and since the height of the cabinet is 39 inches—not including feet—it is necessary to use trim that

(Continued on page 141)
INEXPENSIVE INTEGRATED SOLID-STATE STEREO RECORD PLAYER

Cool, compact amplifier fits into record changer base

By JAMES E. ROHEN, K8NQH/2

ONE MAJOR TREND these days in hi-fi circles is towards integrated sound systems in which all components are in one cabinet. This trek towards compactness has been considerably aided by the availability of small all-transistor amplifiers that run cool and sound good.

The push-pull amplifier used here has 10 transistors, measures only $8\frac{1}{2}'' \times 6'' \times 1\frac{1}{2}''$, puts out about 8 watts (music power), and has a frequency response of 30 to 20,000 Hz. It costs only $19.95. According to the Burstein-Applebee catalog, the amplifier is marked down in price because of factory overproduction, and is a high-quality import. It requires only 10 volts a.c. for power, which can be obtained from a transformer selling for $2.00. See Parts List on page 66.

Assembly. You can spend an evening assembling a compact integrated stereo record player and enjoy many years of record listening. All you have to do is drill a few holes, mount a few components, and solder a few connections. The completed unit is adaptable to AM and FM tuners, tape decks, etc.

Connect the step-down transformer to the a.c. line through the record changer on-off switch to automatically shut off the amplifier after the last record has played. If you intend to connect a tuner to the amplifier, use a separate on/off switch to allow operation of the tuner without having the record changer running.

No dimensions are given for location of the holes in the changer base as different changers have different size bases, and different clearances inside the base. The bezel plate furnished with the amplifier can be used as a template for marking the position of the front panel controls. The transformer and other switches can be placed wherever they will fit. Before cutting any mounting holes, let the changer run through a change cycle to be sure that there is enough clearance between the amplifier and other components you install and the record changer mechanism.

Optional Features. A pilot light, and speaker channel and speaker phase reversal switches are optional items, but do much to enhance the record player's versatility and ease of operation. The wiring diagram shows how to hook up these switches.

The speaker channel reversal switch is handy when a friendly neighbor comments that the French horn is playing on the wrong side of the orchestra. The phase reversal switch enables you to quickly change the phase of the speaker in one stereo channel to agree with the phase of the speaker in the other chan-
Switches add versatility. You can instantly flip right and left channels, as well as check and change speaker phase, with S2 and S3 respectively. Stereo/mono switch S4 "desensitizes" cartridge to vertical stylus motion in mono position—a desirable feature for mono recordings. S1 may be on record changer.

### PARTS LIST

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1, S4</td>
<td>S.p.s.t. toggle switch</td>
</tr>
<tr>
<td>S2, S3</td>
<td>D.p.s.t. toggle switch</td>
</tr>
<tr>
<td>TI</td>
<td>Power transformer: primary, 117 volts; secondary, 20 volts with center tap</td>
</tr>
<tr>
<td></td>
<td>(Burstein-Applebee, Kansas City, Mo., 18B508, $1.99)</td>
</tr>
<tr>
<td>I1</td>
<td>Pilot light (Drake indicator lamp with built-in resistor, Tinnerman nut mounting)</td>
</tr>
<tr>
<td>1</td>
<td>Push-pull amplifier (Burstein-Applebee, 30C27, $19.95)</td>
</tr>
<tr>
<td>1</td>
<td>Stereo record player, ceramic cartridge</td>
</tr>
</tbody>
</table>

Solid-state stereo amplifier runs cool and is compact enough to fit into record changer base. Parts location is not critical, but adequate clearance for the changer mechanism must be provided. It's a good idea to run the changer through a cycle by hand in order to check clearance requirements.

Proper phase is achieved when the sound is best. A stereo-mono switch is also shown and is optional, but it can improve the sound from many mono records. When the switch is open, normal stereo operation is obtained. When the switch is closed, both channels are paralleled and the cartridge becomes effectively insensitive to vertical stylus movement. (Vertical stylus motion on a mono record can cause undesirable responses in a stereo cartridge.) All wires leading to the cartridge and stereo/mono switch should be shielded and grounded at one end.
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1967 Spring Edition

CIRCLE NO. 8 ON READER SERVICE CARD

CL-259
INTERSTATION HISS SUPPRESSOR FOR FM TUNERS

By JAMES T. SAMUELSON

If you have a hi-fi FM tuner similar to the Heathkit PT-1, the addition of only four parts will kill the “Niagara Falls” sound effect heard between stations. This interstation hiss is unwelcome and unnecessary. A hiss suppressor can be added to most FM tuners equipped with a built-in tuning meter amplifier.

Referring to the schematic diagram, you simply open the cathode-to-ground connection of V15 at pin 3, and wire in the parts as shown. A small piece of phenolic board can be used to support the added components. Connect the collector of Q1 to pin 7 of V16. Then set potentiometer R1 to a desired threshold level, and button up the set.

Interstation hiss, or “white noise” as it is often called, is usually heard when r.f. or i.f. amplifiers are operating under maximum gain conditions. When no signal or a very weak signal is present, little or no a.g.c. voltage is developed so the amplifiers run wide open. A strong or medium signal, on the other hand, develops a negative voltage which biases the amplifiers to a lower amplification level and reduces white noise accordingly.

When negative a.g.c. voltage is weak or missing, V15 also runs wide open, and a relatively large current runs through R1, V15, and the meter, developing a relatively large voltage across R1. This voltage at the junction of R1 and Q1 is positive with respect to Q1’s emitter and causes Q1 to conduct, “shorting” the signal input (which is now nothing but noise) on the grid of V16 to ground.

But when a signal is present, a.g.c. voltage cuts down the current flow through V15, reduces the voltage drop across R1, removes the forward biasing voltage on the base of Q1, and Q1 stops conduction. When Q1 doesn’t conduct, collector resistance to ground is very high and the audio amplifier operates as though the anti-hiss circuit doesn’t exist.

Threshold level is determined by D1 and D2 (general-purpose silicon diodes), and the setting of R1. Once R1 is adjusted, it does not have to be reset, except perhaps to compensate for tube aging. A fixed resistor can be substituted for R1 after it has been properly adjusted and the amount of resistance needed in the circuit is determined.

This circuit can be added to any FM tuner with a tuning meter amplifier and a cathode follower or audio amplifier output. Only four components are needed and they can be mounted on a small piece of punched phenolic board measuring only 1” x 2”. The “subchassis” can then be attached to a convenient support under the chassis deck of the FM tuner. To keep the size small, a low-cost, multiple-turn potentiometer is suggested for R1; after several months of use, as the tuner tubes began to age, this control still did not require resetting.
Maybe we’re letting the cat out of the bag—in more ways than one—with the feature construction article in this chapter (page 72). Not only does the sun emit very low frequency r.f. radiation—particularly from sunspots—but this receiver can be used to monitor the blast-offs of the larger booster rockets. The mechanics of how these rockets emit low frequency r.f. are not completely understood and very little has appeared in the technical electronics press on this hush-hush topic. Nevertheless, it is known that booster rockets can be detected in this fashion—regardless of the distance between the launch site and the receiver. Undoubtedly, both the U.S. and Soviets maintain extensive low frequency receiving and monitoring stations around the globe for this purpose. So, if you build this project, and can find a clear channel with no interference (QRM), you may be rewarded by spotting solar flares—and if you’re very lucky—a missile blast-off.

Show this project to friends interested in radio astronomy, weather, etc. But, be careful; you may end up building a couple of receivers, instead of just one for your own use.

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84 SURE-SHOT Q5'ER HOOKUP....................Bradley J. Thompson
85 POWERHOUSE 2-TUBE SHORT-WAVE RECEIVER Charles Green, W6FFQ
90 BC-454 GOES MARITIME..........................E. H. Marriner, W6BLZ
LISTEN IN ON THE SUN

COVER STORY
THREE-TRANSISTOR VLF RECEIVER TUNES IN ON SOLAR FLARES

By HOWARD BURGESS, W5WGF

FEW THINGS happen in space that are as important to earthlings as those which occur on the surface of the sun. Centuries ago, Chinese astronomers were fascinated by the black “spots” that appeared to travel across the solar surface. Latter-day scientists simply referred to these imperfections as “sunspots”—for lack of a better name—and were quick to ascertain that the number and area occupied by the sunspots varied from week to week, month to month, and in particular, from year to year. Sunspots affect every living being, and while our principal interest in them is in regard to radio wave communications over long distances, the effects of sunspots have been correlated with the growth of tree rings, severity of winter storms, etc.

Throughout the next few years, anyone using the short-wave bands will find that the sunspots have produced some unusual effects. Some high-frequency bands may be momentarily blacked out while other bands will open up over unusual DX paths. Thousands of CB operators will be tempted by the rare 27-MHz skip conditions, and millions of TV viewers will occasionally pick up strange stations on their screens from thousands of miles away. This will be the period of the sunspot maximum; some scientists are predicting that the 1969 maximum will be only slightly below the great sunspot peak of 1958-59.

What Are Sunspots? The cause of sunspots has puzzled scientists for many years. However, according to recent investigational work, when some of the larger planets in our solar system form a special pattern in space, it is assumed that the force fields created combine to disturb the hot gasses of the sun. This same combination of forces probably drives atomic particles, from the sun, through space like the beams of a giant cathode-ray tube. Sunspots themselves are violent storm-like disturbances that appear to move across the face of the sun, but do not really do so because the sun is actually rotating and changing its position in our field of view. They vary in definite cycles. At intervals of about 11 years, the number of sunspots reaches a peak and then declines to a very low amount. The highest portion of the peak can last as long as two to two-and-one-half years. The sunspots discharge atomic particles and radiation into outer space and these particles and radiation seem to originate in turbulent areas known as solar flares—which appear to the astronomer as huge flames spouted by the sunspot. The flares (or bursts) last for less than two to three minutes, but during this short interval intense radiation is released. At the peak of sunspot activity, a number of bursts can take place in one day.

Effects of the space debris on the ionosphere and the resulting blackouts have been discussed in many articles appearing in POPULAR ELECTRONICS and the contemporary press.

“Warning” Receiver. The radiation given off by a solar flare travels at the speed of light and arrives at our planet in about eight minutes. However, the charge particles drag along at about a thousand miles per second and arrive outside the earth’s atmosphere 24-36 hours later. The particles that arrive late affect all short-wave transmissions, while the fast-moving radiation has a pronounced effect on the lower frequencies and occasionally causes a short period of radio blackout. By listening in on the sun, it is possi-
At the very low radio frequencies tuned by this receiver, the circuit is simply “straight-thru.” Regeneration is not desired, and when T1 and L1 are resonated to the same frequency, R9 must be turned down to curb feedback. Output jack J1 is optional if the user wants to “look” at some of the strange VLF signals between 25 and 35 kHz.

All of the components surrounding transistor Q1 are positioned above the chassis. Although presumably T1 and L1 would only be tuned once, they are both mounted with knobs attached to the threaded shafts. The three binding posts permit the receiver to be connected to a variety of antennas—short, long, or of an “in-between” size.

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PARTS LIST

B1—9-volt transistor battery
BP1, BP2, BP3—5-way binding post
C1—0.001-mF mica capacitor
C2, C3—0.005-mF mica capacitor
C4, C5, C6—5.0-mF, 15-volt electrolytic capacitor
C8—0.02-mF paper capacitor
C7—0.0033-mF ceramic capacitor
C8, C12—0.1-mF paper capacitor
C10—0.01-mF paper capacitor
C11—350-mF, 15-volt electrolytic capacitor
D1—1N34 crystal diode
J1—Optional female connector (BNC, RCA, etc.) for scope cable
J2—Closed-circuit phone jack
L1—8-60 mH variable inductor (similar to J. W. Miller width control coil 6310)
M1—0-1 milliamphere meter, full scale
O1, O2—2N404 transistor, or similar
R1, R2—15,000-ohm, 1/2-watt resistor
R3—22,000-ohm, 1/2-watt resistor
R4, R12—3300-ohm, 1/2-watt resistor
R5—5600-ohm, 1/2-watt resistor
R6—570-ohm, 1/2-watt resistor
R7—36,000-ohm, 1/2-watt resistor
R8—2700-ohm, 1/2-watt resistor
R9—10,000-ohm potentiometer, audio taper
R10—1000-ohm, 1/2-watt resistor
R11—68,000-ohm, 1/2-watt resistor
RFC1—30-mH r.f. choke
S1, S2—5-p.s.t. toggle switch
T1—4-30 mH variable inductor (similar to J. W. Miller width control coil 6316)
Misc.—Aluminum box, terminal boards, knobs, wire, solder, etc.

tors are followed by a diode rectifier whose output is amplified by another transistor which will work at these frequencies, although the resistance values shown in the circuit diagram apply particularly to the 2N404 and 2N508—both of which are inexpensive and work well.

The diode circuit which rectifies the noise into a d.c. component needs no explanation except for capacitors C10 and C11. These capacitors are used to smooth out the individual noise and static pulses into a slowly varying output which follows only the major changes in the atmospheric background noise—such as solar flares, or severe local thundershowers. The actual value of C11 will depend upon the resistance of the meter or recorder coupled to transistor Q3. The value should be between 15 and 350 microfarads. Switch S1 removes C11 from the circuit and shortens the time constant of this stage when it is desirable to monitor the lightning flashes during a local thundershower.

A phone jack, J2, is provided for connection to the external chart recorder—which is the ideal instrument for monitoring solar flares. Until recently the cost of chart recorders has been prohibitive, but now they can be found on the surplus market at reasonable prices, or a brand-new chart recorder—such as that pictured on the cover of the Handbook—can be purchased for under $90.

Construction. Construction of the low-frequency solar flare monitor is relatively non-critical. The only precau-
The three photographs on these facing pages show the arrangement of all parts mounted under the chassis. The author found it necessary to cut out the bottom of the aluminum chassis to eliminate "closed loop" regenerative feedback—otherwise the open bottom has no effect on receiver performance.
action can be controlled by changing the value of \( R5 \)—reducing the value of this resistor should reduce the tendency toward regenerative oscillation. The receiver should show signs of regeneration with the antenna connected and the gain control turned “full-on.”

The simplest way to tune up this receiver is to use an audio oscillator. Couple the output of the oscillator loosely to the antenna and tune \( T1 \) and \( L1 \) for maximum meter reading.* Tuning should be done with the antenna connected, since the antenna can change the resonance of \( T1 \). If an audio oscillator is not available, the tuning can be peaked by simply adjusting \( T1 \) and \( L1 \) for maximum background noise. Adjustments are always made for maximum meter deflection. A fluorescent light is an excellent substitute generator and an antenna lead brought close to the lamp bulb will always show a high reading. Reduce the gain of \( R9 \) as \( T1 \) and \( L1 \) are tuned for maximum readings.

After the receiver has been tuned—say to a frequency of 27 kHz—plug in a pair of earphones and open switch \( S1 \). You should hear nothing but a small amount of noise. If any low-frequency CW signals are heard, the receiver must

*Don’t be fooled into thinking you can hear a “tone signal”—remember that you are using your audio generator to line up the receiver, not a modulated radio-frequency generator.

---

**A solder lug terminal board is used here to support the parts in the circuit around transistors \( Q2 \) and \( Q3 \). The transistor leads are soldered to the terminals to eliminate a need for sockets. Board can be pre-assembled and then mounted under the chassis with 6-32 screws, metal standoffs, lockwashers and nuts.**

This view is toward the rear of the chassis. Jack \( J1 \) is under \( J2 \)—one jack being regular phone size, the other a miniature. Switch \( S1 \) controls the time constant of the output circuit so that a chart recorder can read a rough average of the background noise—not individual noise bursts. Circuit values given are suitable for use with a Rustrak low-cost chart recorder such as the one shown on the cover.
This "fake" chart recording shows some of the things you might observe with this VLF receiver. Reading up, the nighttime background noise level drops before sunrise, rises to a new peak, then falls to the usual daytime level. The sudden "kicks" in the graph (except the "X") are solar flares. The last flare of the day, at 9 p.m., is buried in the nighttime noise. Thundershowers produce considerable electrical disturbance, shown peaked here between 2 and 4 p.m. The "kick" at "X" indicates the type of noise associated with rocket booster firings.

be retuned to avoid these signals. All tuning should be done during the day with the antenna connected. When the receiver is ready for use, your first observation will be that the nighttime noise level is several times greater than the daytime noise level.

After verifying the differences in the noise level, adjust gain control R9 for a nighttime noise level reading about two-thirds of the way up the meter scale. Just before dawn, the background noise level will drop. It will continue at a low level throughout the day with slight variations until sundown, when it will quickly rise to the nighttime level. However, a daytime thundershower can raise the background noise level to a very high meter reading.

**Identifying Solar Flares.** The occurrence of a solar flare will produce a sharp rise in the daytime background noise level. The peak noise level will hold for several minutes and slowly subside. On occasion, the fading out of the solar-flare-induced noise burst may last for more than a hour and this slow-fade helps to distinguish a solar flare from unusual electrical noises. A local electrical noise will usually rise fast and drop fast. Of course, thundershowers will always mask solar flare indications.

Many experimenters may find that it is possible to detect natural electrical disturbances when no clouds are visible in the sky. If capacitor C11 is switched out of the circuit, it is possible to see each lightening stroke on the meter.

A few words of caution will prevent disappointment in the use of this receiver. The output of the receiver will not be a nice smooth line with an occasional lump that can be labeled "solar flare." Many things, known and unknown, can be read with the help of this receiver. In one day's recording, the author logged three solar flares, a severe thundershower up in the mountains, what appeared to be a rocket booster blast-off, and the sudden onslaught of a very noisy electrical motor.

So, when you get many signals, do a little detective work and find the source, if possible. A strange little squiggle on your recording chart could be a missile test in Mongolia, or—your neighbor's toaster.
BUILD THE MODBOX

End guesswork with this plug-in adapter—now you can instantly check percent and quality of modulation

By GEORGE J. WHALEN

ASK ANY amateur or CB operator about the efficiency, power input, or stability of his AM phone transmitter and you'll likely be in for fifteen minutes of enlightening statistics about final amplifier plate current, grid excitation levels, and field strength measurements. Then, ask him what his average percentage of modulation is. In all probability, you'll be met with a blank stare and an answer something like: "Oh, about a hundred percent... I guess."

You can hardly blame him for not knowing much about his modulation, simply because most transmitters have no provisions for checking either quality or percent of modulation.

The "Modbox" takes the guesswork out of monitoring modulation. It is a simple, inexpensive modulation analyzer, designed for easy addition to any plate-
modulated AM transmitter or transceiver running up to 200 watts input. It provides three important monitoring features: first, it reads your average percentage of modulation; second, it flashes a warning whenever overmodulation or serious distortion is occurring in your final amplifier; and third, it lets you hear the audio applied to the final amplifier, for an on-the-spot listening test. This three-way quality check is the best insurance policy you can get against splatter, hum feedback, distortion, and loss of contacts due to poor modulation.

**How It Works.** A ratio voltmeter circuit is used to measure percentage of modulation, a peak-reading neon lamp "voltmeter" to detect overmodulation and audio distortion, and a direct audio monitoring circuit to couple audio out of your rig to a pair of headphones for a listening quality check.

The ratio voltmeter circuit makes it possible to measure both a.c. and d.c. voltages and the relative amounts of each voltage present with respect to the other. From these readings it is an easy matter to determine percent of modulation.

For safety’s sake, the ratio voltmeter used in the Modbox operates from a resistive voltage divider installed in your transmitter's final amplifier as shown in Fig. 1. In this manner, high voltages are kept off the Modbox cable. The divider resistors have negligible effect on the transmitter and may be installed without violating any FCC regulations.

To better understand the operation of the ratio voltmeter circuit, imagine that the transmitter is in operation, but without modulation. Unmodulated B+ appears across R1 and R2, and is divided down to a low voltage across R2, on the order of about 10 volts. This low voltage is connected by cable (through pin 1) to the Modbox (Fig. 2) where it appears across CALIBRATION potentiometer R5, but is blocked from the meter circuit by capacitor C2. When PUSH TO CAL switch S1 is depressed, a path is created for d.c. to flow, through resistor R3, to d.c. milliammeter M1, and R5 can be adjusted to obtain a full-scale reading of 1 mA. After this adjustment is completed, S1 is released. The ratio voltmeter...
ter is now calibrated for the unmodulated d.c. plate voltage in the final amplifier, and is ready to accurately measure a.c. modulation voltages with reference to this d.c. voltage.

When you speak into the microphone, your rig's modulator applies an a.c. modulating voltage to the final amplifier, superimposed on the d.c. plate voltage. This combination of voltage is also divided down by R1 and R2, and appears across R5. Since S1 is open, d.c. is blocked from the meter circuit, but the a.c. modulating voltage is coupled to rectifier diodes D1 and D2 and the meter by C2. Rectified audio voltages are filtered by C3 and M1 indicates the relative effective value of the a.c. modulating voltage. For 100% modulation, M1 will give a reading of 0.7 mA. Readings exceeding 0.7 mA indicate overmodulation, which could result in "splatter" and distortion.

The distortion-indicating circuit is coupled to the modulated B+ by C1 (Fig. 1) and because of the small amount of capacitance (68 pF) does not readily see audio voltages at frequencies in the range of 300 to 3000 Hz. However, when a condition of overmodulation exists, high-frequency harmonics are usually generated in the final amplifier on the order of 10,000 to 30,000 Hz, which are more easily passed by C1. When the harmonic voltages appear across C2 and exceed a peak of about 65 volts, the neon lamp (I1) flashes and provides a visual indication.

A listening quality check of the audio can be made simply by plugging a pair of 2000-ohm headphones into jack J1. The rectifier and meter circuit is disconnected when the phones are plugged in. Potentiometer R5 can be used as a volume control to adjust the sound level in the headphones.

Construction. Layout and type of cabinet used are matters of choice and are not critical. The few parts required for the entire circuit could be made to fit into your present rig, if you have the space on the front panel for M1. However, you will get more mileage out of the Modbox if it is a separate unit; you can plug it into different transmitters as needed.

A 5" x 2 1/4" x 2 1/4" aluminum utility box can be used. The holes should be located and drilled as shown in Fig. 3.

![Fig. 3. Type of box used and layout are not critical, but make the four bolt holes for the meter a bit oversized to permit rotating the meter if necessary to keep it straight. If you have enough room on your transmitter, you can mount all the parts directly on it, and thus do away with the cable and the box.](image-url)
The meter hole should be made to conform to the meter used. Mark the positions of the four-meter-mounting screw holes and drill them somewhat oversize to permit slight rotation of the meter, if necessary, to mount it straight.

Appearance counts in home-brew gear just as much as it does in commercial equipment. So, if you want a really professional-looking job, smooth all burrs, polish the box with fine steel wool, paint, and apply decals. A final coat of clear acrylic lacquer will protect the unit from normal wear and tear. Four tiny rubber feet cemented to the bottom half of the box will enhance the appearance of the unit and protect your furniture.

When the chassis work and appearance details have been completed, assemble the three-conductor cable and connector P1. Cable length is not critical, but it should be just long enough to make a neat hookup to your transmitter. If you have to cut the shaft of R5 down to size, do so without subjecting the control head to stress. The neon lamp is held in place with a ⅜”-i.d. grommet.

Mount the meter after you have completed the wiring. Be sure to observe polarity of the meter, diodes, and electrolytic capacitors. And avoid overheating the diodes when soldering.

**Calibration.** No calibration is necessary as the meter readings are relative to the setting of R5 for an unmodulated signal. However, if you would like to double-check your work, you can put together the test setup shown in Fig. 5. The VOM should be a 20,000 ohms-per-volt meter, capable of good accuracy on the low-voltage a.c. and d.c. ranges. Do not substitute a peak-to-peak VTVM for the VOM since this procedure calls for a meter capable of reading r.m.s. rather than peak a.c. voltages.

Connect the test setup to the Modbox, but do not connect the primary of the transformer to the 117-volt a.c. source just yet. Set the VOM to read d.c. volts and adjust R6 until the VOM reads 6.3 volts d.c. Next, depress switch S1 and adjust the Modbox **CALIBRATION** potentiometer (R5) until meter M1 shows 1 mA. Readjust R6 if necessary, to obtain the 6.3-volt d.c. reading on the VOM. Then, without disturbing any adjustments, release S1, set the VOM to read a.c. volts, and connect the calibrator to 117 volts a.c. The VOM should read 6.3 volts a.c., and Modbox meter M1 should indicate 0.7 mA—corresponding to a 100% modulation reading.

If M1 reads higher than 0.7 mA, decrease the value of the 6800-ohm resistor (R3) and repeat the calibration check. If M1 reads lower than 0.7 mA, increase the value of R3 and repeat the calibration check. One precaution: the a.c. voltage from the transformer must be no more and no less than 6.3 volts for this calibration procedure.

If you want to convert your meter to a direct-reading modulation meter, transfer the readings from the accompanying calibration chart (Table 1) onto the meter face, using a fine-pointed pen or colored pencil. If you are just interested in knowing how close your average modulation percentage comes to 100%, mark a line on the meter scale just beyond the 0.7-mA division and write in “100%”

---

**Fig. 4.** Mount the parts in any convenient manner, but observe polarity of the meter, diodes, and electrolytic capacitors. Use a clamp to hold the cable.
above it. Then, carefully fill in the scale divisions between 0.7 and 1 mA in color, so that readings exceeding the 100% mark will stand out at a glance. If you wish, you can type out a small chart and cement it to the side of the case.

Transmitter Hookup. Select a suitable place in the transmitter, preferably as close to the final amplifier as possible, and mount J1. Next, compare your transmitter's schematic diagram with the two typical final amplifier circuits shown in Fig. 1, and locate the modulated B+ feed-point in your circuit. Once you've located the connection point, determine the d.c. plate voltage appearing at that point, either by measuring it directly or from the transmitter schematic. The plate voltage in your transmitter determines the value of divider resistor R1. See Table 2.

Install R1, R2, and C1 in your final amplifier circuit, and keep the leads as short as possible. Insulate any lead which might come in contact with the chassis. Pay particular attention to the grounding of R2, and pin 2 of S01. After these components have been installed, connect the Modbox to the transmitter by plugging P1 into S01, and perform a quick continuity check on the interconnecting cable. Be sure that the Modbox's case shows continuity with the transmitter's chassis. Check all wiring carefully, button up the Modbox—and your transmitter—and you're ready to try it out on the air.

On The Air. It's a good idea to run your transmitter into a dummy load to make your adjustments and to avoid cluttering up the airways with extraneous sounds prior to going on the air, especially after a modification or repair has been made. Warm up the rig, cover the microphone or run the modulation control down to zero to prevent modulation of the carrier, depress the PUSH TO CAL switch (S1) on the Modbox and simultaneously adjust the CALIBRATION potentiometer (R5) until the meter indicates 1 mA. Release S1 and speak into the microphone at a normal level. If your rig has a modulation gain control, bring the level up while speaking, observing the meter as it "kicks" in response to your speech. Bring the mod-

Table 1. You can obtain direct meter readings of percent modulation by inscribing these figures on the meter dial, or you can paste this table on the side of the box. If you are just interested in knowing how close you can get to 100% modulation, without overmodulating, paint that portion of the dial above 0.71 mA in red, or any suitable color.

<table>
<thead>
<tr>
<th>METER READING (d.c. mA)</th>
<th>% MODULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.07</td>
<td>10</td>
</tr>
<tr>
<td>0.14</td>
<td>20</td>
</tr>
<tr>
<td>0.21</td>
<td>30</td>
</tr>
<tr>
<td>0.28</td>
<td>40</td>
</tr>
<tr>
<td>0.35</td>
<td>50</td>
</tr>
<tr>
<td>0.42</td>
<td>60</td>
</tr>
<tr>
<td>0.49</td>
<td>70</td>
</tr>
<tr>
<td>0.56</td>
<td>80</td>
</tr>
<tr>
<td>0.63</td>
<td>90</td>
</tr>
<tr>
<td>0.70</td>
<td>100</td>
</tr>
<tr>
<td>0.71 to 1.0</td>
<td>Overmodulation</td>
</tr>
</tbody>
</table>

Table 2. Value of R1 depends upon the final amplifier's plate voltage. If necessary, you can parallel a couple of resistors to obtain needed wattage and resistance. Don't go below the wattage indicated.

<table>
<thead>
<tr>
<th>FINAL R.F. AMPLIFIER</th>
<th>D.C. PLATE VOLTAGE</th>
<th>OHMS</th>
<th>WATTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>36,000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>175</td>
<td>43,000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>62,000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>325</td>
<td>82,000</td>
<td>4</td>
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<tr>
<td>400</td>
<td>100,000</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>475</td>
<td>120,000</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>550</td>
<td>130,000</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>625</td>
<td>150,000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>180,000</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

1967 Spring Edition

83
SURE-SHOT Q5-er HOOKUP
WHY DETUNE YOUR I.F. WHEN YOU CAN ISOLATE YOUR BC-453

If you are in possession of a surplus BC-453 long-wave receiver, you have probably given thought to using the BC-453 as a "Q5-er." Unlike the commercially available "Q-multipliers" (Heathkit, WRL, etc.) that electronically increase the Q of an i.f. stage—thus increasing selectivity—the Q5-er is a separate receiver with its own highly selective i.f. strip. When you use the Q5-er, you disable your regular receiver's detector and audio and use those in the BC-453.*

In the circuit shown on this page, the author modified the second i.f. stage in his short-wave receiver so that this stage could also act as a cathode follower.

*The BC-453 tunes through the 455-kHz i.f. of most receivers. The i.f. signal is converted to 85 kHz where better selectivity can be obtained without resorting to Q-multiplier gadgets.

The output of the cathode follower is then fed into the antenna terminal of the BC-453 through jack J1. A d.p.d.t. low-capacity rotary switch (S1) enables the operator to switch back and forth between the Q5-er and the regular receiver. Without this cathode follower arrangement, the input of the BC-453 would have been taken from the plate of the second i.f. tube and consequently misaligned i.f. output transformer T3.

Mount switch S1 as close to the i.f. stage as possible to curb potential feedback problems. Use coaxial cable or a good shielded lead between the switch and jack J1. Although there is modest loss of signal strength through the cathode follower arrangement, the BC-453 has more than enough "sock" to compensate for the unity gain of the rewired i.f. stage. —Bradley J. Thompson

In the "Normal" position, the receiver operates as originally designed. In the "Q5-er" position, the output of the i.f. stage is bypassed to ground and the 455-kHz i.f. signal fed into the connection to the Q5-er.
BUILD:

POWERHOUSE

2-TUBE

SHORT-WAVE

RECEIVER

By CHARLES GREEN,
W6FFQ

DON'T LET
THE "2-TUBE" ANGLE
THROW YOU . . .
THIS RECEIVER
IS ACTUALLY
THE HOTTEST THING AROUND

HERE'S a short-wave receiver that's built like a brick house, yet fires up like a real powerhouse. True, it cannot claim style . . . but it sure can boast plenty of class. Far more important is the fact that it pulls in more stations—from all over the world—than many commercial short-wave receivers with a lot of fancy circuitry that adds nothing but complexity. This "little monster" covers frequencies from 500 kHz to 30 MHz in four bands! How about that?

Just imagine picking up your local broadcast stations, then switching to the marine band, then to the international short-wave bands, all the way down to the 10-meter amateur band! A simple bandspread tuning circuit is incorporated to provide maximum selectivity in the crowded bands, and provisions are included for either speaker or headset operation.

About the Circuit. The "little monster" is a transformer-operated regenerative receiver employing switchable coils (see Fig. 1). A twin triode (12AT7) op-
erates as an r.f. amplifier and regenerative detector. A power pentode (6AK6) drives the speaker or headphones through output transformer T1. Transformer T2, silicon diode D1 and a filter consisting of C15, R11 and R12 provide B+ power.

The r.f. signals from the antenna are cathode-fed to grounded-grid reflex amplifier V1a through C1. The amplified output is applied to V1b through C4. The detected audio is fed back to the grid of V1a through C6-R5, and after amplification is coupled to gain control.

**Fig. 1.** Featuring a sensitive regenerative circuit, this transformer-operated receiver employs a single triode functioning as r.f. amplifier and regenerative detector, and a power pentode as audio driver.

R9 thru R4-C5 before it is applied to V2.

Switch S1 selects the coils for the desired band while R8 varies the regenera-

### PARTS LIST

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1, C2, C10</td>
<td>560-pF, 400-volt ceramic disc capacitor</td>
</tr>
<tr>
<td>C3, C14, C16</td>
<td>0.001-µF, 400-volt ceramic disc capacitor</td>
</tr>
<tr>
<td>C4</td>
<td>47-pF, 400-volt ceramic tubular capacitor</td>
</tr>
<tr>
<td>C5, C6, C13</td>
<td>0.005-µF, 400-volt ceramic disc capacitor</td>
</tr>
<tr>
<td>C7</td>
<td>10-365 pF variable capacitor</td>
</tr>
<tr>
<td>C8</td>
<td>2-14 pF miniature variable capacitor (E.F. Johnson 160-107 or equivalent)</td>
</tr>
<tr>
<td>C9</td>
<td>100-pF, 400-volt ceramic tubular capacitor</td>
</tr>
<tr>
<td>C11</td>
<td>25-µF, 6-volt electrolytic miniature capacitor</td>
</tr>
<tr>
<td>C12</td>
<td>0.01-µF, 1000-volt ceramic disc capacitor</td>
</tr>
<tr>
<td>C15</td>
<td>20-30-40 µF, 150-volt electrolytic capacitor</td>
</tr>
<tr>
<td>C17</td>
<td>300-pF, 400-volt mica capacitor</td>
</tr>
<tr>
<td>D1</td>
<td>1N1697 diode</td>
</tr>
<tr>
<td>F1</td>
<td>½-ampere fuse (and fuse holder)</td>
</tr>
<tr>
<td>J1</td>
<td>Phone jack</td>
</tr>
<tr>
<td>J2</td>
<td>Closed-circuit phone jack</td>
</tr>
<tr>
<td>L1</td>
<td>Oscillator coil (J.W. Miller 71-OSC or equivalent)</td>
</tr>
<tr>
<td>L2</td>
<td>L4-B &amp; W 3016 Miniature coil</td>
</tr>
<tr>
<td>L3</td>
<td>B &amp; W 3013 Miniature coil</td>
</tr>
<tr>
<td>R1</td>
<td>1600-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>R2</td>
<td>1-megohm, ½-watt resistor</td>
</tr>
<tr>
<td>R3, R7</td>
<td>100,000-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>R4, R5</td>
<td>180,000-ohm, ½-watt resistor</td>
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<tr>
<td>R6</td>
<td>2-megohm, ½-watt resistor</td>
</tr>
<tr>
<td>R8</td>
<td>100,000-ohm potentiometer, linear taper</td>
</tr>
<tr>
<td>R9</td>
<td>500,000-ohm potentiometer, audio taper (with on-off switch S2)</td>
</tr>
<tr>
<td>R10</td>
<td>330-ohm, 1-watt resistor</td>
</tr>
<tr>
<td>R11</td>
<td>15,000-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>R12</td>
<td>1500-ohm, 2-watt resistor</td>
</tr>
<tr>
<td>S1</td>
<td>3-pole, 4-position rotary switch</td>
</tr>
<tr>
<td>S2</td>
<td>S.p.s.t. switch (on R9)</td>
</tr>
<tr>
<td>T1</td>
<td>Output transformer: primary, 10,000 ohms; secondary, 4 ohms (Stancor A8379 or equivalent)</td>
</tr>
<tr>
<td>T2</td>
<td>Power transformer, 125 volts @ 15 mA and 6.3 volts @ 0.6 ampere (Stancor PS-8415 or equivalent)</td>
</tr>
<tr>
<td>V1</td>
<td>12AT7 tube</td>
</tr>
<tr>
<td>V2</td>
<td>6AK6 tube</td>
</tr>
<tr>
<td>SPKR</td>
<td>4&quot;, 3.2-ohm speaker</td>
</tr>
<tr>
<td>Misc.</td>
<td>Terminal strips, a.c. line cord, knobs, 7-pin and 9-pin tube sockets, etc.</td>
</tr>
</tbody>
</table>

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tion of the detector. Capacitor C7 is the main tuning capacitor and C8 provides bandspread tuning. Band A covers approximately 0.5 to 1.6 MHz; band B from 1.7 to 5 MHz; band C from 4.5 to 14 MHz; and band D from 13.5 to 30 MHz.

Construction. The receiver is assembled on a $3/16^\text{th}$-thick $47/16^\text{th} \times 8^\text{th}$ aluminum plate mounted in a utility box (LMB 146) approximately two inches from the bottom of the box. The speaker, dial plate, and the tuning and operating controls are all mounted on the front panel of the utility box.

Mounting dimensions and drill sizes for the chassis and cabinet are given in Fig. 2. After drilling out and deburring the holes, install the tube sockets, rubber grommets, speaker and metal grille, transformers, coils, and the tuning capacitor at the locations shown in Fig. 3.

Coil details and terminal connections are given in Fig. 4. Note that the B & W coils must be cut down to a specified number of turns, and that in each case a #6 ground lug is attached to one end of the coil. To attach the lug to the coil, file the lug to get a sharp edge, heat it, and then insert it into the plastic coil form nearest the end of the coil, after soldering the coil terminal to the lug. Use the shortest lead possible. The ground lug is secured to the chassis with a #6 self-tapping screw.

You can now follow the pictorial diagram (Fig. 5) for the layout of com-
Fig. 4. Coil L1 is installed by inserting clips near screw end into mounting hole and pressing down on coil until a click is heard. The B & W coils (L2 through L4) must first be cut down to the specified number of turns.

- L1: TO SIC A (TAP 15 TURNS) TO GND
- L2: TO SIC B (39 TURNS) TO GND
- L3: TO SIC C (TAP 15 TURNS) TO GND
- L4: TO SIC D (6 TURNS) TO GND

Components and circuit wiring. Be sure to dress the 6.3-volt filament wires close to the chassis while keeping them away from the coils. Keep all wiring as direct and as short as possible.

Use 3/8"-long spacers to mount the tuning capacitor to the front panel, and make sure the lugs on the capacitor are not grounded to the chassis. After completing the assembly, install the template (Fig. 6) on the front panel over the tuning capacitor. Then install a tuning knob with pointer and the remaining control knobs.

Fig. 5. Pictorial diagram shows wiring details. Keep all leads as short and direct as possible, and be sure to dress the 6.3-volt filament wires close to the chassis while keeping them away from the coils. Diode D1 must be installed with polarity as shown.

Fig. 6. FRONT PANEL WIRING.
Adjustments. During initial adjustment of the receiver, you may find that the frequencies of the stations tuned in do not correspond to the dial markings. This could be due to lead dress and other variables that can change the receiver tuning slightly. If this is the case, it is suggested that you either modify the template by changing the markings on it, or else make a new template which you can calibrate as necessary.

If you have a signal generator, then by all means use it to calibrate your dial settings. If you happen to live in the vicinity of a broadcasting station and find that your receiver is swamped by strong signals, you can easily clear up this condition with a series wave trap connected between the antenna jack and chassis.

Use a J. W. Miller 71-OSC coil with a 365-pF trimmer capacitor connected between pins 1 and 2 (the grid winding) of the coil to form the trap. Then simply adjust the trimmer until all interference is reduced to a minimum. This adjustment should not affect reception of other stations.

Operation. Plug in the receiver to a convenience outlet and turn the GAIN control all the way up. Hook up a good antenna to J1, and advance the REGEN control until you hear a loud noise or a whistle. Then back off on the REGEN control until the noise or whistle just disappears, and your station should come in loud and clear.

With a little practice, you will soon become a pro at adjusting the REGEN to the proper level while you pull in stations from all over the band.
ANY small boat owner or SWL can change a BC-454/ARC-5 receiver into a bandspread 2.5-MHz marine band receiver. The BC-454 24-volt unit is easily modified for 117-volt a.c. operation (see "Converting Your First Command Receiver," POPULAR ELECTRONICS, June, 1963). To confine the original 3.0-6.0 MHz tuning range to 2.2-2.8 MHz, the builder need only buy three capacitors and wire them in parallel with the existing tuning gang.

Turn the receiver over and remove the bottom plate. The tuning capacitors are ganged together under the aluminum box cover that runs from one side of the receiver to the other. Temporarily remove this second protective cover. Using the diagram as a guide, mount three silver mica capacitors in the approximate physical positions indicated. If you wire-trace the electrical position of these capacitors, you will see that they are in parallel with the tuning gang and r.f., mixer, and oscillator coils.

When the capacitors are soldered in place, tune in a station around 2500 kHz and peak up the antenna trimmer capacitor on the front panel. Next, adjust the mixer tuning gang (the middle capacitor) paddler for maximum signal strength. And you're in business. If you find the oscillator frequency needs adjusting to cover the approximate frequency range mentioned above, touch up the oscillator paddler. Then replace the capacitor cover and the bottom plate.

Keep in mind that radiotelephone conversations are not to be revealed to a third party. Discussing, recording for playback, and disclosure of such conversations is a violation of the 1934 Communications Act.
If you read all the advertisements for test equipment kits, you may be surprised to find that some readers of the ELECTRONIC EXPERIMENTER'S HANDBOOK actually build some of their test gear. More often than not, the reason that hobbyists build test equipment is that they are looking for something special, something not found in run-of-the-mill equipment. With that thought in mind, your editors selected the following test equipment projects as being something out of the ordinary.

The "Pulser" (page 92) is undeniably a piece of equipment that not every hobbyist is going to build, or even want in his shop. But, wait a minute—take a look at the circuit. Did you ever see a generator that was simpler? Or had the output range? Or had the frequency range? Probably not, because this generator is built around a third generation solid-state component—the four-layer diode.

And, if we want to talk about third generation components, the IC in the $6 amplifier (page 103) certainly qualifies. This handy little project could be useful around any lab or workshop bench.
ADVANCED EXPERIMENTER PROJECT

PULSE GENERATOR

By DON LANCASTER

Variable amplitude and frequency trigger for counting, testing, and experimenting

A GOOD commercial pulse generator can sport a $200-and-up price tag. Here is a versatile unit you can build for less than $15 . . . or as little as $2.00. If your workshop is well-stocked, chances are you will only need to buy one $2 part. The circuit is simple, foolproof, and easily built in one or two evenings.

The Pulser produces a free-running series of sharp trigger pulses, variable from 0 to 10 volts in amplitude and with a variable repetition rate of from one pulse every ten seconds to 11,000 pulses per second. It has five overlapping scales and a choice of pulse polarity. It is battery-operated and draws less than 0.0005 ampere, and can put out almost 8 watts of peak pulse power.

To boot, the Pulser has a low-output impedance and is short-circuit-proof. You can run it all day into a dead short. The rise-time is quite snappy—only 50 nanoseconds. Pulse width varies from scale to scale, but always stays at roughly 1/1000 of the repetition time.

Applications. An important experimental use for the Pulser is as a trigger source for multivibrators and counter circuits. If you have a scope, here is a convenient pulse source for resonance demonstrations, time constant experiments, and “Q” measurements. It is dandy for testing radio control modules and escapements, and doubles as a trigger source for experimental transistor and SCR power inverter circuitry.

The lower repetition rates are tops for timing displays, exhibits and flashers. For example, you can use the Pulser to trigger an SCR lamp controller. Set the Pulser to 58 hertz and the bulb will smoothly oscillate at a 4-hertz rate. Place a photocell in front of the light, and you’ll wind up with an ultra-low-frequency audio oscillator.

The Pulser easily drives a speaker and produces a series of “pock-pock-pock” sounds to enable you to check out speakers and output transformers. You can also use it as a signal injector for all sorts of audio testing and troubleshooting. And, finally, you can use the “pocks” themselves; the unit will serve as a metronome or as a darkroom timer.

How It Works. It’s all made possible by a new semiconductor which sells for $2 . . . a four-layer diode. Unlike ordinary diodes, the four-layer diode is a
voltage-sensitive switch. It is normally off, leakage current is negligible, and it snaps on when it "sees" 12 volts. It stays on as long as there is significant current (more than 1 ma.) left in the circuit. In the on state, the impedance is so low that you must limit the current externally; otherwise the diode will destroy itself. Just like a regular diode, the four-layer diode operates only in the forward direction.

Add two resistors, a capacitor, and a battery to the diode, and you have a pulse generator, as shown in the simplified circuit of Fig. 1. Capacitor C takes on a charge from B1 through R1. When the charge reaches 12 volts, the diode snaps on, producing a sharp spike across current limiting resistor R3. This spike is the output pulse and is almost 10 volts high; its width is R3 x C.

As the capacitor discharges (very rapidly, since R3 is much smaller than R1), less and less current flows through the diode, and it finally turns off when the capacitor voltage drops close to zero.

As battery current through R1 in this circuit is held to 0.5 ma. or less, it cannot hold the diode on; the capacitor recharges, and repeats the cycle.

One output pulse is produced for each charge and discharge cycle. The waveforms in Fig. 2 show the exponential charge-discharge waveform at point A in the simplified circuit, the sharp output pulse at point B, and their relationship to the on-off time of the diode.

Figure 3 shows the entire circuit of the Pulser. You can change the frequency by varying R2 or by switching in different capacitors. Potentiometer R2 provides a continuously variable frequency range, on the order of 11 to 1. Each of the five capacitors is ten times

![Fig. 1. Four-layer diode conducts when the capacitor charges up to about 12 volts, and stays "on" as long as there is more than 1 ma. of current flow.](image1)

![Fig. 2. Typical capacitor charge-discharge waveform is present at point "A" in Fig. 1. At output "B," the rise time is so fast that you'll need a fairly good scope to see it. When the diode is "off," the capacitor has a chance to build up a charge until it is large enough to trigger the diode into conduction. Current flow through the diode is relatively so large that the capacitor discharges and cannot take on a new charge until the diode stops conducting.](image2)
its neighbor, and they provide five frequency ranges in decade steps from x 0.1 to x 1000.

In spite of its simplicity, this \( RC \) configuration makes it possible to select any frequency within the Pulser's range. Potentiometer \( R_3 \) varies the output pulse amplitude; it works like a volume control. Switch \( S_3 \) performs the simple task of reversing output pulse polarity. And to make the whole thing short-circuit-proof, \( R_4 \) limits peak current to a safe value.

**Construction.** You can build the Pulser in a plain-Jane fashion in a 3" x 4" x 5" Minibox, or assemble the unit in a deep drawn aluminum case, as shown in the photos. Any chassis will do; the one shown here was made from a piece of 5" x 7" x \( \frac{1}{2} \)" soft aluminum.

The switches, battery bracket, and chassis sides are "pop"-riveted in place, but you can use 6-32 x \( \frac{1}{4} \)" machine screws and nuts if you wish. The Keystone 177 battery holder is a suitable mount for a 22\( \frac{1}{2} \) volt battery, but you can modify a penlight cell holder (Keystone 139) if you are not able to get a 177. (Note: no part of the circuit, including even one side of the battery, comes in contact with the case, except for outer portion of \( J_1 \).)

The dialplate is drilled to match the openings in the chassis for the controls and output jack; the nuts on \( J_1, R_2, R_3 \) and \( S_2 \) hold the plate in place. Four feet for the bottom of the case can be made from four #10 nylon countersunk washers and four #6 panhead sheet metal screws. The screws through the front two feet also go through the chassis, and hold it in place.

Wiring is a cinch. All unused terminals on \( S_2 \) are tied together and used to secure the negative ends of the capacitors.

**Modifications.** Any reasonable value can be employed for any of the parts, but the battery supply should be 22\( \frac{1}{2} \) volts or more. Use linear pots; avoid ordinary volume controls. Audio controls with their log tapers will give you a nonlinear scale.

Larger tantalum capacitors can be used to extend the range on the low end. The high end is limited by \( D_1 \) and cannot be increased.

The scales are only accurate to \( \pm 15 \) percent, and will vary with battery voltage and the exact values of capacitors used. If you need greater accuracy, go to a line-operated, zener-regulated supply and hand-pick your capacitors. —90—
Low-cost, high-efficiency calibrator also serves as portable signal source

By FREDERICK FORMAN
and EDWARD NAWRACAJ

SIMPLE, useful, accurate . . . that about sums up this versatile oscilloscope calibrator which puts out a selectable 10-volt, 1020-Hz square-wave or a 50-microsecond, 1- to 2-volt amplitude, 1020-Hz pulse. With this $18-to-build instrument, you can not only check the vertical calibration and time-base (horizontal) linearity of your oscilloscope, but get this . . . you can even check its basic sweep frequency! The calibrator can also serve as a portable signal source with one thousand and one applications.

How It Works. The scope calibrator (Fig. 1) is basically a simple solid-state astable multivibrator designed to close tolerances. Transistors Q2 and Q3 comprise the multivibrator, whose frequency is determined essentially by the values of timing components C1, C2, R3 and R4.

The nominal 1020-Hz frequency can be reduced to an exact 1000-Hz signal by merely shunting C1 and C2 with a 20-pf. capacitor.

Emitter follower Q4 serves to isolate the multivibrator from the loading effects of the output circuit while functioning as an impedance-matching device. Transistor Q1 serves only as a battery condition indicator. It is employed in an emitter follower configuration with a 10-volt lamp (11) serving both as an indicator and as the emitter resistor.

As the source battery deteriorates, its output gradually approaches the zener

Actual photographs of square-wave (left) and pulse (right) produced by solid-state scope calibrator.
(D1) voltage, reducing Q1’s base bias, and thus causing the lamp to glow more and more dimly. This can be observed by pressing the battery test switch (S2). However, because the calibrator would normally be used only on occasion, rather than continuously, the life of the battery can be expected to approach its no-use or shelf life.

**PARTS LIST**

- **B1**—22V, 600-volt battery
- **C1, C2**—0.001-µf., 2% disc capacitor
- **C3**—100-µf. disc capacitor
- **C4**—10-µf., 25-volt electrolytic capacitor
- **D1**—12-volt zener diode (Sarkes Tarzian VR12A or equivalent)
- **D2**—1N457 diode
- **I1**—10-volt indicator lamp (Sylvania 10 ES or equivalent)
- **Q1**—2N404 transistor
- **Q2, Q3, Q4**—2N697 transistor
- **R1**—1500-ohm, ½-watt, 10% resistor
- **R2, R5**—27,000-ohm, ½-watt, 10% resistor
- **R3, R4**—698,000-ohm, ½-watt, 1% resistor
- **R6**—250,000-ohm carbon potentiometer
- **R7**—100,000-ohm, ½-watt, 10% resistor
- **R8**—3900-ohm, ½-watt, 10% resistor
- **S1**—2-pole, 3-position rotary switch
- **S2**—S.p.s.t. momentary-contact push-button switch
- **S3**—5” x 4” x 3” utility cabinet (Bud C-1795 or equivalent)
- **S4**—2¼” x 4” printed circuit board*
- **Misc.**—Binding posts, battery holder, machine screws, solder, hookup wire

*Available from Fred Forman, 2421 West Berwin Ave., Chicago, Ill., for $2 drilled or $1.50 un-drilled.
Series resistor $R_1$ drops the battery voltage to within 0.1 volt of the nominal 12-volt zener diode level.

The multivibrator square-wave output which appears at the collector of $Q_3$ measures approximately 12 volts. This is reduced to the required 10 volts by adjustment of $R_6$. To produce the 50-µsec. pulse, the square wave at $Q_3$ is differentiated by $C_3-R_7$, and rectified by $D_2$ to remove negative overshoots. The output is switched to $Q_4$ by $S_1$, and coupled to the external circuit through $C_4$.

**Construction.** Although the model shown uses a printed circuit board (which the author sells for $2—less parts), you can lay out the circuit on a
When you use the calibrator, connect its output to your oscilloscope's vertical input. Be sure to place a plastic graticule, ruled 10 lines to the inch, over the face of your scope for greater accuracy.

piece of 2½" x 4½" unclad perforated phenolic board if you wish. Use flea clips or solder lug strips for the connections.

The calibrator is housed in a 5" x 4" x 3" utility cabinet. The selector switch (S1), battery test switch (S2), and output binding posts are mounted on the front panel. You can also mount the battery test lamp on the front panel, to the left of the selector switch, although it is shown here mounted on the top of the unit. Calibration potentiometer R6 is on the unit's back panel, and the battery can be secured at any convenient spot inside the cabinet.

Mount the parts on the component side of the circuit board in accordance with Fig. 2. Then install the circuit board in the cabinet (Fig. 3) and complete the wiring connections as shown in Fig. 4.

**Adjustment.** With the battery installed, adjust the amplitude of the square wave to exactly 10 volts, as follows:

1. Set selector switch to SQUARE and connect a jumper between Q3's base and ground to disable the multivibrator.
2. Connect an accurately calibrated d.c. voltmeter across R8 and adjust potentiometer R6 (on the rear of the unit) for a 10-volt meter reading. Then remove the jumper and voltmeter.

After calibrating your scope, you can use it to measure the pulse at the calibrator's output. You cannot adjust the pulse amplitude independently since this is a function of the square-wave frequency.

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**FREQUENCY-TO-METER CONVERSION CHART FOR HAMS & SWL'S**

By JAMES G. LEE, W6VAT

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**FREQUENCY IN MEGAHERTZ**

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**WAVELENGTH IN METERS**

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**By James G. Lee, W6VAT**

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When you're planning to install antennas for various frequencies, it's useful to have a rough idea of the equivalent wavelengths. You could use the formula: wavelength (meters) equals 300 divided by frequency (megahertz), but this quick-look chart will give you almost as precise an answer. The formula is only necessary when you want to cut an antenna to the nearest fraction of a meter. Calibrated to cover the 3.0- to 300-MHz range, this chart makes it possible to convert from frequency to meters or vice versa. Read up and across for meters, across and down for MHz.
COMBINATION
RC SUBSTITUTION BOX

By CARLETON A. PHILLIPS

Just flip the switch to substitute heavy-duty resistors
or capacitors individually or in series
or in parallel networks in your construction projects.

HERE'S AN ITEM that's a must for
shack or shop—an RC substitution box which provides substitute resistors
and capacitors individually, or in series
or parallel RC combinations. You can
use it to bridge suspected defective compo-
ments, or to rapidly switch in different values of resistance and capacitance
to

Fig. 1. Circuit consists of four substitution networks: resistor, capacitor, series-connected RC,
and parallel-connected RC. If capacitor and resistor values shown are not suitable for your
applications, substitute others.
check transistor characteristics and circuits, and to perform various electronic experiments. Simple to build, it can be fashioned from ordinary parts.

How It Operates. Essentially, the substitution box is composed of a bank of capacitors and a bank of resistors which can be switched in by front panel controls to obtain desired values. See Fig. 1.

To use the box as a substitute resistor, place the SELECTOR switch in the RES position, and rotate either the RES switch (S2) or the VARIABLE RES control (R5) for the value you want. The RES control, which switches in one or more resistors (R1 through R5), provides a resistance value of from 0 to 12,500 ohms in increments of 2500 ohms. The VARIABLE RES control fills in all the values between each 2500-ohm step.

To use the box as a substitute capacitor, place S1 in the CAP position, and rotate the CAP switch (S3) to select the capacitance you want.

When bridging a suspected defective capacitor, especially in a transistor circuit, throw the CHARGE switch (S4) to the OPEN position to allow the substitute capacitor to charge slowly through R7 and CAP CHARGE lamp II. When the capacitor is charged, the lamp will go out. Now you can throw S4 into the CAP position. This procedure prevents temporary healing of the bridged capacitor, if it is defective, and current surge. By rotating the SELECTOR switch back to the RES position, charges built up on the capacitors used in the substitution box will be dissipated through R6.

To obtain a parallel-connected resistor and capacitor network, rotate the SELECTOR switch to the PARALLEL RC position. Capacitance value is selected by S3 and resistance value by R5 and S2. To obtain a series-connected resistor and capacitor, place the SELECTOR switch in the SERIES RC position.

**PARTS LIST**

- C1—1 µf.
- C2—2 µf.
- C3—4 µf.
- C4—10 µf.
- C5—15 µf.
- C6—NE-11 neon lamp.
- R1, R2, R3, R4—2500-ohm, 10-watt resistor.
- R5—2500-ohm, 10-watt potentiometer.
- R6—1000-ohm, 2-watt resistor.
- R7—100,000-ohm, ½-watt resistor.
- S1—Two-gang, four-position rotary switch.
- S2, S3—Five-position rotary switch.
- S4—S.P.S.T. toggle switch.
- S5—S.P.S.T. toggle switch with center-off position.
- 1—7" x 12" x 4" box (Bud CU-2111A or equivalent).
- Misc.—Knobs, hardware, etc.

Fig. 2. Use of heavy-duty components puts this substitution box in a class all by itself. You need have no fear of burning out the 10-watt resistors.

Construction. All components are mounted in a 3" x 5" x 7" box as shown in Fig. 2. You can select any assortment of resistors and capacitors to put into the substitution box should you desire a different range of values from that shown. If electrolytic capacitors are used, polarity should be observed and indicated at the BINDING POSTS. Paper capacitors were used here to avoid polarity problems.

All components, except for the three large capacitors, are fastened to the cover of the box. The resistors can be mounted on a small phenolic board. The board can be fastened to the cover, but kept in the clear by a pair of standoff bushings.
AT LAST...

AN INTEGRATED CIRCUIT AMPLIFIER you can build for under $6!

By DON LANCASTER

SIMPLE PROJECT OPENS DOOR TO NEW MICROCIRCUITS

HERE'S the "bargain basement" integrated circuit (IC) amplifier that hobbyists and experimenters have been waiting for. Ideally suited for use as a phonograph or dynamic microphone preamplifier, as a boost amplifier in a receiver i.f. or r.f. stage, as well as in practically all applications employing low-level signals, the complete IC amplifier can be built for under $6.00. The IC, packaged in a TO-5 case, contains the equivalent of six 2N918 transistors and seven resistors, and provides a voltage gain of 40, a current gain of 120, and a power gain of nearly 5000.

Frequency response is essentially flat from 20 Hz to 30 MHz, and distortion is negligible at outputs of up to 0.7 volt peak-to-peak. Clipping occurs at output levels of 1 volt peak-to-peak and over. When assembled with the external components itemized in the Parts List, the IC amplifier has an input impedance of 3300 ohms, and an output impedance of approximately 25 ohms.

How It Works. The integrated circuit amplifier (Fig. 1) consists of two separate transistor differential amplifiers (they respond to the difference between...
two voltages), each of them coupled to an emitter follower stage. The output of the first emitter follower is applied to the base of the second differential amplifier input transistor through coupling capacitor C2.

Capacitor C1 couples the input from J1 to the base of the first amplifier which is biased through R1. Resistor R2 applies bias to the base of the second differential amplifier input transistor. The IC amplifier output is applied to J2 through C3.

Base bias for the second transistor of each amplifier pair is applied directly from a 112-volt tap on the 6-volt supply battery. The full supply voltage is applied to the circuit through S1.

Important: The values of capacitors C1, C2, and C3 determine the frequency response of the circuit. For low-frequency response (about 20 hertz) only, 100-µF capacitors are used; for frequencies above 100 kHz, 0.02-µF disc capacitors are used instead of the 100-µF units. For a full frequency coverage (20 hertz to 30 MHz), parallel the two capacitor values.

Fig. 2. The complete IC, including the battery supply, can be mounted on a small (3" x 5") aluminum plate, drilled and bent to form a chassis support.
Construction. The circuit is easily assembled on an improvised aluminum plate laid out and drilled as shown in Fig. 2. The IC socket used by the author is made up of 10 teflon press-fit standoff terminals inserted into appropriately sized holes drilled in the plate. Then the leads from the IC case are fanned out and each soldered to a standoff.

However, it is possible that the builder may want a much easier and efficient procedure. A single Sealectro press-fit socket (see Parts List) can be press-fitted in a ½" hole drilled in the plate instead of bothering with the 10 small holes.

The four ½"-diameter holes in the upper portion of the plate mount the two penlight battery holders that are either riveted or screwed to the plate. Slide switch S1 is mounted on ½"-long spacers threaded at both ends for #6 screws, through the two ¾"-diameter holes. The three unidentified holes in the vicinity of the IC socket accommodate press-fit standoffs that serve as tie points for component leads. The input and output jacks are mounted on the raised front panel as shown in Fig. 3.

All circuit components should be mounted and wired in place before installing the IC package; but do not (Continued on page 138)

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**Parts List**

| B1, B2, B3, B4 | 1.5-volt penlight cell |
| C1, C2, C3 | 100-µF, 6-volt electrolytic capacitor for 20 Hz to 1.5 MHz; 0.02-µF ceramic capacitor (10 volts or more) for 100 kHz to 30 MHz; both values in parallel for full range |
| IC1 | Motorola dual two-input gate MECL circuit (Allied Radio MC359G, $3.70) |
| J1, J2 | Chassis-mounting phono jack |
| R1, R2 | 3300-ohm, 34-watt resistor |
| S1 | S.p.s.t. slide switch |
| 1 | Sealectro IC 10-pin socket, Part No. RTC-1010 SL |
| 1 | 3" x 5" sheet of 1/32"-or 1/16"-thick aluminum |
| Misc. | Battery holders for four penlight cells (2), teflon press-fit terminals (13), ground terminal, ½"-long threaded spacers (2) with #6 ⅜"-long screws (4), rivets or screws for battery holder, solder, hookup wire |

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Fig. 3. Pictorial of fully assembled integrated circuit shows simplicity of layout and wiring details. The 10 teflon terminals that mount the TO-5 case can be replaced with one Sealectro IC socket.
ETERNAL VTVM
“C” CELL

By GARRY BOROSS

Substitute a rechargeable battery — and forget it

EVERY seasoned experimenter/hobbyist will agree that the VTVM is a basic tool for circuit testing and electronics repair work. But it has one shortcoming—hidden inside that metal case is an ordinary flashlight battery. Too often this battery is forgotten until the experimenter realizes that the ohmmeter readings are way off and a corrosive fluid is seeping out the bottom of the VTVM case.

If you believe that an ounce of prevention is worth a pound of cure, try substituting a nickel-cadmium battery (B1) for that old flashlight cell. Simultaneously, wire into the VTVM a simple half-wave rectifier using a silicon diode. This diode (D1) and a series current limiting resistor (R1) are fed from the 6.3-volt filament winding.

The nickel-cadmium cell can be inserted into the battery holder in the VTVM. Or, if you would like to solder the battery into the circuit, you can obtain a nickel-cadmium cell equipped with soldering tabs. When power is applied to the VTVM, the battery will receive a small trickle charge—generally 20-30 ma. There is no danger of the battery being overcharged, even if the VTVM is left on continuously.

*Mercury batteries are not used in VTVM's because of their high internal resistance. Alkaline batteries are occasionally recommended for use in VTVM's, but they sometimes release corrosive gases that damage switch contacts.

ELECTRONIC EXPERIMENTER'S HANDBOOK
This is the “fun” chapter in the ELECTRONIC EXPERIMENTER’S HANDBOOK. The seven projects are a “mix” of Science Fair ideas, practical jokes, and games. As a practical joke, we recommend the “Tickle Stick” (page 125)—a harmless, but surprising little gadget that will provide you with hours of fun. For games, try either the “Dozen” (page 114) or the “Reflexometer” (page 127).

As a Science Fair project, our highest recommendation goes with the “Li’l Atlas” (page 119), one of those science-fiction devices that you see every now and then in the movies. Suspended below an electromagnet is a small globe of the earth. As gravity pulls the globe down, the magnet pulls it back—just enough to counteract the pull of gravity—and the globe is seen hanging in space with nothing touching it. This is a project you really must build in order to appreciate the startling effect.
A LIGHT on one side of this mystery box flashes, and a ring jumps toward it like a trained animal. Within a few seconds a light on the opposite side flashes, and the ring leaps over to it with the same rapidity. This action continues as long as power is applied.

What facet of space-age technology has made it possible for a light to attract what appears to be a black metal ring? Is it an ionic generator of some sort, or some heretofore unknown plasma or form of energy at work? What electronic genius thought this thing up in the first place? Chances are that you will get as many different explanations as there are viewers, if you insist upon answers to your questions.

The flashing light creates the illusion of attracting the ring, and the illusion attracts a crowd. Aside from the commercial aspect of being able to capture the attention of large groups of people, a principle of mutual induction can be demonstrated and the project should make an intriguing entry in science fairs or other similar events.

**How It Works.** A slow-revolving (6-rpm) timing motor alternately energizes a coil located at each end of a semicircular soft iron rod. See Fig. 1.

**Fig. 1.** As the timing motor alternately energizes the two coils, the ring jumps from one side to the other. When the lamp on the right lights, the ring jumps to the right. When the lamp on the left lights, the ring jumps to the left. It looks as if the light attracts the ring.

Coil $L_1$ is energized when contact 1 or 3 is touched by the rotating arm; coil $L_2$, when contact 2 or 4 is made. When a coil is energized, a magnetic field is created.

The soft iron rod in the center of the coil concentrates much of the energy in the magnetic field and increases the coupling of the magnetic field to the aluminum ring. This causes an induced current to flow in the ring, which sets up a...
By WALTER B. FORD

BUILD THE

CROWD STOPPER

magnetic field of its own. These fields magnetically oppose each other, and the ring is vigorously repelled. It shoots upward and away from the coil, travels around the loop, and lands on the other side, near the other coil. When the other coil is energized, the ring is shot back to where it came from. This back-and-forth motion is in step with the rotation of the timing motor.

The timing motor operates directly off the 117-volt line. Coils L1 and L2 operate off the 12-volt secondary winding of T1. Lamp L1 is wired across L2 and lights when this coil is energized. Similarly, lamp L2 is connected across L1 and lights when L1 is energized. Because each lamp is physically located opposite its coil, there is the illusion that the lamp attracts the ring.

Construction. Drill the Masonite panel as shown in Fig. 2. Place the drilled panel over the open space on the aluminum chassis; then mark and drill around the flanged edges of the chassis as shown. Drill a few additional holes in the chassis for ventilation, line cord entrance, switch mounting, and rubber feet.

Remove any nicks from the 24" soft iron rod being used for the loop, with a fine file or sandpaper. Then polish the rod with emery cloth and steel wool. Make a wood form for shaping the loop (Fig. 3). Attach another piece of wood to the form by means of a back plate so as to provide a slot for holding one end of the rod.

Place the form and back plate in a vise, and insert the iron rod into the slot so that the end of the rod is positioned 5½" from where the semicircle ends. Bend the steel rod around the form, using a rubber mallet or block of wood as necessary. If one side of the rod is

Fig. 2. Drill a 7" x 12" x 3/16" Masonite panel to hold the soft iron loop and the pilot lamp sockets. Position of mounting screw holes is not critical.

Fig. 3. Carefully bend the rod around the wood form to obtain a smooth shape in the loop. Rod must be clean and free from burrs to permit the ring to travel freely without interference.
PARTS LIST
11, 12—12-16 volt miniature bayonet lamp
L1, L2—See text
S1—S.p.s.t. toggle switch
S2—See text

T1—Filament transformer; 117-volt primary, 12-16 volt secondary, 2 amp., minimum (Allied Radio 65 G 331 or equivalent)
1—6-volt timing motor, 117 volts a.c., 60 cycles—see text
1—7" x 12" x 3/16" piece of Masonite
1—23/4" x 2 3/4" x 3/16" piece of Masonite
1—3" x 7" x 12" aluminum chassis (Bud AC-408 or equivalent)
1—24" soft iron rod, 1/2" diameter
2—13/16" fiber or Micarta washers, 1/8" thick
1—8" length of soft iron wire, 16 or 18 gauge
1—22-gauge enamelled magnet wire—see text
2—Pilot light assemblies (Allied Radio 7 E 891)
1—1/2" brass rod, 1/2" diameter
4—Pieces of 20- or 22-gauge round brass tubing, 1/2" o.d., 3/8" long
1—5/16" piece of 20- or 22-gauge seamless aluminum tubing, 3/8" o.d. (won't work with a seam)
4—5/16" x 9/16" pieces of 26-gauge spring brass
1—5/16" x 13/16" piece of 26-gauge spring brass
Misc.—Line cord, 3/8" x 6-32 brass round-head machine screws (4), 2" x 6-32 steel round-head machine screws (2), 6-32 hexagon brass nuts (8), 6-32 hexagon steel nuts (2), rubber screw bumpers (4), 3/16" x 6 sheet metal screws (14), 1/8" x 1 1/2" wood dowels (2), 1/4" rubber grommet, 1/8"-20 hexagon steel nuts (4), 3/16" diameter steel washers with 1/8" center (2), #6 lock washers (4); and #8 brass washers (4)

Fig. 4. Construct coil forms as shown. Each coil takes about 80 feet of No. 22 enamel-coated wire. A 1/2-pound spool should be enough for both coils.

Fig. 5. Cement the finished coils to the bottom of the panel. Use extra long coil leads to avoid undue stress on the connections when assembling the unit.

Fig. 6. Fabricate the rotary switch on a 2 3/4" x 2 3/4" piece of Masonite and bolt it to the chassis using two 1/2"-long dowels and 2"-long screws.

longer than the other after forming, cut it to make both sides even. Then thread about 1/2" from the ends using a 3/4" die.

Construction of L1 and L2. Make two coil forms with fiber or Micarta washers and strips of thin cardboard as shown in Fig. 4. Wrap a strip of 2"-wide cardboard around a 1/2" wood dowel and apply glue between the layers of cardboard without getting any glue on the wood dowel. Drill holes in the fiber coil ends to fit the cardboard tube and cement the tube and the ends together. Then drill two 1/8" holes in one end washer of each coil form to pass the wires through.

Wind approximately 80' of No. 22 enamel-covered magnet wire on each form. The exact amount is not important, but it is important to wind the coil turns close together and evenly. Suppliers of magnet wire generally sell the wire wound on 1/2-lb. spools. One such spool is usually enough for both coils.

Mount the pilot light assemblies to the Masonite as shown in Fig. 5. Then center the two coils on the underside of the panel and over the 1/4" holes, and cement the coils in place. The aluminum ring
You'll than 16 position. Cut a down yond the top ends 20-loop is positioned to provide gentle contact Fig. 8. rotating contact to fit snugly on the motor shaft.

which flips back and forth on the steel loop is made from 1/2''-long, 3/8''-o.d., 20- or 22-gauge aluminum tubing; both ends of the ring should be reamed before the ring is placed on the loop.

Insert the ends of the loop from the top of the panel through the centers of the coils until the ends extend 1/4'' beyond the coils. Then turn the unit upside down and support the ends in the same position. Cut a number of pieces of No. 16 or 18 soft iron wire, each slightly less than 2'' long, and straighten the pieces as much as possible. Then insert the wires around the steel loop ends (Fig. 4) in the center of the coils, applying a coating of epoxy cement to each piece as it is inserted in place.

Tightly pack both coils with the wires. You'll find it easier to insert the wires if you sharpen one end of the wire with a file. Then cut notches in the steel washer to clear the coil leads; place the washers and nuts over the 1/4'' rod projecting from the coil ends. Do not tighten the nuts until the epoxy glue has set.

Drill the 2 3/4'' x 2 3/4'' Masonite board used to mount switch S2 as shown in Fig. 6. Measure the spacing of the mounting holes on your timing motor and drill corresponding holes in the base.

Herbach and Rademan Inc., 1204 Arch St., Philadelphia, Pa., 19107, offers a line of synchronous timing motors from 1/2 to 30 rpm. The 6-rpm model is priced at $4.95, f.o.b. Philadelphia. Motor rpm is not critical and almost any timing motor, down to 1 rpm, will work well.

Next, start making the four stationary contacts from 20- to 22-gauge, 1/4''-o.d., brass tubing cut to 1/2'' in length. As shown in Figs. 7, 8, and 9, they are made by soldering a 1/10'' x 1/10'' 26-gauge piece of brass spring into the slotted tubing. When making the contacts, cut each length in line with the "grain" of the metal to prevent it from snapping when bent. The alignment of the grain can be determined by observing the direction in which the metal tends to curl when laid on a flat surface.

The rotating contact is made by soldering a strip of spring brass into a piece of slotted brass rod as shown in Fig. 7. Dress down the edges of the rotary and stationary contacts to insure quiet operation. Each of the four sta-

(Continued on page 138)
YOU CAN'T BUY a Wurlitzer organ like the one at Radio City for ten bucks, but you can build the Mini-Organ for less than that. Your youngsters will be delighted—and you'll be, too—at the ease with which such well-known tunes as "Red River Valley," "Blue Bells of Scotland," "Home, Sweet Home," and many others can be played on an instrument you can put together in a couple of hours.

How It Works. The Mini-Organ is a two-transistor, battery-operated multivibrator whose frequency (pitch) is determined by the \( RC \) time constant of \( C1-R1 \) (Fig. 1). The lowest frequency of oscillation—and hence the lowest tone—is determined primarily by the value of capacitor \( C1 \) and series capacitors \( C2 \) through \( C8 \), while the highest frequency of oscillation (highest pitch) is determined essentially by the setting of potentiometer \( R1 \) in series with resistor \( R2 \).

When capacitors \( C2 \) through \( C8 \) are alternately switched in series with \( C1 \), a change is produced in the multivibrator frequency which in turn produces a one-octave musical scale. Depending on the characteristics of transistor \( Q2 \), capacitor \( C9 \) may be required to aid the multivibrator action. Diode \( D1 \) provides the feedback path to sustain oscillation.

Switches \( S1 \) through \( S8 \) are the push-button operating keys that apply the right amount of capacitance in series with \( C1 \) to produce the desired tones when pressed. Transistor \( Q1 \) is an \( npi \), high-current, high-frequency switching type, while \( Q2 \) is a \( pnp \) audio frequency type which provides sufficient volume for comfortable listening in a small room. If greater volume is desired, the builder can add as many stages of amplification as may be necessary.

Operating power is supplied by four ordinary flashlight cells in series.

Construction. The Mini-Organ can be laid out and breadboarded on wood or on
a perforated phenolic board as shown in Fig. 2. Breadboard dimensions are best determined by the builder. The push-button keys are spaced \( \frac{3}{4}" \) apart at the bottom of the panel, and the opening for the speaker is spaced midway between the holes for the keys and the top edge of the panel.

Main power switch S9 can be combined with the potentiometer, or may be a separate slide or toggle switch as desired. The transistors, the 1-megohm resistor, and the capacitors are mounted on terminal strips.

The entire unit can then be housed in a plastic or wooden case as desired. The keys can either be color-coded or numbered for easy recognition.

**Operation.** Try out the organ by adjusting the potentiometer at different settings as the keys are depressed. If you want a lower tone, increase the value of \( R2 \) in 500,000-ohm increments. To change the tone range slightly, change the value of \( C1 \) in small increments. Using less capacity will give you a higher tonal range.

From here on, you are on your own. Practice with simple tunes within the instrument’s range until you can master your favorites. And have fun.

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**PARTS LIST**

- **B1** — 1¾-volt cells (4 required)
- **C1** — 0.005-µF ceramic disc capacitor
- **C2-C8** — 0.02-µF ceramic disc capacitor
- **C9** — 0.001-µF ceramic disc capacitor (optional — see text)
- **C10** — 0.2-µF paper capacitor
- **D1** — 1N54 diode
- **Q1** — 2N388 transistor
- **Q2** — 2N408 transistor
- **R1** — 1-megohm potentiometer with switch
- **R2** — 1-megohm, ½-watt resistor
- **S1-S8** — Momentary-contact push-button switch
- **S9** — S.p.s.t. switch
- **SPKR.** — 8-ohm speaker
- **Misc.** — 5-lug terminal strips (3), small knob, hardware, wire, solder, etc.

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*Fig. 1.* Mini-Organ operates on single 6-volt transistor radio battery or four ordinary flashlight cells. If transistors different from those specified are employed, or if oscillation is unstable as indicated by a wavering note, insert C9.

*Fig. 2.* This photograph shows the rear panel of the author’s prototype organ which was later rewired to improve lead dress. Parts are mounted on terminal strips, and the battery is strapped down in the case.
ELECTRIC DOZEN GAME

SOME TIME AGO when the author saw an advertisement for a Mallory 24-contact point rotary tap switch, the thought occurred to him that this low-cost switch might be useful in a game or gambling device. The switch detent mechanism is easily removed, and when it is eliminated the switch rotor can be con-

tinuously rotated. The switch contacts are 15° apart, and in the unit pictured on this page the two switching decks are paralleled and the contacts paired. Thus, neon lamp 9 is lit when switch S4 is at either lug 13 or 23, lamp 3 when S4 is at lug 1 or 20.

To drive the rotor, the author used a 120-rpm, 117-volt a.c. motor. The 1/4” shaft of the motor is attached to the switch rotor through a flexible coupling to eliminate binding and permit the switch to be rotated freely. The wiring is obvious from the diagram, although a few words on the additional switching might be in order.

The motor is activated by a s.p.d.t. push-button switch (S1). If all 12 lights are required in your game, switch S2 is closed. If only 6 lights are preferred, S2 is opened and only the neon lamps with the numbers 1 through 6 will be lit. Without switch S3 in the circuit, the lamps will go out as the motor revolves the rotary switch rotor. With S3 in the circuit (and closed), the neons blink on and off as the motor works.

—Ken Greenberg
IN YOUR KITCHEN you’ll find more than just food. Look around and you’ll come across some of the things needed to make a small Van de Graaff generator. Here’s a “recipe” for an electrostatic generator which can put out upwards of 100,000 volts of harmless static electricity, and which requires very little culinary skill to prepare. Ingredients called for include a small pie tin, a large aluminum salt shaker, and a few “condiments.”

Although it's diminutive in size, there is little difference in principle between this midget powerhouse and the massive 2-million-and-more-volt units used in atomic research. This generator makes a perfect science fair project and is easy to build. You can use it to demonstrate the laws of electrostatics—and don’t be surprised if it makes your hair stand up as well!

How It Works. As you know, the simplest way to generate static electricity is to rub two pieces of material together. Walk across a carpeted floor on a dry day, and chances are you’ll draw sparks when you touch a metal surface; or run a comb through your hair, and you’ll hear

“Hopped-up” utensils and about $2.50 worth of ingredients desert the kitchen for the science fair.

By Ed Francis
things snap, crackle, and pop. While this static electricity is commonplace, it is no different from that produced by the little Van de Graaff generator "cooked up" here. A hollow insulating column held in place by a pie-plate base supports a salt-shaker dome. Within the base, a small toy motor drives a rubber belt around a plastic pulley.

When two dissimilar substances are rubbed together, they become electro-statically charged. The one with the higher dielectric constant usually takes on a positive charge, and the other takes on a negative charge. Plastic materials generally have a higher dielectric constant than rubber, and if this is the case with the materials you select, the plastic will become positively charged by giving off electrons to the rubber. But regardless of which material is positive and which material is negative, the rubber

While construction is quite simple, assemble the parts as neatly as you can and be sure to align them properly. The soft rubber belt should exert a small amount of tension. The wire mesh brushes are dressed close to the belt—but do not touch it.

Be certain that the dome contact clip makes contact with the inside of the dome. One way to get higher voltage is to use a larger or rounder dome. The diameter of the smallest exposed curve determines maximum voltage.

The small d.c. motor can run on flashlight batteries, but you may find it more convenient to assemble a small power supply.
belt transfers the charge deposited on it to the dome, until a certain maximum charge is reached. This charge is dependent upon the roundness of the dome—it’s usually on the order of 30,000 volts per inch of diameter of the smallest curve or point. Therefore, if you want to build up high voltage, use a large diameter ball without any ripples, points, or other small projections.

The wire mesh brushes at top and bottom merely aid the flow of electrons to or from the dome and the base, depending upon which is positive and which is negative. You can use flashlight batteries to power the motor, or you can build a small half-wave-rectifier power supply to convert the line voltage to 6 volts d.c., and eliminate the batteries.

**Construction.** Most people associate the Van de Graaff generator with a huge ball-shaped metal dome, but the shape of the metal dome need not be perfectly round as long as it has no sharp edges or small curves. An inexpensive large-size aluminum salt shaker with a plastic lid can be used with excellent results. The plastic lid is a good electrical insulator and prevents corona discharge from the small diameters of the threaded end of the salt shaker.

The column is made from a 4" length of 1/2"-o.d. Lucite, Plexiglass, or polystyrene tubing. The inside diameter must be wide enough (about 7/8") to pass the rubber belt. You might try obtaining a large pill vial from your druggist to serve as the column. The small pie tin should be large enough to keep the structure from toppling over.

Drill a hole in the center of the shaker lid which is the same size as the outside diameter of the tubing, and cement the cover in place about an inch down from what will now become the top of the column. Drill holes in the pie-plate base to mount the motor, and the jack (J1) for the batteries or power supply. Bolt the retaining ring made from about 1/8" wood stock to the pie pan. Do not cement the column to this ring, at least not until after you have aligned the belt, and then only if you have to. The hole in the center of the pan is only as large as the inside diameter of the tube, and
does not allow the tube to pass through the pan.

Make the upper pulley from a ¾” length of ⅜”-diameter plastic or wood dowel. Drill a ¼” hole lengthwise through the center of the dowel and insert a ¾” length of rod cut from ¼”-diameter brazing wire or piano wire so that it protrudes about ½” from each end. Cement a layer of aluminum foil around the pulley. The lower pulley is made from the same material except that it should be drilled for the motor shaft and covered with an even layer of plastic electrical tape.

Cut two notches about ½” deep on top of the column to cradle the upper pulley shaft. Then drill a ¾” hole approximately one-quarter inch below one of the notches for the upper brush bracket and dome contact. Fasten the lower brush in the base on the side of the belt which travels upward.

A wide variety of motors will work with the generator; in fact, almost any miniature, fairly high rpm toy motor will do.

The 1¼” x ½” belt can be fashioned from a piece of thin sheet rubber of the type available from surgical supply houses or cut from an old swimming cap. Angle both ends to obtain a long, smooth butt seam. Apply rubber cement—the kind used to fix a flat tire—to each end, and when dry, carefully press the ends together and apply a thin coat of cement over the joint.

After the joint is bonded, install the belt by dropping it down through the tube and engaging both pulleys. Check the belt for proper alignment and tracking. You can do this by running the motor. If the belt doesn’t track, shim up the motor where necessary, or cut one of the upper pulley notches deeper. Belt tracking can also be improved by constructing the pulleys with a slight crown or hump in the center.

Both upper and lower brush brackets are made by soldering a small piece of No. 18 copper wire, bent to shape as shown, to a ⅜” x ⅜” bronze or other metal window screen material. The dome contact clip, which is also a piece of copper wire bent to shape, should be mounted so as to make contact with the inside of the salt shaker body when assembled. Use a 6 x ½” sheet metal screw to attach the contact and brush to the column.

Adjust both brushes so that they are close to the rubber belt but not touching, and in line with the pulley. Then screw the dome in place. Miniature phone jack J1 is then mounted on the base and attached to the motor to facilitate the battery or power supply connections.

A small wooden box houses the power supply components. A miniature phone plug on the end of a 3’ lead plugs into the pie pan. If you happened to use a large enough pie pan, you might get away with installing the power supply inside the base.

**Operation.** Some laws of electrostatics can be demonstrated by placing small bits of aluminum foil, paper or sawdust on the metal dome and watching them fly away from the dome as a charge is built up. These bits take off because they gain a like charge. *Like charges repel; unlike charges attract.*

The Indian rope trick, in miniature form, can be duplicated by attaching a few long strands of string or tissue paper to the dome. When the strands take on a charge, they will stand on end as they try to fly away. Touch the strands with your fingers, and they’ll lean toward your hand as your body steals the charge.

A jumping ball demonstration can be performed by placing two or three small pith balls inside a small plastic tube, covering the tube with a metal disc, and placing it on top of the dome. As the balls are repelled upward from the dome, they will cling to the metal disc on top and then fall back to the dome. This action repeats itself until the disc approaches the potential of the dome.

To send corona discharge into the air, bend a piece of stripped hookup wire so that it will sit on top of the dome with one end pointed up. This end should be filed to a sharp point. Douse the lights, turn on the unit, and sit back and watch man-made lightning in miniature being produced. Another indication of the presence of corona is the peculiar smell of ozone which is usually generated.

Moisture and dust in the column and dust on the dome will rob your unit of its prowess. So keep it clean.

---

118 ELECTRONIC EXPERIMENTER’S HANDBOOK
Li’l Atlas Defies Gravity

UNLIKE the Atlas of Greek mythology, condemned to carry the heavens on his shoulder for all time, “Li’l Atlas” is no myth. It’s an electromagnetic photoelectric type of servo system that can establish a weightless condition on small metallic objects. And it’s sure to steal the show at any Science Fair.

You place an object—an ordinary door key, a child’s tin toy, or a small metal globe like the one shown—in the device’s “sphere of influence.” Then, like the boys at the Cape, you man the controls to suspend the object in space. You can move it up or down, or even wiggle it, if you wish.

How It Works. A photoelectric cell serves as a position sensor, and controls the intensity of a magnetic field that is used to counteract the pull of gravity on the object being suspended. (See photo.) Photocell PC1 is mounted on a wooden column opposite a light source.

Like orbiting satellites, objects just float in space when magnetic attraction overcomes the pull of gravity

By WILLIAM J. PRICE

When an object is suspended, it breaks part of the light beam reaching PC1.

If the object begins to fall, more light reaches the photocell, increasing the photocell’s output current (Fig. 1). This current increase is amplified by Q1 and Q2, and direct-coupled to power transistor Q3, whose output is in series with an electromagnet (coil L1). The resulting current increase through L1 causes an increase in its magnetic field to overcome the pull of gravity, raising the object back up in place.

Similarly, if an object is raised above its predetermined height, less light falls on PC1, reducing the current to Q3. The magnetic field intensity is decreased, al-
Fig. 1. Like a Palace Guard, photocell PC1 keeps an eye on the object in space. If the object tends to fall, the photocell rushes the information via the transistors to coil L1 (the electromagnet) which, in turn, acts to increase the pull on the object to prevent it from falling. Conversely, if the object is being pulled too close to the coil, PC1 detects this condition and reduces magnetic pull to re-establish equilibrium.

lowing the object to drop down to its proper position.

The BIAS potentiometer, R1, controls the amount of current through Q1 for proper operation under existing lighting conditions. Similarly, the HEIGHT control, R6, adjusts the bias on Q2, and establishes the height range through which an object can be suspended. The C2-R4 coupling network stabilizes Q2's base current for a smooth response. STABILITY control R2 stabilizes the oscillatory tendency of the suspended object by adjusting the amount of feedback voltage developed by R8 and fed back to Q1 through Q1.

The power supply is comprised of filament transformer T1, a full-wave bridge rectifier (D1 through D4), limiting resistor R10, and filter capacitor C3.

Construction. If you use the chassis listed here, your first task is to lay out and drill the holes as shown in Fig 2. If you elect to use a different chassis, the suggested layout can still be followed except for the dimensions—which may change.

Once the chassis has been drilled and deburred, lay it aside temporarily while you proceed to make the wooden bracket,
photocell mounting bracket, and the coil support strap, as shown in Fig. 3.

Winding the Coil. The coil is wound on a 1/2” x 3/4” x 3 1/2” core made from laminated strips of mild steel (Fig. 4). You can have these strips made up by your local sheet metal shop, or they can be salvaged from an old power transformer core.

Clamp the laminations tightly together, then wrap a layer of black plastic tape around the core to hold the laminations close together while the coil is wound. This will also prevent the wire forming the first layer of the coil from being stripped by the sharp edges of the core. At one end of the core, keep the tape 3/8” away from the edge.

Cut a 1/2” x 3/4” opening in the center of one of the two Lucite or Bakelite end stops. Insert the piece with the cutout over the end of the core with the 3/8” recessed tape. Center the other piece of Lucite over the other end of the core. Then, cement both pieces of Lucite in place using epoxy cement.

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Allow sufficient time for the epoxy to dry thoroughly, and close-wind 800 feet of #26 Formvar magnet wire (approximately 2500 turns) on the core. Wrap one or two layers of plastic tape around the finished coil to protect the wires and hold the turns in place. Remove about one inch of varnished insulation from both ends of the coil using a fine file or sandpaper, then tin the bare wire. The d.c. resistance of the finished coil is approximately 30 ohms.

Installing the Parts. You are now ready to begin mounting the components on the 4” x 3 1/2” prepunched Vectorbord. Do not mount Q1 and Q2 any closer to the 5-watt resistors than is shown in Fig. 5. Also, make certain the capacitors and diodes are connected with polarities as shown.

Mount the filament transformer and terminal strip using 8-32 x 1/2” screws and nuts. Note that the terminal strip is held in place with one of the transformer screws.

To mount Q3, drill the base and emit-
ter holes using the mounting kit’s diamond-shaped mica washer as drill guide. Apply silicon heat-sink grease to the transistor mounting surface to insure good heat transfer. The base terminal must be positioned toward the top of the chassis while the emitter faces toward the bottom. The collector is grounded to the case. Be sure the #6 solder lug is mounted on the screw as shown.

Now install the two 3/8” rubber grommets, controls R1, R2, and R6, and the pilot light assembly. Connect a 100,
000-ohm resistor (R11) from one of the pilot light terminals to the terminal strip, and connect one end of a 3" length of insulated hookup wire to the free terminal of the pilot light. Insert the line cord through the grommet provided, and connect one of the leads to the terminal strip. Then connect one of the transformer primary leads (black) to the terminal strip. Solder all leads.

Position the power switch (S1) close to its chassis mounting location. (Do not mount the switch at this time.) Connect the remaining transformer black lead to one of the switch terminals. Then connect the free end of the hookup wire from the pilot light to the same switch terminal, and the free lead from the line cord to the other switch terminal. Solder all leads and mount the switch on the chassis.

Mount the coil and photocell on the assembled wooden bracket as shown in Fig. 6, and secure the bracket to the chassis. Feed the leads through the grommet, and connect the wires as shown in Fig. 5.

Finally, insert four 6-32 x 1¾" screws down through the top of the chassis, tightening the nuts against the inside of the chassis. Thread a second nut ¾" down on the screw to act as a standoff for the component circuit board. Then mount the circuit board and complete all wiring.

**Operation.** Before plugging in the Li'l Atlas, check to make sure that (1) exposed coil terminals are not grounding out against the supporting metal strap, if one is used; (2) the coil and photocell are properly positioned as shown in Fig. 6; (3) all connections have been soldered, and there are no shorts.

Place a light source (a 50- or 60-watt desk lamp will do) opposite the photocell, and about two feet away from it. Position the light so that the exposed end of the coil core casts a shadow on the upper portion of the photocell. If Li'l Atlas is to perform in a strongly lighted room, shield the photocell with a piece of cardboard or paper tubing.

Now all you need is a small object that will remain suspended in space. Almost any small iron or steel object, such as a key, can be used. If you want something that will spin as it floats around, obtain a round object such as a tiny globe which you can get in a dime or stationery store.

Turn on Li'l Atlas and set its **STABILITY** control for maximum resistance, the **BIAS** control for minimum resistance, and **HEIGHT** control to midpoint. Loosely hold the object about ¾" below the magnet, and advance the **BIAS** control until the magnet begins to pull. Then adjust the **STABILITY** control to "settle down" the object as it begins to oscillate. Remove your hand and the object will remain suspended.

You can cause the object to vibrate rapidly for special effects by advancing the **STABILITY** control.
ONE LOOK at the foil-covered electronic stimulator is enough to give you the creeps. Do you have enough guts to hold onto it with both hands? Under that shiny aluminum "skin" beats a "stout heart" with enough zip to pulse your muscles without so much as moving a finger. After your first reaction, if you are still holding on, you will feel great—especially after you let go. While it may come as a shock to you, the stimulator is completely safe; there's no dangerous high voltage or current to worry about.

How It Works. Pulses generated by a simple single-transistor modified Hartley oscillator are transformer-coupled by a reverse-connected filament transformer to a couple of electrodes. Resistor $R1$ and capacitor $C1$ determine the frequency of the pulses; changing the values of either of these components or changing battery voltage will change the frequency. Different frequencies create different sensations, but it's best to stick to the values given in the Parts List.
Construction. All components are mounted inside a cardboard tube about 9" long and 2⅜" in diameter. End plugs for the tube can be fashioned from styrofoam plastic such as that used in packaging. They can easily be cut to shape with a small knife. (If you can't get styrofoam, you can use wood, metal, or even cardboard.) Hollow out one plug to hold the on-off switch. Then drill a ¼" hole ½" from each end of the tube to accommodate the wires for the electrodes.*

Follow the pictorial diagram when wiring the unit. Note that the transistor is mounted directly onto the transformer mounting flange and the flange is bent upward slightly to allow clearance when you insert the circuit into the tube. Use long leads between the components and the tube to allow for the removal and replacement of the entire electronic package, or just removal of the battery. Leads of 8" or more should be used to connect T1's center tap to S1, the emitter of Q1 to the battery holder, and one side of the secondary winding of T1 to the cardboard tube. The other side of T1's secondary should be made about 12" long. Strip about 3" of insulation from the 8" and 12" leads attached to the primary winding of T1, and insert one lead through the hole in the one end of the cardboard tube and the other lead in the other end of the tube. Wrap the leads around the tube at each end once or twice.

Now cut two 4" x 14" strips of aluminum foil and roll them "squarely" over the tube flush with the ends of the tube, leaving a 1" separation in the middle as shown in the photo on page 125. To obtain good electrical contact with the bared wires coming from the inside of the tube, roll the aluminum foil on tight, smooth and squeeze out any trapped air, and tape the ends. Each strip of foil must make contact with only one lead. Incidentally, a good source of aluminum foil is your local grocery store.

Using the Stimulator. After you insert the circuitry into the tube, tissue or other soft filler can be stuffed in to keep the works in place. Cap the two ends of the tube with the styrofoam, and you're ready to go into the shocking business.

Push the button, hold on to the two aluminum electrodes and you'll feel that stimulating flow of current travel up your arms. Then try it out on your friends. Stimulation, anyone? —90—

**PARTS LIST**

<table>
<thead>
<tr>
<th>B1</th>
<th>1.5-volt battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>160-μF, 10-volt electrolytic capacitor</td>
</tr>
<tr>
<td>Q1</td>
<td>2N70 transistor (or equivalent)</td>
</tr>
<tr>
<td>R1</td>
<td>1800-ohm, ½-watt resistor</td>
</tr>
<tr>
<td>S1</td>
<td>S.p.s.t. switch</td>
</tr>
<tr>
<td>T1</td>
<td>Filament transformer: 117-volt primary, 6.3-volt CT secondary (Thordarson 21F09 or equivalent)</td>
</tr>
<tr>
<td>1</td>
<td>9&quot; x 2½&quot; cardboard tube (approx.)</td>
</tr>
<tr>
<td>Misc.</td>
<td>Aluminum foil, wire, solder, etc.</td>
</tr>
</tbody>
</table>

*An ideal tube for this project is a stiff, white plastic rolling pin which is now being sold at most large stores. If you want to use it instead of the cardboard tube, simply twist off the handles and use a small screwdriver or knife to remove the end plugs. Enlarge the hole in one of the plugs to accommodate the switch.
Are you a flincher? Try your hand at Reflex... an electronic game of skill

BUILD A REFLEXOMETER

By JAMES FISHBECK

THE PERFECT Rx for pooped-out parties or for those rainy evenings when you're looking for something to do is to play "Reflex"—a game of skill which shows your wizardry with electronics, and also shows which of your guests can respond properly and more quickly to a given situation. The situation in this case is created by certain selected dice throws. All you need to play is a pair of dice, a set of poker chips, a jaw-tight determination to prove how fast your reactions really are, and a "Reflexometer."

Two, three, or four people can play the game.

There's a bonus for you, too; the Reflexometer has other applications both for work and for play, some practical and some not so practical.

Four hand-held push-button responders, each a different color and each manned by a different player, tie man and machine together. The first man to press the button lights a lamp that corresponds to his responder. The lamps are wired through a system of four relays which permit only one lamp to light at a time. Once a lamp lights, it remains lit even after the button is released. Second best is no good: the other lamps cannot be illuminated, at
least not until the winner collects, and the reset button is pressed.

How To Play "Reflex." Each player starts with 25 poker chips. All players roll the dice once to see who starts. The one who rolls the highest number goes first. He starts the game by rolling the dice.

Any double or combination of 7, or 11, is a "reflex" roll, and the first person (including the player who rolled the dice) to press his responder switch in response to a reflex roll, wins the round and collects a chip from each of the other players. If no proper reflex action occurs on the throw, the player who rolled the dice does so again until one of the players wins. The dice are then passed to the next player on the left. Of the 36 possible combinations of the dice, 14 (approximately 40%) are reflex rolls.

Sounds simple, doesn't it? But there's a human element to complicate matters. Quite often those who respond first lose; edgy players, those most anxious to register first, are most likely to flinch. A flinch is a false or a premature response that causes the light to come on when it shouldn't. If a player flinches, and his lamp shows that he did, he pays a penalty of one chip apiece to the other players. The dice are not passed on a flinch.

Tension mounts as the game progresses, and if you are a good student of human behavior, you may try some maneuvers such as feigning a flinch to send an anxious player over the hill.

Fig. 1. Responders S1 to S4 can complete only one relay circuit at a time. The first switch closed latches its respective relay, lights its lamp, and disables the other relays until the circuit is reset.
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- RCA Add-On Heat Sensor Kit (KD2110). Containing three thermistors for different temperature ranges; special solder for heat control circuits.
- Readily available passive components and hardware.

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with his nervousness. The player with the most chips, after another player loses all, is the winner.

You can also use the Reflexometer to show which event in a series of actions occurs first, such as in a foot race or a slot-car race. Switches installed on the track and wired to the unit act as impartial judges. (Perhaps, if such a device were available years ago, we would know today which came first—the chicken or the egg.)

How the Reflexometer Works. Each of the four responders, containing one of the switches S1 to S4 (Fig. 1), is connected to one of the relays (K1 to K4) and to one of the lamps (II to I4). The first button depressed completes a circuit for its associated relay and indicating light. If S1 is pressed first, for example, I1 lights and K1 energizes. When the armature of K1 pulls in, one of the contacts on the relay completes the relay circuit to ground and, like an electrical latch, holds the relay energized and the lamp lit even after the responder button is released.

The three remaining sets of contacts on K1 open the B+ leads to K2, K3, and K4 to prevent these relays from kicking in on a second-best response. The circuit remains latched until S5 is depressed. When S5 is momentarily opened, K1 de-energizes and the Reflexometer is ready for the next round of play.

Transformer T1 steps down the line voltage to 24 volts, and D1 functions as a half-wave rectifier. Capacitor C1 filters the B+ and R1 acts as a bleeder and tends to regulate the voltage.

Construction. A 12" x 7" x 3" aluminum chassis holds all the parts, except the responders. The four relays and (Continued on page 150)

**PARTS LIST**

C1—50-µf., 150-volt electrolytic capacitor
D1—5.14 diode (or equivalent)
P1—1/2-ampere fuse
I1, I2, I3, I4—313 28-volt miniature lamp
K1, K2, K3, K4—Relay, 4-p.d.t., 24-volts, d.c. (Potter & Brumfield KHP17D11 or equivalent)
P1—Octal plug (Amphenol 86-PM8 or equivalent)
R1—6800-ohm, 1-watt resistor
S1, S2, S3, S4—Normally-open push-button switch (Eagle 108 or equivalent)
S5—Normally-closed push-button switch (Arrow-Hart & Hegeman 3392-AE or equivalent)
S6—S.p.s.t. toggle switch
S01—Octal socket (Amphenol 88-8 or equivalent)
T1—117-volt to 25-2-volt filament transformer, 1-ampere (Chicago-Stancor P6469 or equivalent)
4—Colored indicator light assemblies (Dialco 931-102, 932-102, 933-102, 933-102)
1—7" x 12" x 3" aluminum chassis (Bud AC-408 or equivalent)
1—7" x 12" aluminum bottom plate (Bud BPA-1975 or equivalent)
1—2" x 13" piece of 20-gauge aluminum
1—Miniature fuse post (Littlefuse 342014 or equivalent)
1—Lamp cord, white vinyl plastic (Knight POT-23' spool)
4—1"-diameter wood dowels
Misc.—Small handle, rubber mounting feet (4), rubber grommets, hardware, hookup wire, etc.
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DON'T BE A SOREHEAD
—CUSHION THOSE PHONES

Headbands used with conventional type earphones can become quite uncomfortable pressing against the skull, even after short periods of time. An easy way to eliminate this discomfort is to cushion the band with some inexpensive foam rubber or plastic. Just cut a 12"-long strip of the soft material, wrap it around the headband, and tape or cement the end. You can also make a foam cushion for each of the ear pieces, but be sure to cut an opening in the center so as not to obstruct the sound.

—Art Trauffer

ADD A 15-VOLT RANGE TO YOUR HEATHKIT VOM

If you have a Heathkit MM-1 VOM, you can add a 15-volt d.c. range for greater ease in measuring 6- and 12-volt d.c. potentials. A 200,000-ohm, 1½-watt resistor and an additional test jack are all you need for this modification. Remove the instrument panel from the meter case and drill a hole to install the new jack approximately ½" to the right of the plus (+) jack. At the rear of the panel, solder the resistor between the new jack and the (+) jack. With the RANGE switch set to "5 V," and the d.c. test lead in the new jack, a full-scale deflection will indicate 15 volts. With the d.c. scale essentially linear, a mid-scale reading will indicate 7.5 volts. Inscribe "15 VDC" on the front panel directly over the new jack, using white India ink or paint. Compared to the 6- and 12-volt readings obtained on the 50-volt range, the new range provides an extra inch or two of deflection and throws the reading into a more accurate part of the meter. Input impedance is 300,000 ohms on the 15-volt range and 1 megohm on the 50-volt range.

—Jerry C. Sutton

PHONE-PLUG-TO-COAXIAL-CONNECTOR ADAPTER

This adapter is useful for mating ordinary PL-55 type phone plugs to coaxial connectors on many types of electronic equipment. Obtain a standard PL-259 conx plug and a UG-176 cable reducer, and cut off ¼" from the shank of the reducer. Solder a short length of ⅛"-wide spring brass or bronze strip to the tip of a No. 4 or 5 flathead screw, ¾" to 1" long. Bend this strip into a stirrup shape to conform to the standard phone plug as shown, then cover with a ½"-i.d. plastic sleeve. Now insert the assembly in the PL-259 so that it is firmly seated and the screw protrudes through the hollow tip of the plug. Trim and solder the screw. Next, take the shortened reducer and screw it part way into the PL-259. Insert the phone plug as far as possible and rotate the reducer until the tip of the phone plug snaps into place and touches the bottom of the stirrup. After checking final results for continuity, solder the reducer in place to prevent further turning.

—F. W. Chesson
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Photographers who constantly use an electronic or other type of flashgun will appreciate this simple, inexpensive gadget—it cuts down the high voltage and current normally "felt" across the camera's contacts and extends their life. You can assemble the 2N3228 silicon control rectifier (SCR) and 100-ohm resistor in any small plastic container; a coin holder will do nicely. If you insert the assembly in the flash cord, you'll be able to use the hookup with different flash units and with different cameras. No additional batteries are required since the gadget is powered by the flash unit. Cost is less than $2.00.

—William S. Gohl

MISMATCH STUB CHASES TV GHOSTS

If you're haunted by ghosts on your TV screen due to transmission line mismatch, you can clear up this condition with a mismatch stub. This is simply an extra piece of 300-ohm transmission line connected across your set's antenna terminals to correct for slight amounts of mismatch. First, tune the TV set to the spooky channel. Then connect one end of a 3' length of lead-in wire across the set's antenna terminals, letting the free end hang loosely toward the floor. Check to see if there's an

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improvement in the picture. Progressively shorten the stub by cutting into the insulation with a razor blade so as to short out the pair of wires. Cut the lead at the point where the ghost disappears or is substantially suppressed. Then twist the two wires together as shown.

—Warren Todd

"PILLBOX" FIRES FLASH UP TO 30 FEET AWAY

Small enough to fit into a pillbox, this slave unit can fire a standard or electronic flash gun at distances up to 30 feet. A General Electric X2A light-activated SCR and a sensitivity control (a 1/2-megohm potentiometer) are installed inside the box. A small PC socket is mounted on the case cover to connect the flash gun to the light-sensitive mechanism. Before inserting a bulb in the gun, turn the sensitivity control all the way down to prevent the gun from firing. Then advance the control just enough to allow the slave to operate when it "sees" the flash gun on your camera take off. If you advance the control too much, the slave may take orders from the available light and fire before you want it to.

—William S. Gohl

WHACKIEST MIKE IN THE SWIVEL PEN HOLDER

Pen holders make excellent swivel stands for both homemade and commercially available crystal microphones. You can glue a mike head onto the top of the pen or mount it directly in the pen holder. If you plan to use the pen case, remove the ink cartridge and drill a hole in the side of the case for the mike cable to pass through. If you decide to mount the mike in the pen holder, locate the hole in any suitable position. One thing you won't be able to do with the pen when you're through is write.

—Art Trauffer

TUBE ANODE MAKES MINIATURE SOLDER POT

Want an easy-to-make solder pot to use for tinning stranded wire? Locate a burned-out high-voltage rectifier tube such as a 1B3; break the glass and remove the cup-shaped anode. Then remove the 1/4" tip from a heavy-duty soldering iron and insert the anode cap. Allow the iron to heat sufficiently, and feed solder into the newly fashioned cup until it's about three-quarters full.—Jan B. Rosenbaum

ATTENUATOR PHONE PLUG CUTS TAPE RECORDER DISTORTION

To prevent a radio or amplifier from overloading your tape recorder with high level signals, you can insert a resistive attenuator network directly into the phone plug on your tape recorder's patch cord. To determine the value of the two resistors needed, hook up a 50,000-ohm potentiometer as shown in the diagram and adjust it for optimum recording level. Then measure the portions labeled R1 and R2 and replace the potentiometer with fixed 1/4-watt resistors of like value.

—Marshall Lincoln

"GIMMICK" CAPACITOR INCREASES BANDWIDTH OF UHF TV BOOSTER

A variable frequency amplifier, such as the Blonder-Tongue UTR-1 UHF booster, can be easily modified to provide a frequency range from 440 to 910 MHz instead of 470 to 890 MHz to take in part of the UHF radio ham band and other services. Solder a 0.47-pF capacitor or "gimmick" across the output resonant tank, and cut the capacitor leads as short as possible—they should be no longer than 1/4 inch. Now connect the capacitor across the two tabs sticking out from the center wafer on the bottom of the chassis.

—Ken Greenberg
MAKE YOUR OWN TV SIGNAL ATTENUATOR

If you live in a very strong signal area, your TV set may be troubled by too much contrast, picture tearing, multiple images, or an annoying buzz you just can’t tone down. You can cure these conditions with a simple attenuator pad inserted between the set and the antenna. The pad attenuates the signal without introducing any side effects such as transmission line mismatch. In the diagram of the pad shown, the values given are for a 300-ohm line feeding into a TV set with a 300-ohm input. If the especially strong signals appear on one or two channels only, you can add a d.p.d.t. switching arrangement in the circuit to switch the pad in and out of the line as desired.

—Vincent Giscombe

Dots and Dashes . . .
Lots of flashes . . . in a pan

If you want to practice land Morse code but have no telegraph sounder, you can do a pretty good job with a transmitting key mounted on a small metal tray or pan. Before fastening the key down, try different locations on the tray until you find a place where the clicks sound the loudest. You can also make louder sounds by increasing spring tension and contact gap, and by pressing harder.

—Carl Dunant

COPPER TUBING MAKES HANDY KNOB BUSHING

Should you find yourself in need of a control knob for a ¼"-diameter shaft, but only have ¼" types on hand, you can use a piece of copper tubing as a bushing to bring the knob opening down to size or the diameter of the shaft up to size, depending on the way you look at it. Cut a short length of ¼" copper tubing, slit it so that it fits around the ¼" shaft, slip the tubing over the shaft, and then fit the knob into place.

—Homer L. Davidson
CROWD STOPPER

(Continued from page 111)

tionary contacts is mounted on a 3/4" x 6-32 brass machine screw, and the rotating contact is mounted on the armature of the motor.

Timing Motor and Switch (S2). Assemble the motor and switch as in Figs. 8 and 9. If you’re using a counterclockwise motor, position the four switch contacts as shown; otherwise, reverse orientation of the switch contacts.

Connect stationary switch contacts 1 and 3 together and 2 and 4 together; use solder lugs beneath the mounting screws to make it easier to solder the leads. Also, solder a 10" lead to each pair of contacts. Then fasten the switch assembly to the bottom of the chassis with two 2" machine screws and two 1/2" wood dowels; the motor faces down.

Final Wiring. Mount T1 so it will clear the coils when the chassis lid is put on. When wiring the rest of the unit, make sure leads are long enough for the lid to be removed without having to break the connections. Turn the rotary contact by hand and note the pressure between it and the stationary contacts: there should be just enough pressure to make contact without slowing down the motor.

Installation. Plug the unit in, and adjust the contacts so a lamp will go out just before the flip ring reaches it. When all adjustments have been made, arrange the wiring neatly inside the chassis to prevent interference with the operation of the motor.

INTEGRATED CIRCUIT AMPLIFIER

(Continued from page 105)

solder the leads to the IC socket until the case is in place. When wiring this unit in the circuit, observe that the locating tab on the IC is directly over pin 1. Viewed from the top of the case, the pins are numbered counterclockwise. Also, observe that pins 2, 7, and 10 are tied together and returned to a terminal on SL.
Operating Hints. Distortion will result if too large a signal is applied to the amplifier input. For applications not requiring a wide bandpass, a step-up transformer can be used to couple the output of the first differential amplifier to the input of the second amplifier, replacing capacitor C2. However, some amount of experimentation is required to select the right transformer, since poor matching of the stages can transform your amplifier into a blocking oscillator due to the sensitivity of emitter followers to inductive loads.

For additional gain, two or more IC packages can be cascaded together. But care must be taken to keep the signal at a level low enough so that clipping will not take place.

The values of R1 and R2 have been chosen for best overall performance and circuit stability. But where it is desirable to change the amplifier input and output impedances, the value of these resistors can be raised to as high as 22,000 ohms with only a slight loss in gain and stability. One advantage of this change is that smaller values are required for C1 through C3 for any given frequency response.

---

MUSSETTE COLOR ORGAN

(Continued from page 52)

rear projection through a plastic or glass screen, or reflected projection from a crumpled aluminum foil surface.

For best results, use red, orange, yellow, green, and blue spotlights to obtain a full spectrum of colors. It has been found that spotlights with built-in optical interference filters perform best, yielding the deepest colors, the coolest operation, and providing the best overall effect. These lamps readily produce all hues, and varying degrees of saturation.

The choice of a display, as well as the arrangement or sequence of colors for the various channels, is yours to make. One logical scheme is to drive the low-frequency color lamp—the color red—with low-frequency audio, and so on up the spectrum to blue.

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**Fig. 11. Actual-size illustration of printed circuit board. For hole drill sizes, refer to Fig. 4.**

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**ELECTRONIC EXPERIMENTER'S HANDBOOK**

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LONG-TAILED PHASE INVERTER
(Continued from page 61)

extends at least 1\(\frac{3}{4}\)" from the top and bottom edges to cover the grille cloth. But be sure to complete your finishing work on the trim before you mount the speaker, so that dust particles will not get into the speaker.

Also, cover all interior surfaces of the speaker enclosure above panel H with a 1"-2" layer of cotton or wool batting. Pack the tube behind G with loose kapok pillows. Then make a tightly packed pillow of wool batting and attach it to the inside of the cabinet, behind the speaker.

If you find it necessary to alter some of the dimensions given in order to accommodate a different speaker, or for effects, you can do so under controlled conditions; but in no case should the cross-sectional area of the tubes be made smaller. In fact, a subtle improvement may be achieved by adding about three inches to the depth of the enclosure and by making each tube about an inch deeper. For this modification, the port should be enlarged to 18\(\frac{1}{2}\)" x 6".

If you have carefully followed the instructions, and have installed a reasonably good low-frequency speaker, your long-tailed phase inverter will provide good listening.

PUT AIR BRAKE ON WOOFER
(Continued from page 58)

wood screws. These screws are fed into the cabinet from the outside.

When installing the woofer, run the wires through one of the holes in the side panel. The opening in the front panel for the woofer is 8\(\frac{1}{8}\)" in diameter; its center is 6\(\frac{1}{4}\)" in from the side and 6\(\frac{1}{2}\)" up from the bottom. Stretch and tack \(\frac{1}{6}\)"-thick polyurethane foam plastic over all inside surfaces of the woofer compartment except the front. Wrap some cheesecloth around a strip of 1"-thick fiberglass (about 1' wide and 3' or 4' long) and fold this strip of pad-

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<td>Quantity</td>
<td>7&quot; Record Case at $3.25 ea.; 3 for $9; 6 for $17</td>
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<td>Quantity</td>
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HEADPHONE CONTROL UNIT

(Continued from page 55)

equipped with a phasing switch which has two positions: "normal" and "reverse." If the speakers have been phased properly, the switch will be in the "normal" position.

It is simple to check the phasing of
shown of tainer. tube. Since 1967 overheat phone sired; control alleled 100 “common” lines phone do so, stereo headphones from the alternate a speaker phasing connected.) in then interchange the If have T2. in this ly “er” and sound in mal” to the “Reverse” position. amplifier back and switch listening just jack. Connect amplifier in “Mode” the headphone control unit and plug the earphones into a comfortable level. Now flip the phasing switch on the amplifier back and forth from the “Normal” to the “Reverse” position. The sound in the headphones will be “cleaner” and undistorted (and possibly slightly louder) in one of the positions. If this occurs when the phasing switch is in the “normal” position, no changes will have to be made within the control unit. If it occurs in the “reverse” position, then interchange the red and blue leads in the primary winding of either T1 or T2. (Note: disregard the blue lead not connected.)

If your amplifier is not equipped with a speaker phasing switch, then simply alternate the red and blue leads on one of the transformers for best sound.

It is possible to operate another set of stereo headphones from the control. To do so, you add another 3-conductor phone jack to the unit. Connect the “common” lines together. Another dual 100-ohm potentiometer should be paralleled across R1a and R1b if individual control of the two headphones is desired; if not, simply parallel the new phone jack across the existing one.}

**AQUARIUM HEATER**

*(Continued from page 31)*

Final Assembly. You are now ready to install the circuit in the plastic container. First, align the ¼”-thick piece of plexiglass on the plastic cover as shown in Fig. 4. Measure out the loca-

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Installation. If your circuit passes the "squeeze test," you are ready to install it in your aquarium. Just in case you haven't used one of these thermostats before, here are a couple of hints:

(1) Hang the thermostat on the outside of the fish tank, and allow the heater to rest at the bottom of the tank. Keep the thermistor well down in the water to avoid faulty operation that could cause the tank to overheat.

(2) Be sure to use a circulating pump. Even in a small tank, there may be temperature differences of five degrees or more between the top and bottom of the tank.

The heat required to maintain the

ELECTRONIC EXPERIMENTER'S HANDBOOK
desired water temperature depends, essentially, on the difference between the water temperature and the room temperature. Since the SCR is a half-wave device, it supplies current to the heater for only half of the on cycle. Thus, a 75-watt heater consumes only about 37 1/2 watts. If your heater never turns off (allow a couple of days for stabilization), you need more heat.

The easiest solution to this problem is to add another heater in parallel with the first. Another solution is to full-wave rectify the line voltage to provide power to the heater during the complete cycle of operation. A fully assembled bridge rectifier, such as the Motorola MDA-952-4, or equivalent, can be wired up as shown in Fig. 5, so that the SCR can conduct on both halves of the a.c. cycle.

Under normal operating conditions, your new thermostat should provide your tropical fish with true living comfort for years to come. Your reward is to sit back and let your little pets enjoy all the transistorized heat they need.

### DWELL ANGLE CONVERSION CHART

<table>
<thead>
<tr>
<th>Full Scale (volts)</th>
<th>Conversion Factor</th>
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<tbody>
<tr>
<td></td>
<td>4 Cylinders</td>
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<tr>
<td>1.5</td>
<td>60°/volt</td>
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<tr>
<td>2.0</td>
<td>45°/volt</td>
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<tr>
<td>3.0</td>
<td>30°/volt</td>
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<td>5.0</td>
<td>18°/volt</td>
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<tr>
<td>6.0</td>
<td>15°/volt</td>
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Zener diode D1 is a 1N3016, or equivalent, rated at 6.8 volts at 1 watt. Diode D2, a 1N91, protects the circuit from a reverse connection to the battery. The other two components are: R1, a 290-ohm, 1/2-watt resistor; and R2, a 150,000-ohm potentiometer.

If your car has a positive ground ignition system, reverse the connections of leads A and B to the distributor and the battery.

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1967 Spring Edition 147
TIME-SIGNAL RECEIVER
(Continued from page 24)

author found that indoor reception could be improved by placing the receiver's antenna close to a telephone or an electrical fixture.

If you find it hard to decide which "band" of frequencies is best suited to your location, you can monitor each frequency for a period of time with a communications receiver. The optimum frequencies and listening time can be determined quickly in this manner.

To change frequencies in the receiver, simply plug in the appropriate crystal, and tune C2 and C6. Remember, you can cover two time-signal stations with the 10-µH coils, and three stations with the 5.6-µH coils.

TIME SIGNAL BROADCASTS

CHU Reception of CHU on 7.335 MHz is possible along most of the eastern seaboard (north of South Carolina) at any time between 0400-1100 and 1400-0100 EST. On the frequency of 14.670 MHz, CHU is heard throughout the remainder of the eastern seaboard and as far west as Denver, Colo., from 0800 to 2100 EST. CHU on 14.670 MHz is also audible along the West Coast in the early evenings.

WWV Check the 10.0-MHz frequency if you live on either the East or West Coast. The signal from the new Colorado transmitters should be very strong. Try 15.0 MHz if you listen mostly during the day and you are over 600 miles away from Ft. Collins, Colo. Far West listeners may be able to pick up both WWV and WWVH, Maui, Hawaii. WWV now sends "GEOALERTS" at 18 and 48 minutes after each hour, broadcast in International Morse Code.

It will be necessary to choose the "listening" frequency best suited to your needs and to your geographical location. Reception 100% of the time, day and night, is not possible on one frequency only (unless, of course, you live close to the transmitters). Some frequencies are better at night, others during the day.

Complete information on the technical services provided by the NBS standard time stations can be found in "Standard Frequency and Time Services of the National Bureau of Standards, Miscellaneous Publication 236," which is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 15 cents. Complete technical information on CHU is contained in a leaflet entitled "Time Service Bulletin B-16," available from the Department of Mines and Technical Surveys, Dominion Observatory, Ottawa, Canada, at no charge.
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Mount the four pilot light assemblies, power switch, reset button, fuse holder, octal socket, and a handle on the main chassis. Use dome-type lens caps instead of jeweled lenses to be able to see the light better at wider angles. A low-cost way to mount the pilot lights is stick them through rubber grommets attached to the cover, and solder the appropriate wires directly to the center contact and base of the lamps. Paint each bulb a different color.

If you happen to have on hand four identical relays that require a different working voltage, such as 6 or 12 volts, you can use them, but be sure the power supply and lamps are rated accordingly.

Responders. Prepare four 4"-long, 1"-diameter wood dowels by drilling a 5/8" hole lengthwise about halfway, then a 1/4" hole for the remainder of the way through each of them. Paint each dowel an identifying color to correspond to each of the different colored lamps. Pass one end of a 4' length of lamp cord through the 1/4" hole and tie a knot in it about 3" from the end to serve as a strain relief. Then connect the leads on this end of the lamp cord to the screws on the switch and force-fit the button assembly into place. The responders can be connected to the relays directly, or to an octal plug (PL1) as shown.

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