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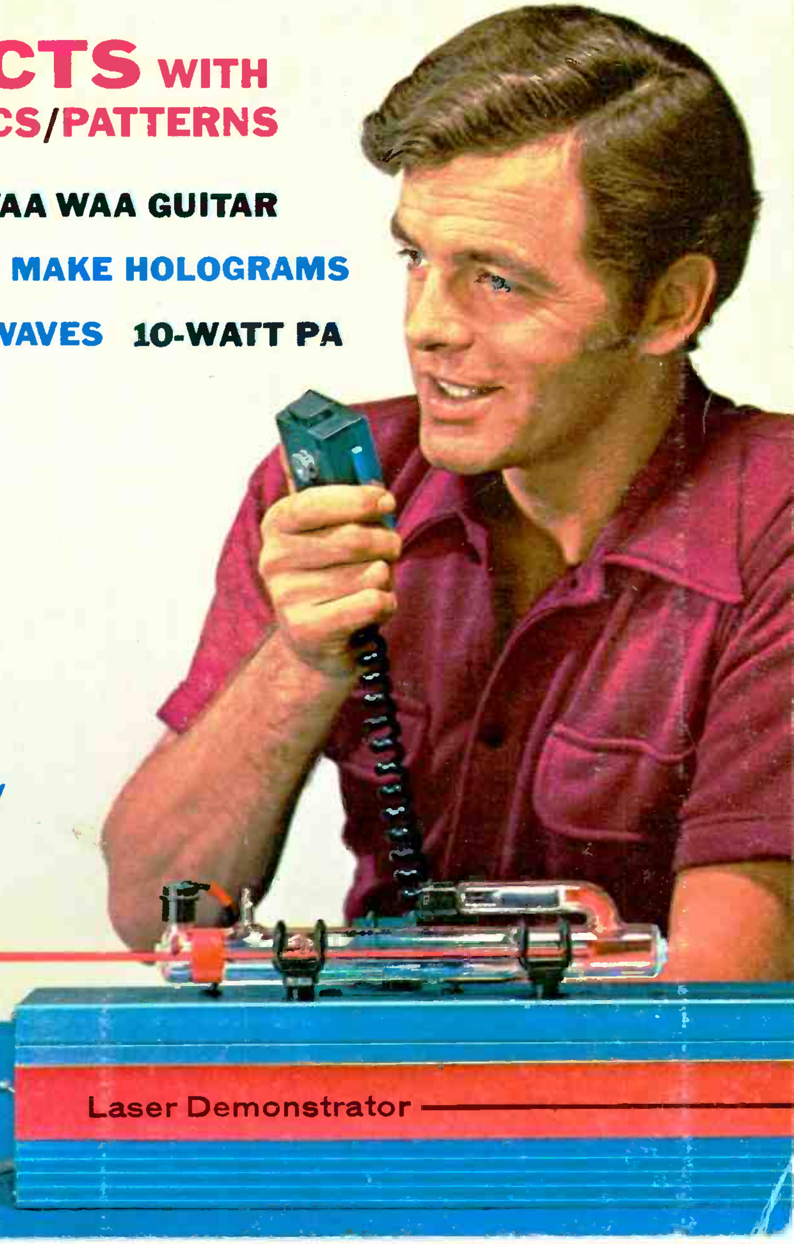

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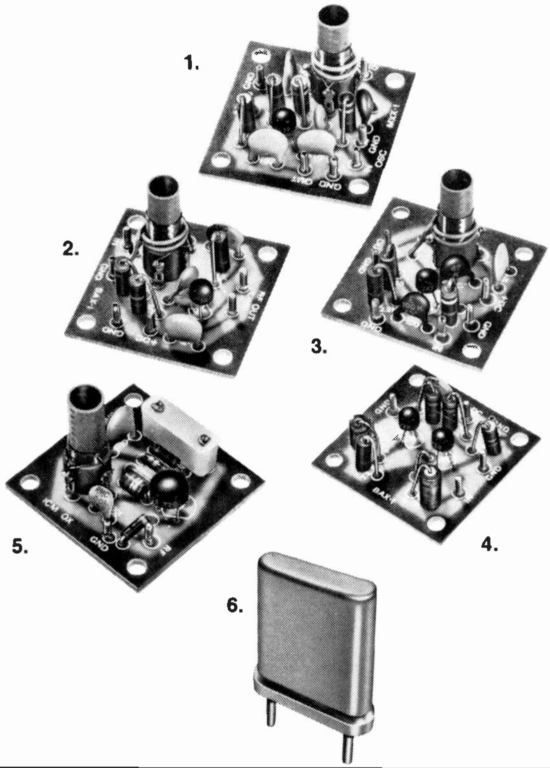

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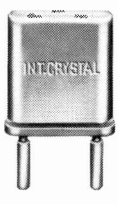

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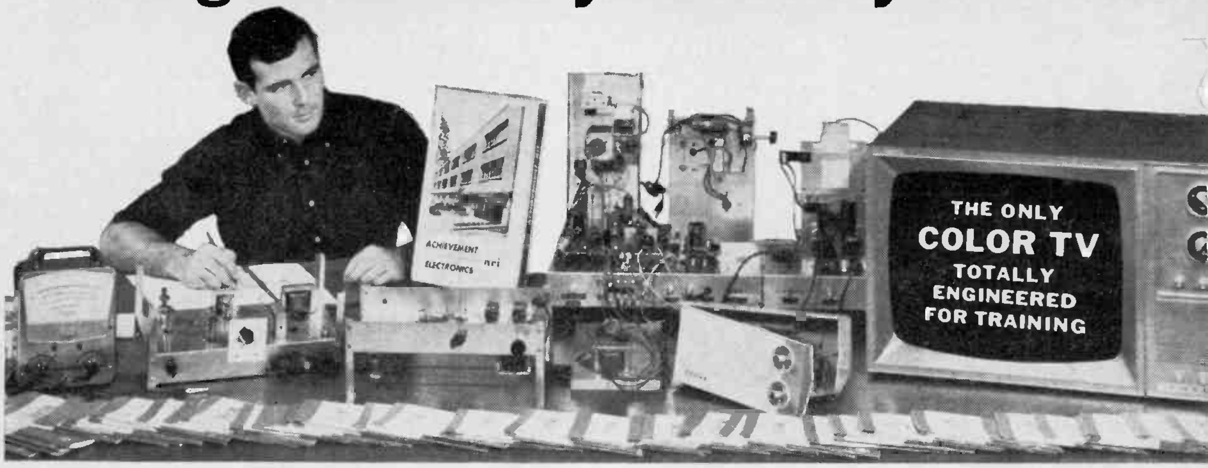

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SPRING EDITION
1971 POPULAR ELECTRONICS ELECTRONIC EXPERIMENTER'S HANDBOOK

KEEPING UP

Six months ago, in the Winter 1971 Edition of this HANDBOOK, I opined that experimental electronics was changing and that audio projects were attracting the most readers' attention. If there was any feeling that the audio trend would not continue, it is certainly not reflected in this, the Spring 1971 HANDBOOK. Audio and sound projects run the gamut from voice scramblers (page 27), to public address (page 77), to wild guitar sounds (pages 95 and 125), to stereo speakers—plain (page 100) and fancy (page 38). However, no discussion of this edition would be complete without mentioning the Science Fair aspects of the features on lasers (page 9 to 26), microwaves (page 48), and ionization detection (page 115). And, among the many other articles, there is a timely piece on electronics engineering technology home study courses—something many readers will want to peruse and ponder.

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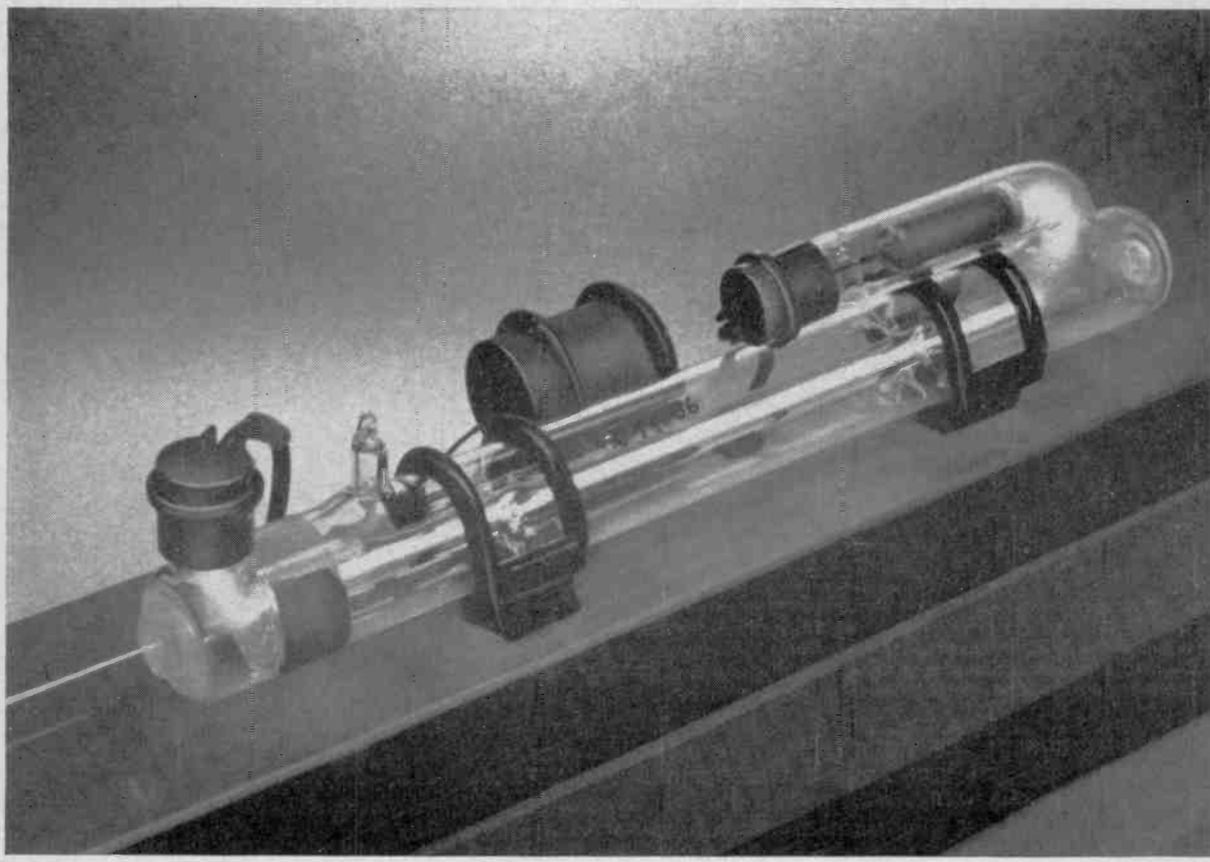


Experimenters' Laser

SAFE, PRACTICAL LASER FOR HOME OR SCHOOL

BY C. HARRY KNOWLES

UNTIL NOW, the experimenter has found three things wrong with lasers: (1) they were expensive; (2) they were dangerous; (3) they were hard to get. That's why lasers have been used primarily by research laboratories and not by the ordinary electronics hobbyist.

In the last year or two, relatively low-cost laser assemblies have been available for use by schools, small research labs, and machinery manufacturers. However, many of these lasers bordered on the danger line with light outputs that could cause retinal damage to the eye if the laser were not handled properly.

With interest in lasers at an all-time high, it was inevitable that research would eventually produce a laser whose output was reduced to the point where the beam was no longer dangerous to the eye and whose price did not require a "government grant" to support experimentation. The result is the safe, low-cost laser described here. Priced at $49.50, this laser generates a modest 0.5 milliwatts at 6328 angstroms. The laser tube itself is available from a mail-order supplier (see Parts List) and the necessary high-voltage power supply may be assembled in a few hours.

Laser Basics. Without delving into the mathematics and quantum theory involved in the operation of a laser, the best way to describe the device is to

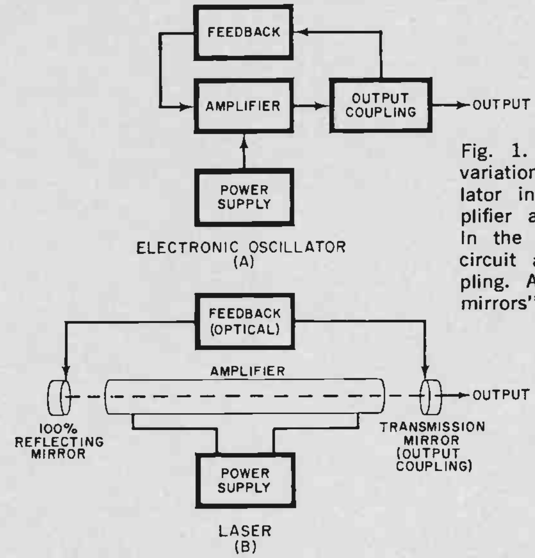


Fig. 1. The laser is essentially a variation of a conventional oscillator in that it has both an amplifier and a feedback mechanism. In the laser, part of the feedback circuit also forms the output coupling. Actually, "it's all done with mirrors"—made up in a special way.

compare it with a conventional electronic r.f. oscillator—the principles of operation of the two are quite similar.

As shown in Fig. 1A, an electronic oscillator has four main parts: an amplifier, a resonant feedback network, an output coupling port (including the antenna), and a power source. Figure 1B shows the corresponding parts of a laser. Here the amplifier can contain a mixture of gases or liquids, or it can be solid state. The laser described in this article contains a gaseous mixture of helium and neon.

When the laser's power supply delivers enough energy to cause a discharge in the gas tube, the neon atoms are elevated to a high energy state by colliding with the helium atoms. When the neon atoms drop back to their lower energy state, they give up energy at certain wavelengths. In this case the wavelength is 633 nanometers or 6328 angstrom units (in the deep red portion of the visible spectrum). As this light energy is propagated within the glass tube, it scatters helter-skelter in all directions. Some of the light is lost through the side walls of the glass tube, but the portion that travels down the center of the tube strikes other excited neon atoms within an internal glass capillary tube creating more light energy of the same wavelength.

Eventually the light strikes a mirror at one end of the laser and most is reflected back down the capillary tube. With a mirror at each end of the tube, the process continues—the beam bouncing back and forth until it builds up enough intensity to pass through one of the mirrors, which is only partially coated. The other mirror is 100% reflective and does not allow any part of the beam to escape in that direction. Thus we see how the laser gets its name —Light Amplification by Stimulated Emission of Radiation. It is important to note that this amplifier, and the critically spaced and designed optical feedback system, has a very narrow bandwidth around the 6328 A wavelength.

In the helium-neon laser, light amplification is only 1.02 on each pass of the beam from one mirror to the other. Thus all losses must be kept below 2%. Very special care is taken in fabricating the laser and in coating and aligning the two mirrors. The gas mixture is pure, containing no contaminants. The transmission mirror is coated to allow 0.8% of the generated light to escape. Thus, as intense as the beam emitted appears to be, it is less than 1/100 as intense as the beam between the mirrors. It will be noted that lasing occurs only in the precision capillary tube that delineates the exact path between the mirrors.

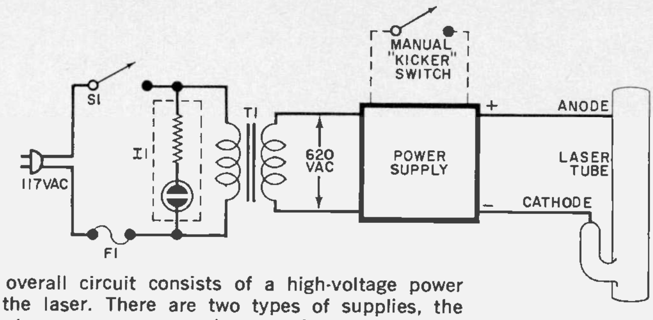


Fig. 2. The overall circuit consists of a high-voltage power supply and the laser. There are two types of supplies, the automatic that comes on a second or so after line power is applied, and the manual start with a "kicker" switch.

PARTS LIST
COMPLETE LASER

F1—1-ampere fuse with holder
I1—117-volt neon indicator and holder (can use NE-2 and 33,000-ohm resistor)
S1—S.p.s.t. switch
T1—Power transformer, 620-to-650-volt secondary

Note—The laser tube is available from Metrologic Instrument Inc., 143 Harding Ave., Bellmawr, N.J. 08030 for $49.50 plus $1.25 postage. A complete laser housing including an aluminum extruded case, steel base, power switch, pilot light, and all mounting hardware is also available from the same source for $15.

Properties of Laser Light. There are four unique characteristics of laser light that make the device itself such a useful tool. These are: directionality, coherence, intensity and monochromaticity.

The directionality of laser light is due to the fact that only the light that is on the axis between the mirrors can escape from the laser. The other light contributes nothing to the output beam. Thus, the laser light emerges inherently well collimated and highly directional, and thus useful for applications where an enormous concentration of light in a given direction is important.

The coherence (phase) of the light is due to the very high-Q resonant feedback network within the optical amplifier. Only light whose multiples of a half wavelength fit exactly between the mir-

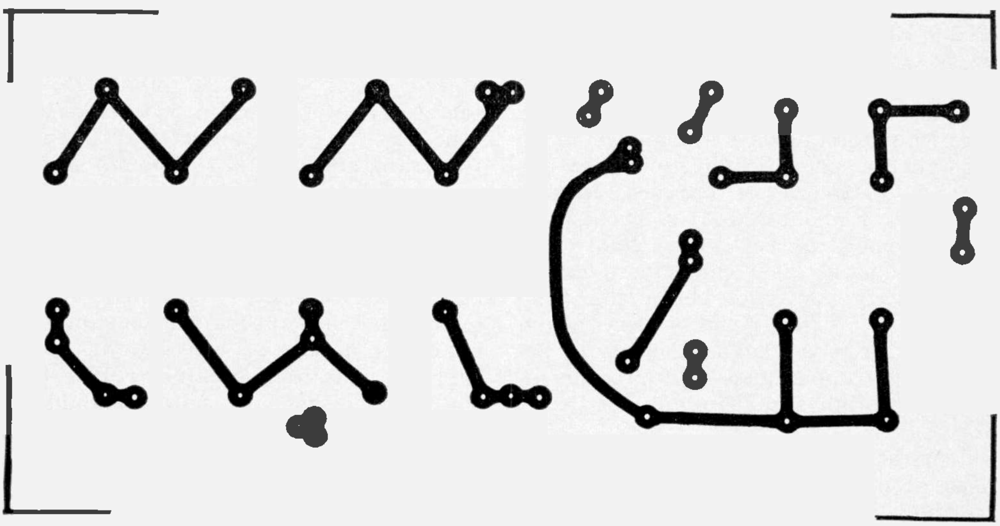
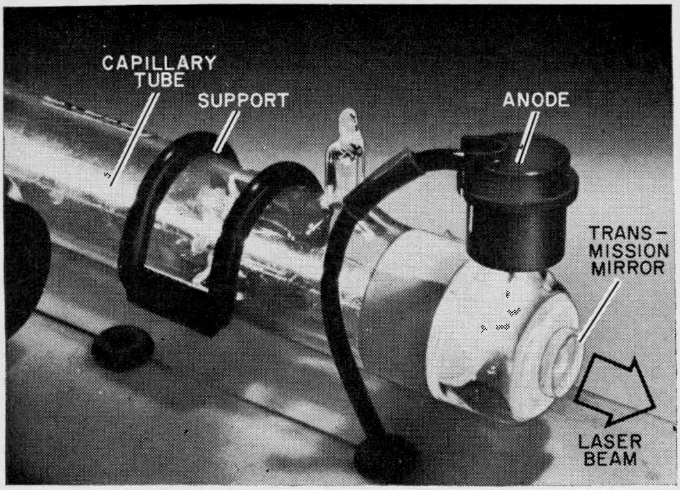


Fig. 3. Actual-size foil pattern for automatic start supply. Drill mounting holes at the four corners.



Close up of "business end" of the laser. Note use of rubber supports which secure laser in place. Make sure that exit optics are clean and laser is rigidly mounted on a chassis.

rors is allowed to propagate. Thus, standing waves are established between the mirrors and each light particle is in step with all the others—creating phase coherence.

Intensity and monochromaticity go hand in hand. Since the laser builds up energy of only one frequency, all the power in the laser beam is at that frequency. The spectral energy of the 6328 A light produced by the laser approaches the intensity of the similar frequency emitted by the sun.

Monochromaticity (one color) is a result of the narrow pass band of the amplifier, plus the selectivity of the resonant feedback mirrors. The pass band of the laser described here is about 1200 MHz at a frequency of 4.8×10^{14} Hz (a Q of 4×10^{5} in the amplifier section). In addition, the filtering of the resonant mirrors reduces the output to lines whose frequencies are separated by one half the speed of light divided by the distance between the mirrors. In our laser, this is about 620 MHz. These lines are extremely narrow—less than 1 Hz wide. Thus, the laser can have a monochromaticity purity of better than one part in 10^{15}. This permits very sharp filtering for laser communication to reduce background noise and provide an extremely high signal-to-noise ratio.

Construction. Before assembling the laser, a power supply must be built. You can use a supply that fires the laser automatically shortly after the line voltage is applied to the supply, or you can use a supply with a momentary contact switch to turn the laser on. In either case, once the laser fires, it remains on until the line power is removed.

The high-voltage source for both power supplies is a 620-volt transformer as shown in Fig. 2. The automatic supply can be assembled on a printed circuit board using foil pattern shown in Fig. 3 and the circuit in Fig. 4A. Assemble components as shown in Fig. 5. The switched power supply can be built on a perf board as shown in Fig. 6 using circuit in Fig. 4B.

Once a power supply has been built, mount it in the metal enclosure (using short spacers) along one of the long walls. Mount the associated power transformer on one of the shorter walls. Mount power switch *S1*, pilot light assembly *I1*, and fuse (in fuseholder) *F1* (see Fig. 2) on the short wall opposite the transformer. Make a small hole to accommodate the line cord, and put a rubber grommet in the hole to protect the cord. If the switched supply is used, mount the pushbutton switch in any convenient location.

The glass laser tube can be supported by either a pair of conventional metal capacitor clamps or a pair of rubber tube supports, either of which should be mounted on a pair of spacers located about 4½″ apart on the upper surface of the chassis.

Place the laser tube in the supports gently, being careful not to damage ac-

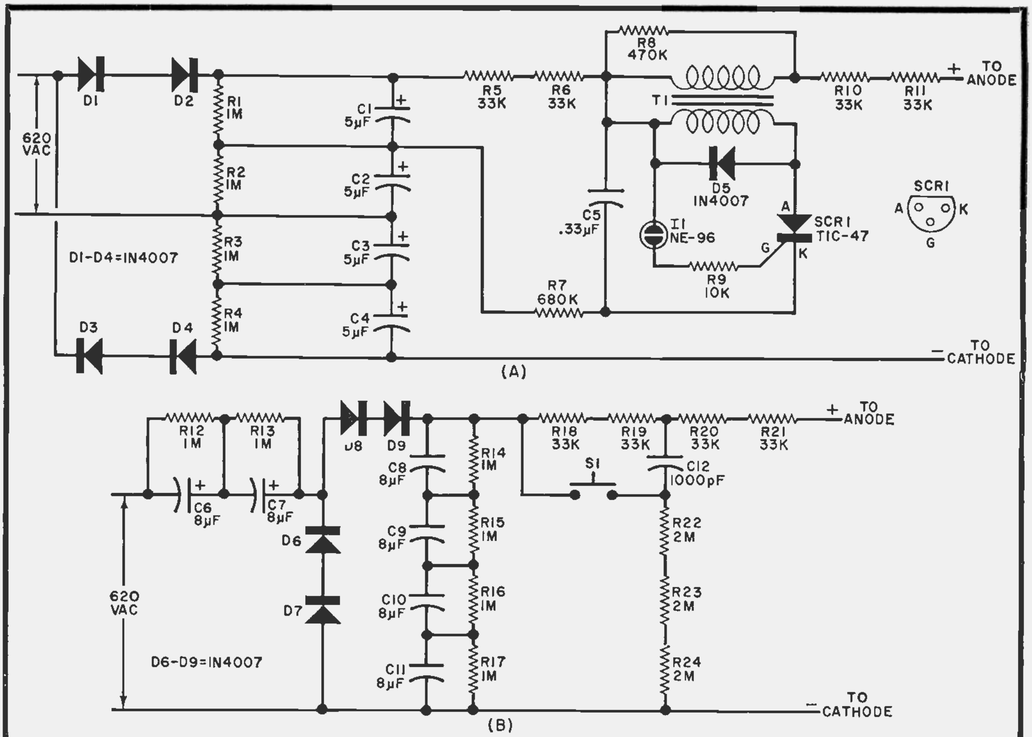


Fig. 4. You can use either of two power supplies—the automatic shown at (A) or the manual start shown at (B). As with all high-voltage power supplies, take great care once they have been turned on.

PARTS LIST (POWER SUPPLY)

C1-C4—5-μF, 450-volt electrolytic capacitor
C5—0.33-μF capacitor
C6-C11—8-μF, 450-volt electrolytic capacitor
C12—1000-pF, 1600-to-2000-volt capacitor
D1-D9—1N4007 diode
I1—NE-96 pilot light
R1-R4, R12-R17—1-megohm, ½-watt resistor
R5,R6,R10,R11,R18-R21—33,000-ohm, 2-watt resistor
R7—680,000-ohm, ½-watt resistor
R8—470,000-ohm, ½-watt resistor
R9—10,000-ohm, ½-watt resistor
R22-R24—2-megohm, ½-watt resistor
SCR1—C106B2 (GE) or TIC-47 (Texas Instruments) silicon controlled rectifier
S1—Normally open pushbutton switch, 2000-volt insulation (see photo page 32)
*T1—Ignition coil, 200:1 ratio**
Note—A complete power supply (automatic) including a PC board and all components is available from Metrologic Instrument Inc., 143 Harding Ave., Bellmawr, N.J. 08030, for $17.50 plus $1.00 postage.
**Conventional ignition coil, critically damped using a resistor across the secondary to produce a single spike. A flashtube trigger transformer (Amglo MT-55, Allied Cat. No. 729-1513) may be substituted.*

cidentally the exhaust seal protruding from the anode end, the large cathode bulb, or either of the two end mirrors. Do not scratch the tube walls as this can affect the wall strength. Especially, do not scratch the end mirrors, which might affect the laser action.

Orient the laser tube so that the exit beam (coming from the anode end of the tube) is aimed as desired on the chassis.

Note that the laser is equipped with terminal caps for the electrical connections, similar to those used on certain types of vacuum tubes. Connections to these terminals are made through conventional "grid caps" or similar connectors. The large cathode bulb can be oriented as desired since its attitude is not important.

With the laser in position in its clamps, mark the chassis locations for the two dc power wires, one directly beneath each electrical connector on the tube. Remove the laser tube and drill holes just large enough to accommodate rubber grommets. Pass the laser power leads

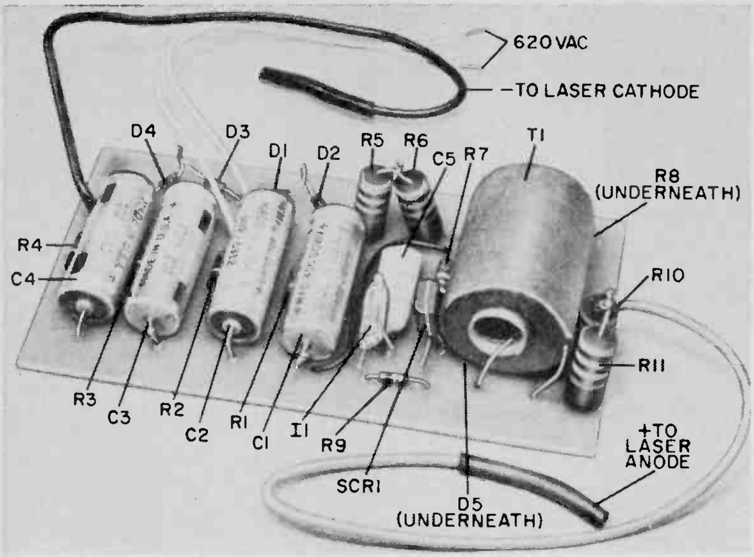


Fig. 5. Component installation on the automatic supply PC board. Transformer T1 is an ordinary ignition coil that has plastic case removed.

through the insulating grommets.

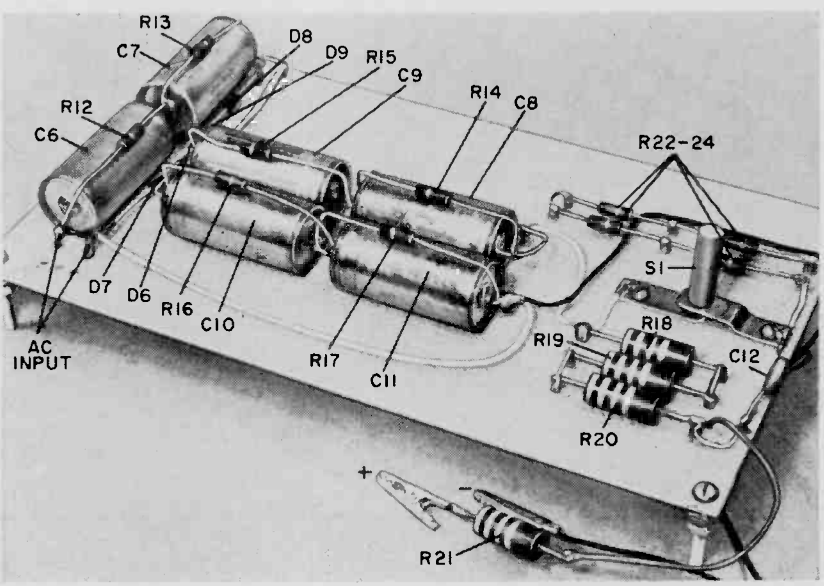
Once the system has been assembled, wire it as shown in Fig. 2. Attach cap connectors to both the positive and negative power supply leads and place them on the respective laser connectors.

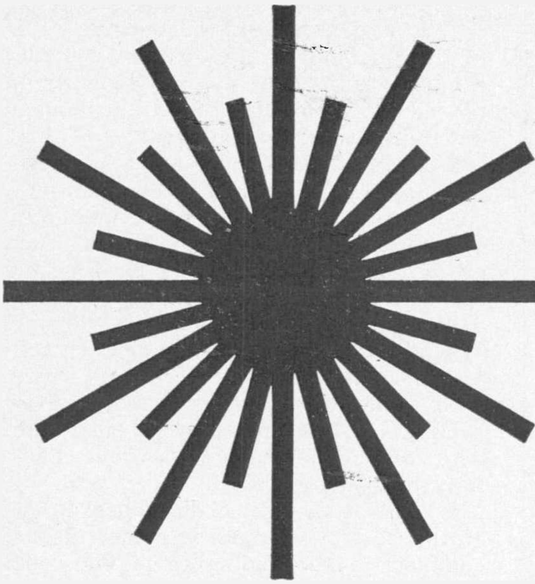
Recheck all wiring, check the physical stability of the laser tube, and make sure the two laser electrical caps make snug friction fits on their terminals. Always keep in mind the fact that the two laser connectors have a high voltage on them, so do not touch them once the system has been turned on.

Operation. Being careful not to aim the laser beam (coming out of the cathode end) at a shiny surface, turn on the line power. If you are using the automatic power supply, the laser will give a couple of short light bursts and then lase con-

(*Continued on page* 34)

Fig. 6. Switch S1 is made from two lengths of phosphor-bronze strip, one as fixed and the other as movable contact. Use a small piece of wood or plastic for pushbutton.





CAUTION LASER

FOLLOW THE RULES— AND THERE'S NO PROBLEM

BY LEWIS B. LLOYD

PART OF ANY new scientific development (especially where electromagnetic radiation is involved—atomic, radio, or light) is the possibility that hazards to human safety may exist. The laser is no exception and, as the presence and use of lasers become more widespread, the importance of the possible hazards is receiving more and more attention.

The dangers involved with the laser are particularly important because they can be so easily overlooked. (Though to date there has been no major laser injury.) Many people fail to appreciate the fact that a simple beam of light can be dangerous. They seem to forget that the output of a weak laser directed at a small spot can be 100,000 times as intense as the same area on the surface of the sun.

Obviously, since the human skin and especially the eyes are very sensitive to light, the application of such an intense light to these photosensitive surfaces can cause permanent damage. Most important, where a laser is concerned, distance does not contribute to safety. At 10 miles, the beam from a 6-inch parabolic-reflector searchlight spreads out to approximately 1760 feet; however, at the same distance, an ordinary laser beam diverges less than four feet—and thus retains its extremely high intensity.

Another hazard connected with the laser is that specular reflections off a smooth surface can also be dangerous. Obviously, then, mirrors, bench tops, shiny tools, rings, wristwatches, etc. can be likened to "secondary lasers" and must be treated with the same caution as the actual laser.

Helium-Neon Laser. The helium-neon laser described in the article in this issue of the HANDBOOK is widely used in alignment and fine measurements in a number of industrial and research activities. With a maximum light output of 0.5 milliwatts, it is considered to be little more dangerous than a white point-source light of comparable intensity. However, since laser effects have been virtually unexplored and because adequate data on chronic exposure do not exist, some general safety rules should be followed in working with this or any other laser. These rules should be followed even though the EXPERIMENTER'S HANDBOOK laser output is considered to be far below the level of possible danger to the eyes.

Laser Safety Rules. Follow these rules at all times:

1. NEVER look directly into a laser

THE THIN RED LINE

The light output of a helium-neon laser is many thousands of times brighter than that of a high-pressure mercury arc lamp. That is why you should never stare directly into the beam.

A laser beam is visible for a considerable distance, even in daylight. At night, depending on the clarity of the atmosphere, the beam is visible (on axis) for many miles. The small laser described in this issue has been tested to slightly less than one mile.

In a typical gas laser, the beam is only a couple of millimeters in diameter when it leaves the laser and diverges (enlarges) at a rate of approximately one part in 2000. Typically, a laser beam would produce a circle about 1 foot in diameter at 2000 feet. Lenses can be used to reduce the circle size and to increase the range.

The laser beam can be reflected around corners using front-surface mirrors. It will also pass through fiber optics. In both of these applications, the laser beam retains its coherency.

beam (on axis) either with the naked eye or through binoculars or a telescope at a distance. Remember that a laser beam usually cannot be seen unless there are airborne particles (smoke, dust, etc.) to provide scattered reflecting surfaces. With some lasers, the beam cannot be seen even under these conditions.

2. DO NOT rely on tinted glass, sunglasses, or other eye-protective devices unless the filtering medium has been specifically designed to attenuate the wave-length of the laser in question. There is no one type of filter glass that protects at all laser frequencies.

3. NEVER leave an activated laser unattended. An unsuspecting person may accidentally look into the beam. A warning sign or audible signal should be used to indicate when a laser is operating.

4. For general experimenting, room lighting should be high (about 200 foot candles) to keep the eye pupil small and reduce the possibility of retinal damage due to inadvertent exposure.

5. Unless the experiment is fully protected, NEVER shine a laser beam on a specular surface since reflections may approach direct beam intensities. Such reflections are difficult to predict and can make off-axis viewing as potentially dangerous as direct on-axis viewing. Special care must be taken with watch crystals, metallic watch bands, rings, tools, glassware, door knobs, screw heads, etc. The floor, bench tops, cabinets, should be covered with a dark, light-diffusing material.

6. BEWARE of electrical hazards. All of the possible danger in a laser is not confined to the light beam. The laser power supply can also cause physical damage if high-voltage terminals are contacted. Remember that high-quality filter capacitors retain a charge after the system has been shut down. Capacitors should be discharged before attempting any adjustments to the laser tube or associated electronics. A protective cover should be placed over the laser tube (except for the end where the beam is emitted) to prevent accidental contact with the high-voltage leads. Adequate grounding should be provided for all metal chassis and other hardware.

7. DO NOT operate a laser in rain, snow, fog, or heavy dust. Here again, potentially dangerous secondary specular radiation can result.

8. DO NOT inadvertently or intentionally track vehicular or airborne traffic with a laser beam.

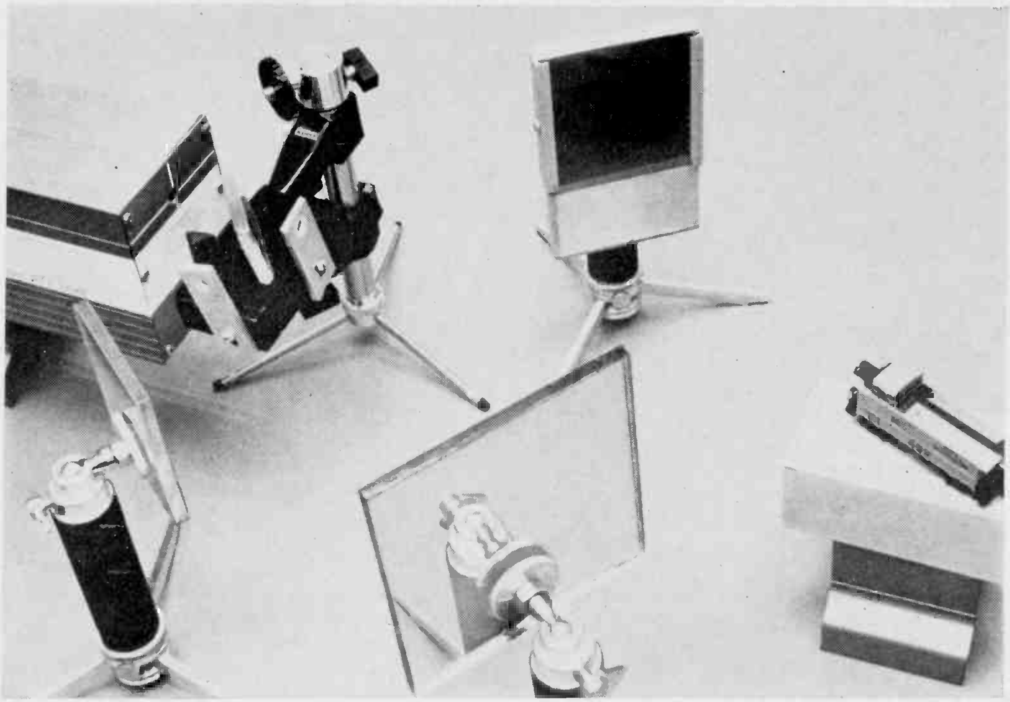
9. Set up a safe laser operating procedure. Make up a check list and follow it precisely each time the laser is used.

10. If a flash-tube pulsed laser is used, the flash tube should be shielded. If it isn't, avoid looking directly at the flash tube when it fires. Intense white light, ultraviolet, and infrared radiation occur at the instant of firing. Overexposure to ultraviolet can cause blindness.

Until a great deal more is known about the biological effects of a laser beam—even those of "safe" lasers—treat all laser beams with the greatest of respect. —30—

THE SMALL RED DOT

When a laser beam is aimed at a light-colored surface, there will not be a clearly defined spot. The spot seems to take on a "graininess" and to "dance" in place. This is caused by a complex afocal interference pattern that exists between the observer and the diffuse surface. The eye of the person looking at this spot tends to relax and he focuses behind the spot if he has normal eyesight (emmetropic) or is far-sighted (hyperopic). If he is near-sighted (myopic), the focus occurs in front of the surface. Because of parallax, if the observer moves his head from side to side, the granular pattern appears to move with him if he has normal eyesight or is far-sighted and opposite to the head motion if he is near-sighted. (All of this is obviously without the viewer's using corrective lenses.)



DO IT YOURSELF LASER HOLOGRAPHY

TRUE THREE-DIMENSIONAL IMAGES ON FILM

BY C. HARRY KNOWLES

THE BASIC CONCEPT of the camera was first developed in the 10th century and ever since, man has attempted to make a photographic record of himself and the world around him. The camera and photographic techniques have improved continuously over the years and no one can say that the clarity and beauty of today's full-color photographs are not truly remarkable.

But there's something lacking! Using standard photographic techniques, it is still impossible to capture on film the three-dimensional quality that characterizes life itself. Many attempts have been made to create the three-dimensional illusion, including the use of multiple cameras and projectors, special glasses for the viewer, special filtering, and a large number of other, lesser-known methods. Most have eventually been discarded.

In the late 1940's, Dr. Dennis Gabor, working with an optical system, demonstrated that, by using coherent monochromatic light, it was possible to imprint a true three-dimensional image on photographic film emulsion. There was only one problem—a source of coherent light was hard to find. When the laser was discovered, a practical, dependable source of coherent light became available; and Dr. Gabor's brainchild, the hologram, was reborn.

Holography is based on the principle of recording interference patterns set up by a reference beam of laser light and the reflected light from a target. The result, a hologram (captured on film), is a true three-dimensional re-

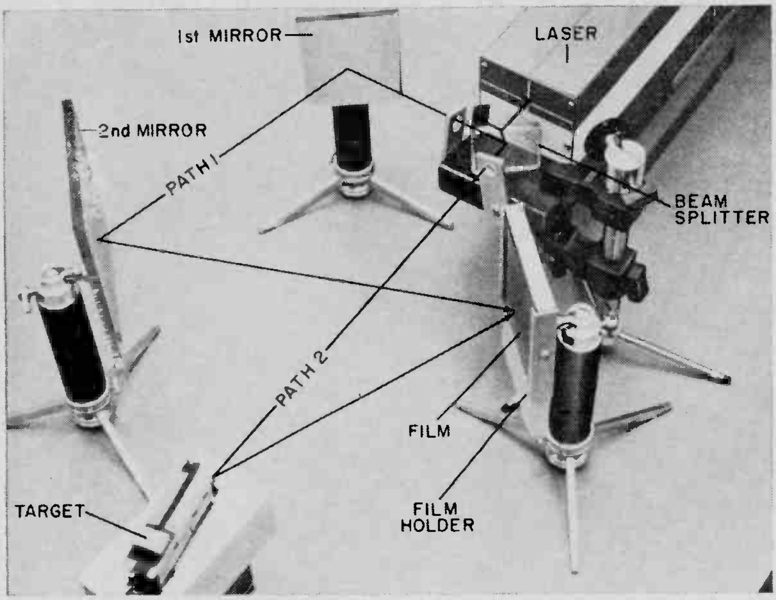


Fig. 1. The basic optical setup showing the two beam paths used to make a hologram. The mounting tripods are conventional camera tripods found in most camera shops. Remember that the most important item is stability—of both laser and optics.

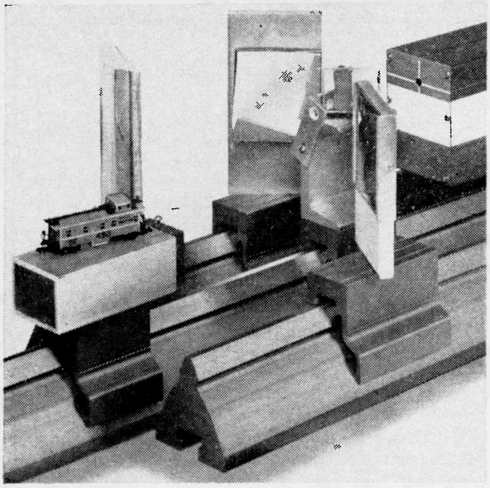
production of the target. The display technique requires no imaging lenses within the system, but does require a laser. (See "What Is a Hologram?" on page 20.)

Although many uses have already been found for holograms, the technology is still essentially in its infancy and promises to play a very important role in our future as laser techniques continue to be developed. For instance, holographic road signs are being developed so that drivers in different traffic lanes will get directions applicable only to them. A system of credit card validation is being developed in which each card contains a very small hologram of its identifying number. The card is inserted in a holder containing a laser which projects the number onto a large-size master transparency. Within microseconds the number is compared with all delinquent account numbers stored on a master and, if a match occurs, an alarm is given.

One major tire manufacturer uses holographic interferometry in a routine inspection of its products. Holographic memories are being developed rapidly—your telephone number and all related information may soon be stored holographically. RCA recently announced a low-cost system of video recording using transparent tape containing holograms. When the tapes are passed between a laser (one quite similar to the one used here) and a TV camera, the images are converted to conventional video. In this low-cost system, the holograms are stored in cassette-type containers. Even color recording is practical.

Three recent developments now make holography a practical project for the electronic experimenter: the introduction of the safe, low-cost laser (see page 9, this HANDBOOK); a new high-resolution, high-contrast, high-speed film (Agfa 10E75); and a low-cost high-quality optical kit complete with optics, film, and chemicals.

The experimenters' holographic system described here requires a working knowledge of electronics, basic optics, and photography. Assuming that the reader has the necessary background in electronics and optics, it is suggested that, before proceeding with construction and actual creation of holograms, he consult friends or some simple home photography manuals—particularly in the area of film development. A darkroom is required, both for setting up the holographic system and for developing the exposed film. It may also be used for proper viewing of a finished hologram.



This is a commercial holographic setup that uses heavy metal extrusions as stable base. The laser shown here, and in Fig. 1, is the low-cost laser mounted within a light-tight aluminum enclosure.

Making the Optics. There are six pieces of equipment required to make a hologram: a laser, a beam-splitter assembly, two reflecting mirrors, a film holder, and a platform for the target. A complete assembly is shown in Fig. 1.

The laser must be mounted in a light-tight enclosure made of wood or metal, painted flat black on the inside. Everything must be inside the enclosure with only a power cord coming out of it. Once the enclosure has been built, drill a small hole (about 1 mm) precisely in line with the exiting laser beam. Inside the enclosure, the laser should be placed so that its exit mirror is very close to the exit hole.

Mount the laser enclosure on a firm support. Stability is extremely important. Be sure that the enclosure does not rock or tilt in any direction. If necessary, place a weight on top of the enclosure to make sure that it sits firmly. Measure the distance from the supporting table or bench top to the laser exit hole. This distance above the table or bench establishes a horizontal plane which will be referred to frequently in the construction of the system.

The beam splitter assembly includes a glass beam splitter and a pair of diverging lenses. A piece of metal or a smooth block of wood about 2 inches square can be used for the beam splitter assembly mount. The height of the mount should be such that the laser beam will strike about the center of the beam splitter. The beam splitter is a small piece (about 1" square) of highly polished optical glass having exactly parallel surfaces. Using pitch, epoxy or other hard-drying cement, affix the glass beam splitter to the top of the wood block as shown in

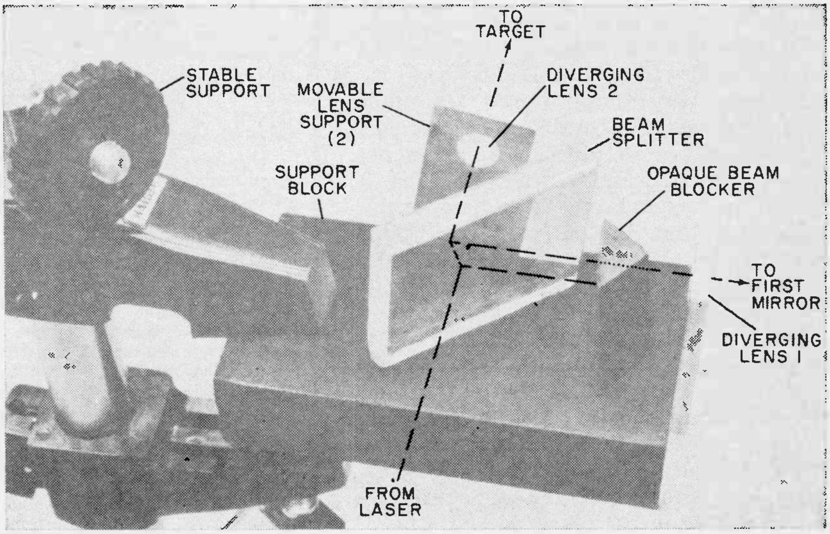


Fig. 2. Details of the beam splitter assembly. The opaque beam blocker is placed to cut out one beam from the glass splitter. The diverging lenses are oriented as required.

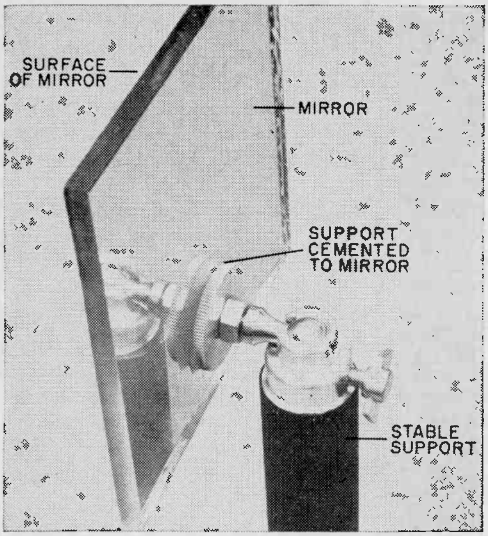


Fig. 3. Tripod support is removed and cemented to the rear surface of the front-surface mirror. Metal nut on tripod screw clamps the mirror tight.

Fig. 2. Mount the two diverging lenses in holes drilled in two pieces of aluminum ¾″ wide, 2″ long and ⅛″ thick. The lenses can be glued or friction fitted in place. Cut half-inch slots in the other ends of the strips to accommodate mounting screws. When mounted, the aluminum strips should be capable of being moved up or down and to left or right when the mounting screws are slightly loose. The centers of the lenses must be movable about the laser beam. The wooden vertical block on the beam splitter assembly should be ignored for the moment as it will be installed later.

The two reflecting mirrors are made from front-surface optical flat mirrors. The first mirror should be about 2 inches square. The second, larger mirror is about 3 inches square. Using firm, stable supports attach the mirrors with pitch or epoxy so that they are vertical and their centers are in the horizontal beam reference plane (see Fig. 3).

The film holder should be designed to support a piece of film 2¾″ square (70 mm) so that it fits flat against a back support. The easiest way to do this is to take a piece of solid aluminum stock ½″ or more thick and 2¾″ wide by 3″ high. Use this to fashion a holder. Secure this to a wood or metal block so that the 3″ length is vertical and the center of the piece of aluminum is on the horizontal

WHAT IS A HOLOGRAM?

A hologram of an object bears absolutely no similarity to a conventional photograph of the same object. It is not even visible unless observed under special conditions. A hologram viewed under normal incoherent light looks like a slightly dirty transparency with absolutely nothing to indicate that it is a three-dimensional view of an object. Despite the fact that the hologram looks so bleak, it contains far more actual information than can be placed on an ordinary photograph. All of this information can be seen when the hologram is viewed in the coherent light from a laser. Of course the most important information that the hologram contains is the third dimension of the object—color is not yet obtainable in a hologram but the possibility is being investigated.

Another remarkable fact about the hologram is that each part of it contains all of the target information. If the hologram is cut in half, each half contains the complete image, including the third-dimension information. In fact, each portion can be cut in two again and the information is still intact. As the hologram is subdivided, although each small piece still contains a complete image, resolution suffers and a point is eventually reached where the image is no longer clear and distinct. Scratches and smears do not affect holograms as much as they do conventional negatives since all parts of the hologram contain all of the image information.

In viewing a hologram, the eye (or camera) can be focused on different parts of the three-dimensional image. As the hologram is moved farther from the diverging lens during viewing, automatic enlargement of the image occurs. If the hologram is turned over while viewing, a very peculiar "inside out" view is obtained.

In the system used here to make holograms, two sources of light reach the film emulsion. One comes from the reference-beam mirrors and the other is reflected from the infinite number of points that make up the target. The light striking the target is exactly in phase with the light in the reference beam.

The frequency of the light from the helium-neon laser is 4.7×10^8 MHz with a wavelength of 6328 A or 6238×10^{-10} meters. Thus one wavelength is very short so that the light reflected from different points on the three-dimensional target reaches the film at slightly different times, depending on the distance of each point from the emulsion. An interference pattern created by the phase relationships between the reference beam and the target reflections is created on the film. It is this interference pattern that is recorded.

Because the distances involved are so small, the film must be able to resolve interference lines spaced about a wavelength apart. This means that a film resolution of about 2000 lines/mm must be used to produce a useful image. (Conventional film can resolve only a few hundred lines per millimeter.)

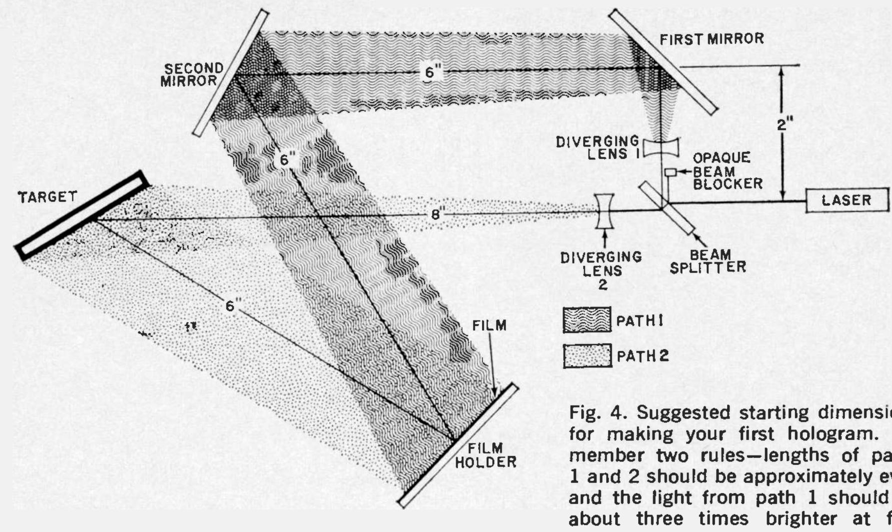


Fig. 4. Suggested starting dimensions for making your first hologram. Remember two rules—lengths of paths 1 and 2 should be approximately even and the light from path 1 should be about three times brighter at film holder than that from path 2 (target).

BILL OF MATERIALS

1—Beam splitter, plano-plano double-polished high-transmittance glass 1" x 2" x ¼" (Edmund Scientific 41,264, Edmund Scientific Co., 300 Edscorp Bldg., Barrington, N.J. 08007)
2—Diverging lenses, 10-mm diameter, 9-mm focal length, coated (Edmund Scientific 94,-726)
2—Front-surface mirror, high-reflectance coating on polished front surface, heavy glass, one 3" x 4", one 5" x 7" (Edmund Scientific 40,041 and 40,043, respectively)
Film (Agfa 10E75, Agfa-Gevaert Inc., Scientific Products Dept., 275 North St., Teterboro, NJ 07608)
Developer (Kodak D-19 or Metinol-U)
Hypo fixing bath
Developing trays (3)
Misc.—Mounting tripods for optics, adhesive, aluminum sheet ¼" x 2" x 3" and L brackets for film holder, metal strip for supporting lenses, alcohol and lint-free tissue for lens cleaning, stable, workbench, darkroom, acetic acid, etc.
Note—A complete kit of all items except those in Miscellaneous but including a test hologram and detailed instructions are available as Model 60-625 Holography Kit from Metrologic Instruments, Inc., 143 Harding Ave., Bellmawr, N.J. 08030, $34.75 postpaid. Mounting holders for optical components are also available for an additional $36. A complete holography kit plus a shock-mounted rigid base with three triangular tracks is available for $103 postpaid.

beam reference plane. Take two 3" lengths of L-shaped aluminum having one 3/16" lip and attach them to the 3" sides of the support so that the lips will hold both sides of the film (see Fig. 4). The target platform is a simple horizontal plate, made from metal or wood and mounted on a firm support so that the platform is about ½" below the horizontal beam reference plane.

Cleaning the Optics. All the optical surfaces must be cleaned very carefully. Any spots, smears, scratches or dust on any of the optical surfaces (including the transmission mirror of the laser) will show up as blotches or "noise" in a finished hologram.

An excellent way to clean the optics is with a fresh, untouched, lint-free facial tissue moistened slightly with pure alcohol. Take care not to let dust or fine grit that may be on a surface scratch the surface as you remove it. A soft cotton swab can be used to remove any residual particles that may be present before cleaning. After cleaning, make sure that no residue from the facial tissue is left on the optical surface.

Once cleaned, optical components should be protected with dust covers and should never be touched with the fingers.

Preparing the Developing Chemicals. Conventional darkroom techniques are

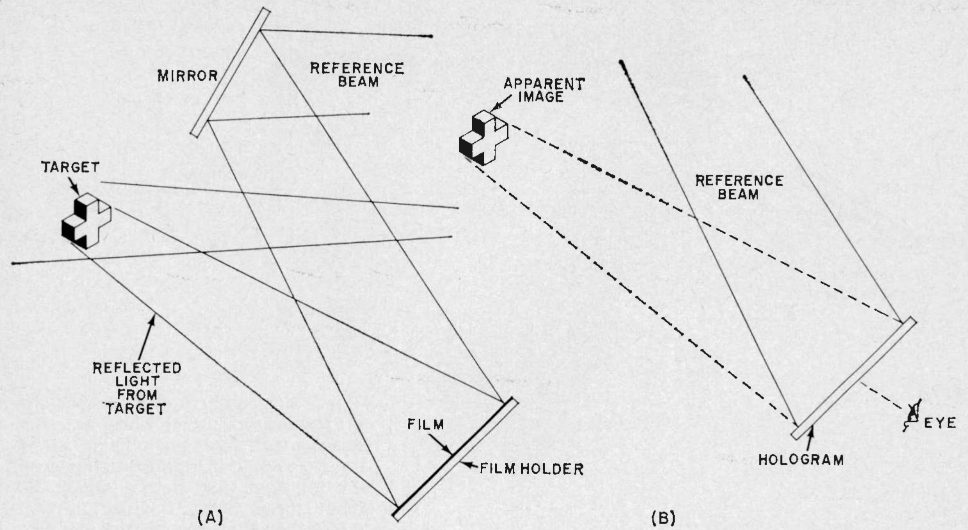


Fig. 5. To view the hologram, you must reproduce the optical arrangement used to make it, as shown in (A) and (B) above. The apparent image is difficult to see at first until you get used to it. Make sure the negative is positioned the same way it was taken and is straight. Viewing should be in a darkened room.

used in developing the hologram. Make up a solution of Kodak D-19 or Agfa Metinol-U developer in a tray. (Any other very fine-grain and high-contrast developer may be used.) Make up another tray of shortstop (dilute acetic acid) and one of fixer (ordinary hypo). Follow instructions provided with the chemicals.

A source of clean running water will be needed for washing finished negatives and you should have some type of darkroom timer to measure the seven or eight minutes required for developing. Allow all chemicals to stabilize to correct temperature. Now make sure that the darkroom can be made absolutely dark during hologram exposure and that all fans and air conditioners are shut off. Air in motion can ruin fine details on a hologram.

The film to be used is Agfa 10E75, which is very sensitive to red and blue light; therefore no safe light should be used while the film is being exposed and developed.

Setting Up and Making a Hologram. In making a hologram, you are dealing with distances as short as a wavelength of light—and shorter—so physical motion of the optical system and the air surrounding the experiment must be at a minimum. Select a very solid work surface that is not affected by building vibrations. The surface need be only a foot or two wide and about three feet long.

Position the laser at one end of the working surface so that the beam shines down the center of the area. Place the optical components as shown in Fig. 4. It is suggested that you use this layout to make your first holograms. Experiment later. Place the beam splitter about 2 inches from the laser beam exit hole, positioned so that it is at a 45-degree angle to the beam. With the laser operating, use a smoke cloud to show up the beam and note that there are three red lines. One passes directly through the beam splitter and shines on down the work table. Two others come off of the beam splitter at right angles. One of these two beams comes off the front surface of the splitter, while the other comes off the internal or rear surface. Position a wooden beam blocker so that it cuts off the beam coming from the surface closest to the laser. Now there should be only two beams—one shining straight down the work surface and one at right angles to it off of the splitter.

Position the first front-surface mirror (the smaller of the two) about 2 inches from the beam splitter and about parallel with the beam splitter surface. Orient this mirror carefully so that the beam from the splitter strikes close to the center of the mirror. Now there should be two separate parallel beams going down the table.

As can be seen from Figs. 1 and 4, two optical paths are required to make a hologram. One (path 1 called the reference beam) is from the beam splitter, through a diverging lens (to broaden the beam), through two front-surface mirrors, to the film holder. The other (path 2, called the target beam) comes from the beam splitter, through a diverging lens and shines on the target. The reflected light from the target shines on the film holder. The positioning of the target, the second reflecting mirror, and the film holder should follow two basic rules: (1) the lengths of paths 1 and 2 should be approximately the same; and (2) the light from path 1 should be about three times brighter at the film holder than the reflected light from the target.

For the target, it is best to use a bright, shiny white or red object less than two inches in any dimension. This type of target does not require long exposure times. A white or red chessman or an HO-gauge train car make good targets.

Once the optics are positioned as described, place a white card or piece of paper in the film holder. Adjust the mirrors in path 1 until the reference beam dot is centered on the film holder. Move the first diverging lens into position in the reference beam. The dot on the film holder should now be enlarged considerably. Do not use the exact center of the diverging lens to avoid unnecessary interference rings on the film plane. Adjust the reference beam mirrors so that the reference beam covers most of the white card in the film holder as uniformly as possible. The placement of the refference beam may also be adjusted by moving the first diverging lens.

Place the target in position and note that the path-2 beam strikes it. Position the second diverging lens for maximum coverage of the target by the beam. The reflected light from the target should cover the white card in the film holder. Block out the light from path 2 and note the level of light from path 1. Now block the light from path 1 and note that the path-1 illumination is about 3 times as strong as that reflected from the target.

Make sure that no stray light from the target illuminating beam strikes the second mirror. Also, check that extraneous light reflected from the optics or the target mounting does not fall on or near the film holder. To do this, remove the film holder and look into the reflected beams from the film holder position. (NOTE: It is quite safe to look into the *diverged* beam from a laser with power as low as this—less than 0.5 milliwatt. However, before looking into the beam or its reflection, *be sure* that the diverging lenses are in position.) Look at the target and the second reference-beam mirror—and other places—and make sure that only light from the reference beam and target strike the film plane. Use dull black paint to touch up any shiny spots and place dull-painted blocks to prevent any stray light.

Replace the film holder and recheck the beam illumination levels. The beam balance can be changed by moving the target one way or the other or by moving the reference beam mirrors. However, the length of the beam paths must remain equal within a couple of inches. You are now ready to expose the film—emulsion side toward the target and reference beams. But wait one more minute—observe these precautions! Since the film is extremely sensitive, the room must be absolutely dark. The laser must have been operating for at least a half an hour to allow it to stabilize. The movement of air in the room must be at an absolute minimum—no air conditioners or fans, no unnecessary body movement and no talking. Air turbulence destroys the fine fringes that make up the details of the picture.

Cut out a strip of black paper for use as a shutter to cut off the beam where it comes out of the laser. With this shutter in place and making sure that there are no other light leaks in the room, take a section of film, holding it by the edge, and place it, emulsion side out, in the film holder. Be sure not to buckle or touch the film emulsion. Allow a few moments for everything to stabilize—don't move or talk or allow air to move across

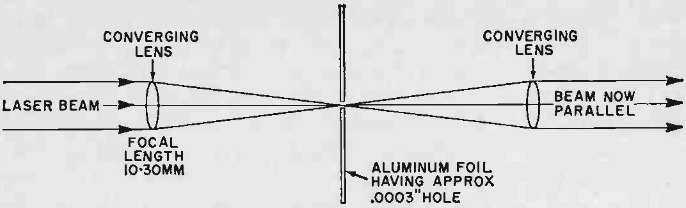


Fig. 6. A spatial filter cleans up laser beam to make better holograms. Sharp needle is used to make the fine hole required.

the beam paths. Now remove the shutter from the beam for 1½ seconds and then replace it. The hologram is now exposed and ready for development—but don't turn on the lights!

Film Development. Processing holographic film is not much different from normal photographic processing. The temperatures of the film storage area, the exposure area, and the chemical baths should be as nearly equal as possible. Handle the film as little as possible, taking care not to touch the emulsion. Place the exposed film in the developer for the recommended amount of time—about 7 or 8 minutes, usually. If anything, a little overdeveloping doesn't hurt. Then insert the film in the conventional stop bath and fixer. After fixing, the safe light can be turned on. Wash the film for about 10 minutes in running water.

Do not be surprised at what you see, or do not see, on a finished hologram. You are not recording a focused picture

THE STABLE BASE

A stable base is required for the optical system if you are to make a good hologram. Ideally, you should use a heavy bench having a thick slate or metal top and sitting on a thick concrete or cement floor isolated from building vibrations. Such vibrations come from elevators, heavy machinery, passing vehicles, or a walkway used by a number of people.

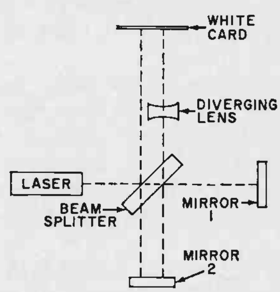
Unfortunately, such an ideal condition is difficult to find. As a substitute, find a location that is as close as possible to the ideal and then try either of the following vibration-reduction systems.

Partially inflate a truck or car inner tube and place it on top of your workbench. Obtain a piece of thick plywood—¾" or more—about four feet square and center it on the tube. Place heavy weights (stones or metal blocks) at each corner of the plywood and orient the weights so that the plywood is horizontal as indicated by a spirit level.

The second approach is the same as the first except that a thick layer of foam rubber—two inches or more—is used instead of the inner tube.

Once you have a stable platform, you can determine just how stable it is by using a simple interferometer setup as shown in the diagram. You can use the same equipment that is used to make a hologram.

Assemble the optical system, as shown, on the stable platform. The distances from the laser to the beam splitter and from the beam splitter to the white card are not important. However, try to make the distance from the center of the beam splitter to each mirror the same. Do not install the diverging lens at first. Turn on the laser. If things are properly positioned, two pairs of dots should be visible on



the white card. You can adjust the optics slightly to make both pairs visible. Further adjustment of the optics will cause one pair of dots to be superimposed on the other pair.

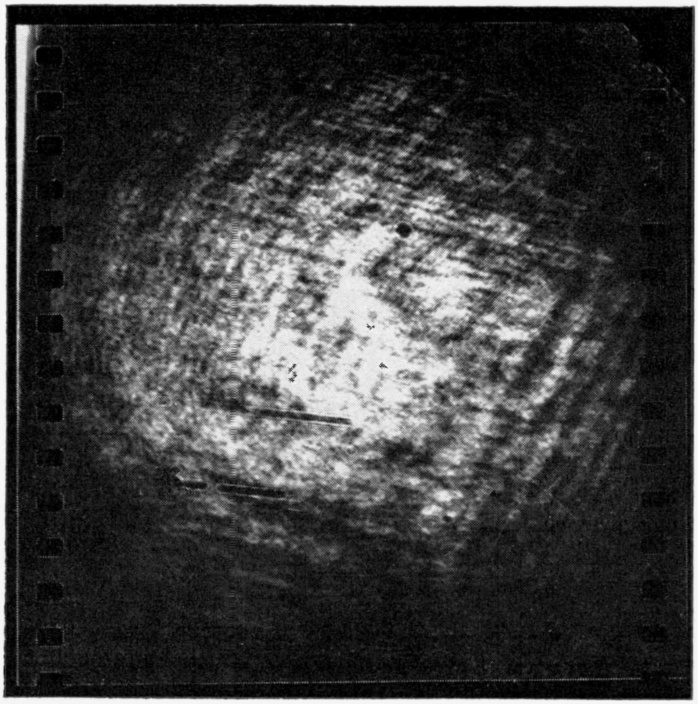
Now insert the diverging lens into one of the beam paths about three inches from the white card. One of the dots on the card will enlarge to a red area—actually, it is two areas superimposed on each other. If you examine the superimposed areas carefully, you will notice a number of black bars that may be stationary or slightly moving within the area. If you very gently touch one of the mirrors the black bars will move. These bars are the result of interference patterns and represent an optical "zero beat." Moving either mirror slightly changes the number of bars. Adjust one of the mirrors until a convenient and easily seen number of bars is visible. Leave the optical system alone and observe the bar pattern for a few minutes. The bars should not move more than about one quarter of the distance between bars over a few minutes' time. If you can obtain this type of vibration-free mounting, you can make good holograms.

so there is no actual image on the film. The most that you will see is a somewhat smudgy negative full of whorls and lines. The dark areas are noise. The actual image is down at the molecular level and can be seen as interference fringes under a microscope.

Viewing the Hologram. This can be a little tricky until you get the hang of it. An important first step is to place the hologram (after it is air dried) in a metal frame so that it is flat. The frame should at least support the hologram by the two edges that have the most curl.

The hologram can be observed without disturbing the exposure setup. Looking at the exposure arrangement from the rear of the film holder, note the angles made to the film holder by the reference beam and the target reflection beam. Referring to Fig. 5, remove the film holder platform and place the hologram in the diverged reference beam at the point where the film was originally positioned. The image should appear where the original target was as you look through the back of the film. You may have to move the hologram around a little, and unless you remember the exact orientation of the film, you will have to turn it until you see the image. If the film is reversed, a weird, unrecognizable blown-up image will result. As previously mentioned, seeing the image is tricky until you are used to it. Have patience and try viewing a hologram that you know is good before giving up on the one you made. If you purchase the hologram optics kit mentioned in the Bill of Materials you will get a sample hologram to experiment with. Other holograms are available from Edmund Scientific Co., 300 Edscorp Building, Barrington, N.J. 08007.

Troubleshooting. If no picture can be found in the hologram, there are several possible reasons. The most probable is that something moved while you were making it. A relative motion of even a few millionths of an inch between target and other components can destroy the image. Also check the following: (1) Beam balance—ratio of approximately 3:1 must be maintained between reference and reflected beams. (2) Stray light from outside or from laser must be eliminated. (3) Exposure time may not be right. Keeping all conditions the same, vary the exposure time until you hit the correct interval. (4) Film resolution may



The finished hologram bears no resemblance to an actual picture. In fact, it may look like this. The hologram from this blotchy negative is quite an excellent three-dimensional image. The dark blotches, accentuated by the magazine printing process, are due to the random moding of the laser, and most can be cleaned up with a spatial filter. Small whorls and lines seen on the hologram are the result of small blemishes on the optics or dust motes on polished surfaces. They carry no picture information so they can be completely ignored. The actual hologram interference lines are so small they can be seen only with aid of a microscope.

be lost due to poor developing techniques or uneven temperatures in the chemical developers.

Refining the Hologram. Since holography is a new technology, perfection is not easy. However, there are a few things that can be done to improve the results a great deal and the serious experimenter will want to try them.

The first refinement is to "clean up" the laser beam where it leaves the housing. You will notice that no matter how you clean the optics, the laser beam is still inclined to be "blotchy." The blotches can be cleaned up by the use of a spatial filter. The latter is easy to make: two convex lenses of short focal length (10 to 30 mm) and a pinhole in a piece of aluminum foil are all you need. The arrangement is shown in Fig. 6. Place the assembly between the laser beam exit hole and the beam splitter.

Multi-mode lasers of the type used here cannot be completely "cleaned up" by this process. There may still be "holes" in the hologram—portions of the target that are not illuminated. To remedy this, you can try a single-mode laser ($69.95) in place of the multi-mode, low-cost laser.

Other refinements are possible, but involve techniques that cannot be adequately described in this article. -30-

TYPES OF LASERS

Helium-Neon. Helium-neon lasers are typically of low power, but they are especially useful where stable single-frequency operation is important. Such systems usually operate at wavelengths of 6328 angstroms, 1.15 microns (11,500 A) or 3.39 microns (33,900 A) depending on resonator design.

A major application is in optical alignment tools. These types are being used increasingly in construction work—bridge building, etc. Most small He-Ne lasers have a beam diameter of 1 to 3 millimeters, which is expanded to about one inch. A fan-shaped beam has been designed so that a reference plane is produced rather than a line.

Carbon Dioxide. The limiting efficiency of approximately 25 per cent is the highest known for any gas laser system; also, the highest unclassified continuous-wave output power is in excess of 8 kW. The system operates at a wavelength of 10.6 microns in either the continuous-wave, pulsed, or Q-switched modes. With the introduction of O_2, He, H_2, argon, and H_2O to a high-power CO_2-N_2 system, the power is further increased by depopulating the lower laser level. The CO_2 laser is attractive for terrestrial and extraterrestrial communications because of the low absorption window in the atmosphere between 8 and 14 microns. This system can also be used for metal cutting and welding. The CO_2 is extremely versatile because one can easily produce a high degree of coherency, high continuous-wave power, or high peak powers through the use of Q-switching techniques. Of major significance from the hazard standpoint is the fact that CO_2 radiation at 10.6 microns can be present in enormous power, yet is invisible to the human eye.

Argon. This ionized gas laser system operates at wavelengths of 4880 A, 5145 A, or 4579 A in either continuous-wave or pulsed mode. Power generation is greatest when operating at 4880 A and 5145 A. Highest CW powers achieved have been on the order of 100 watts for one minute.

Solid-State Crystalline. The solid-state laser continues to find wide application. Of the ions with which laser action has been produced, perhaps Nd^{3+} in garnet or glass and Cr^{3+} in aluminum oxide have the greatest general interest. A most attractive host for the neodymium ion is garnet (yttrium aluminum garnet, YAG, or yttrium iron garnet, YIG) because the 1.06-micron laser transition line is sharper than in other known host crystals. Frequency doubling to 5300 A using lithium niobate crystals produces powers approaching the power available in the fundamental at 1.06 microns. In addition to frequency doubling, an interesting development which raises some questions about potential hazards is the production of picosecond (10^{-12} sec) pulses such as those obtained through modulation of the internal losses in the YAG-Nd system at the correct mode-locking frequency. Also, through the use of electro-optic materials such as KDP, barium strontium niobate or lithium tantalate, "tuning" or scanning for laser frequencies over wide ranges may be accomplished.

Semiconductors. The best-known example of an injection laser is the gallium-arsenide type whose operation depends on a *pn* junction. This device operates at a wavelength of 8400A but it should be noted that the wavelength range of all available types of semiconductor lasers is approximately 4560 A to 51,000 A. Generally speaking, the semiconductor is moderately low power in continuous-wave operation (milliwatts to several watts) and has a typically broad beam divergency (about 15 to 20°), unlike gas lasers which do not usually exceed a few milliradians. Certain semiconductor lasers are pumped by multi-kilovolt electron beams (for example, CdS at 4900 A) which may introduce the additional question of ionizing radiation hazard.

BUILD

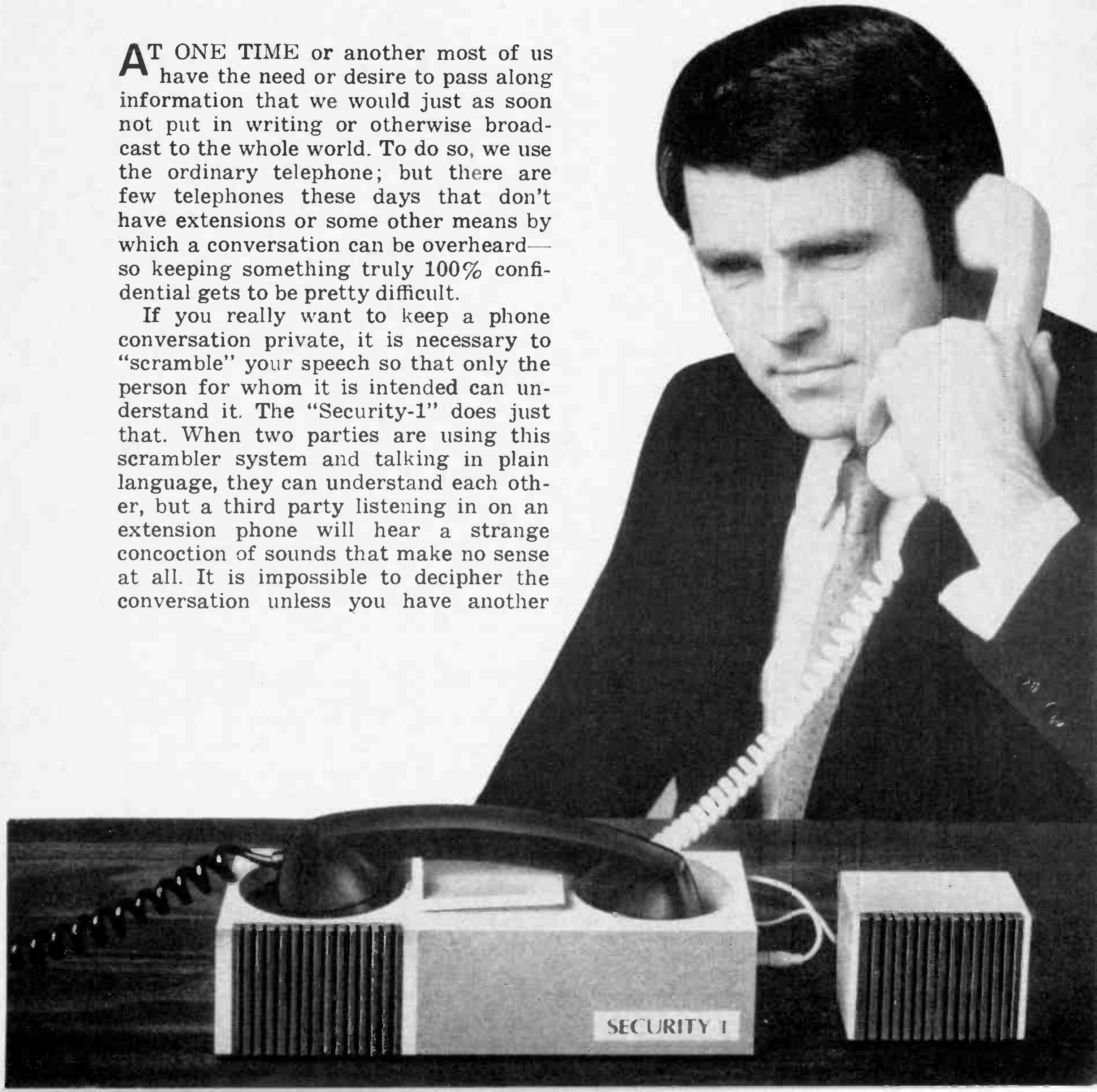
SECURITY 1

SPEECH SCRAMBLE YOUR TELEPHONE CONVERSATIONS

BY J. PINA

AT ONE TIME or another most of us have the need or desire to pass along information that we would just as soon not put in writing or otherwise broadcast to the whole world. To do so, we use the ordinary telephone; but there are few telephones these days that don't have extensions or some other means by which a conversation can be overheard—so keeping something truly 100% confidential gets to be pretty difficult.

If you really want to keep a phone conversation private, it is necessary to "scramble" your speech so that only the person for whom it is intended can understand it. The "Security-1" does just that. When two parties are using this scrambler system and talking in plain language, they can understand each other, but a third party listening in on an extension phone will hear a strange concoction of sounds that make no sense at all. It is impossible to decipher the conversation unless you have another



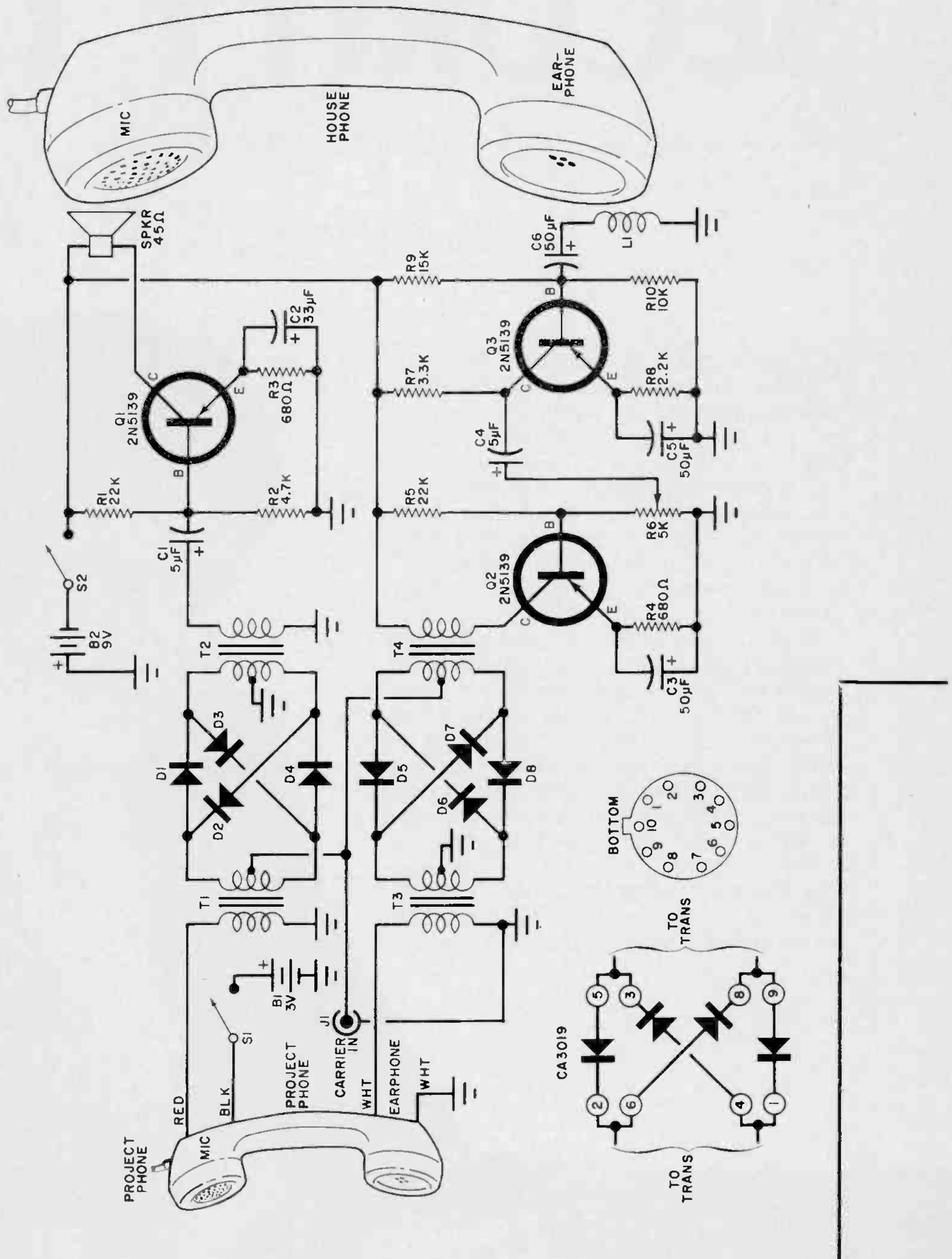


Fig. 1. An RCA CA3019 IC may be used in place of the diodes shown. The transistors and most of the components, including two transformers may be salvaged from the commercial telephone amplifier. L1 is built into the plastic container.

PARTS LIST

B1—C or D cell (2)
B2—9-volt transistor radio battery
C1,C4—5-µF, 15-volt electrolytic capacitor
C2—33-µF, 10-volt electrolytic capacitor
C3,C5,C6—50-µF, 15-volt electrolytic capacitor
D1-D8—Small-signal silicon diode (1N34A or similar or use RCA CA3019 IC)
J1—Earphone jack
L1—Telephone induction coil pickup (Lafayette 99E10340 or similar)
Q1-Q3—Small-signal pnp transistor (2N5139 or similar)
R1,R5—22,000-ohm
R2—4700-ohm
R3,R4—680-ohm
R7—3300-ohm
R8—2200-ohm
R9—15,000-ohm
R10—10,000-ohm
(All resistors ¼-watt)
R6—5000-ohm PC potentiometer
S1,S2—S.p.s.t. switch
T1-T4—500-ohm to 500-ohm center-tapped transformer (Lafayette Argonne AR162 or similar)
Misc.—Telephone amplifier (Allied Radio Shack 43B230 or similar, optional), surplus telephone, battery holders, transistor radio earphone cable and connector, audio signal generator, radio, mounting hardware, etc.
Note—A printed circuit board, etched and drilled, is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216 at $4.50.

scrambler and know the electronic key being used. The Security-1 requires no electrical connections to the telephone—all coupling between the scrambler and the telephone is made by magnetic induction and acoustic means.

Besides the scrambler devices, the users at each end of conversation must have conventional audio sine-wave generators capable of delivering about 1 volt, tunable between 1 and 3 kHz. These are used as the scrambler sources. If a scrambling scheme that is almost impossible to decode is desired, the audio output from a conventional transistor radio (through the headphone connector) may be used as the scrambler source. In this case, of course, both parties must be able to tune their receivers to the same broadcasting station.

The basic principle of the Security-1 employs what is known as a balanced ring demodulator—the same circuit being used for both coding and decoding. This particular circuit has been employed for many years by the telephone company and radio amateurs for the generation of single-sideband suppressed carrier signals. Because of the strange sounds coming from the scrambler, the same basic circuit may also be used for experimenting with far-out music. One electronic instrument can be substituted for the speech input while an audio generator or another electronic instrument could be used for the scrambling source. Although not tested by the author, such a system should produce some really weird effects.

Each end of a scrambler system requires two telephone hand sets: the conventional house telephone (called the "house phone" here) and another handset (called the "project phone"). The project phone can be any surplus telephone handset that has a conventional carbon microphone and dynamic earphone with a connecting cable.

Construction. The mechanical construction of the scrambler involves making a mounting for the house phone so that a pickup coil and small loudspeaker can be placed in close proximity to the earpiece and microphone, respectively, of the house phone. It is best to prepare this mounting first and then construct the electronic portion of the scrambler and fit it into the support.

The prototype shown in the photos uses a commercially available plastic telephone amplifier for the cabinet. You can build any type of cabinet (preferably of wood) slightly longer than the telephone handset and a few inches deep. If you build your own cabinet, lay the house phone handset down on the upper surface and mark the locations of the microphone and earpiece. Cut out holes of the correct size so that the phone drops smoothly into place when it is in position.

Using appropriate mounting hardware and spacers, mount the small 45-ohm loudspeaker under the microphone hole so that it is about half an inch from the house phone microphone when the phone is placed on the support. Mount the induction pick-up coil in the usual fashion to the earpiece. Any of the low-cost telephone pickup induction coils, available at most electronic supply stores, can be used here.

If you decide to use the commercial

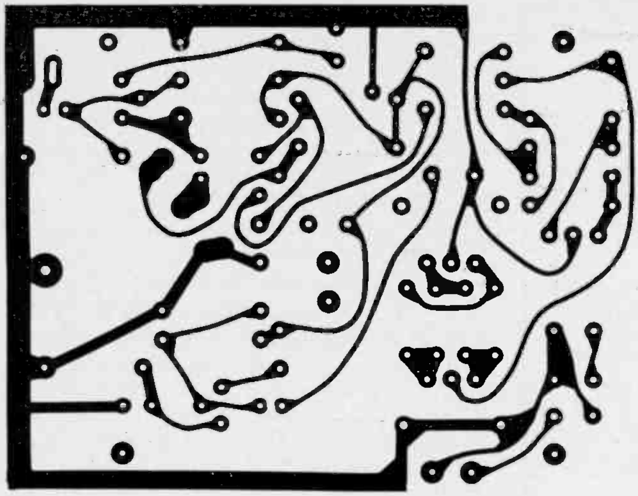


Fig. 2. Actual size foil pattern for the scrambler. This layout can be used only with subminiature transformers such as the Lafayette TR98 or similar types.

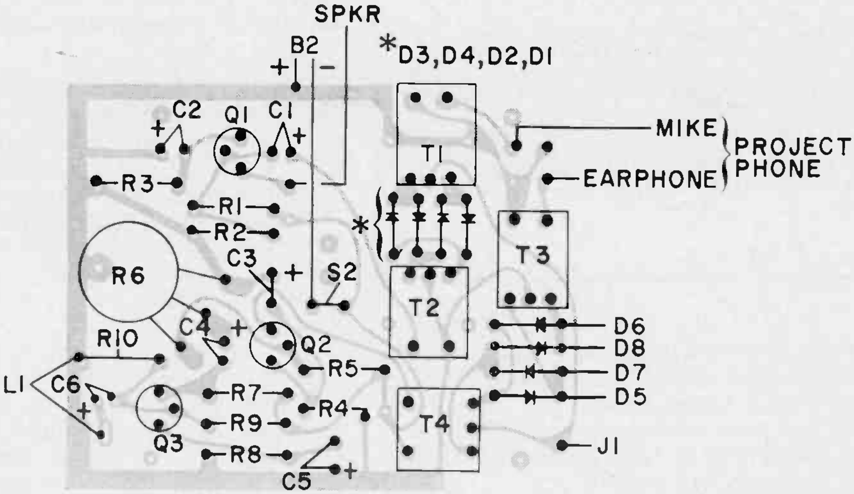
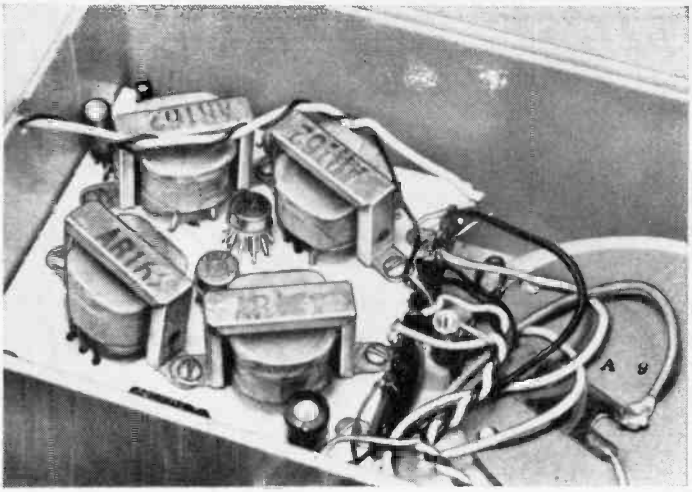


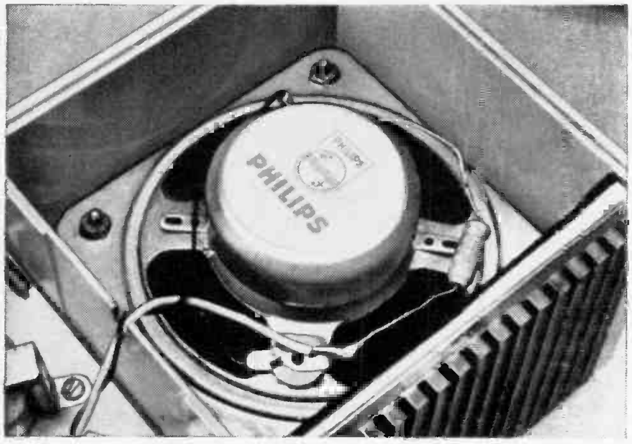
Fig. 3. Component installation on the board. The bulk of the components, including the transistors, can be salvaged from the printed circuit amplifier that comes with the commercial unit.

telephone amplifier set (see Parts List of Fig. 1) you will find all of these holes already made. You will also find an induction coil built into the earpiece hole. Remove the bottom cover of the cabinet, and remove the plastic insert from the microphone chamber. Then remove the built-in audio amplifier. Do not remove the induction coil. Also remove the small loudspeaker from its plastic cabinet. Using appropriate hardware and spacers, mount the loudspeaker in the microphone chamber as previously described. Although a 45-ohm speaker is specified in the Parts List, you can use the low-impedance speaker that comes with the built-in amplifier. In this case, also remove the speaker output transformer from the PC board and wire it to the speaker, using a pair of leads to run the primary back to the circuit.

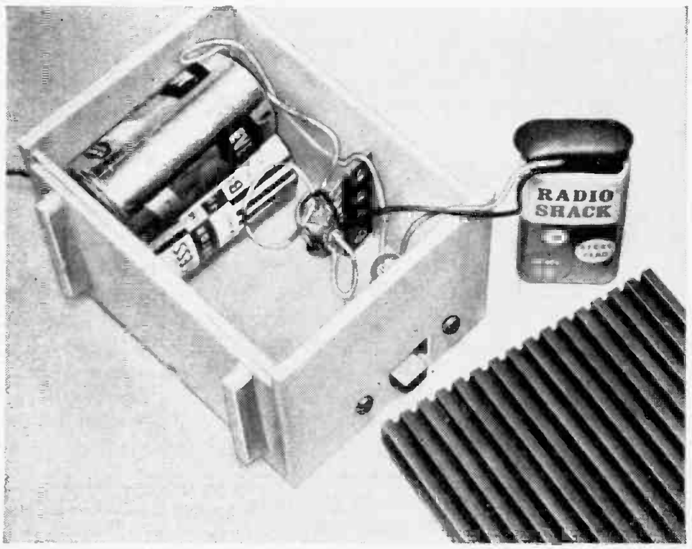
In both the commercial and homemade cabinets, once the speaker has been mounted, use foam rubber to pad the perimeter of the microphone hole so that the house phone microphone fits snugly in place. You can also insert foam-rubber sound-deadening material under the speaker to keep the acoustic energy within the mike chamber. In the commercial unit, leave the earphone jack in place; in the homemade unit, mount an earphone jack on one wall.

The circuit for the scrambler is shown

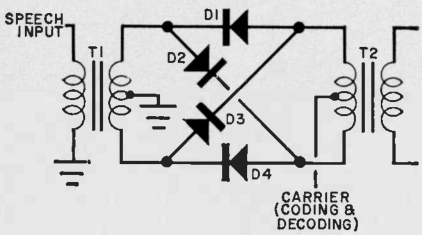




Three views of a non PC board prototype. The photo above shows the use of an IC for each diode bridge, and the larger-sized transformers. The speaker (left) is a 45-ohm type that is mounted on standoffs within the old microphone chamber. The batteries and power switch were contained in the old loudspeaker housing.



HOW IT WORKS



With no speech applied to the primary of *T1*, when the applied encoding carrier is positive going (with respect to ground), the currents in the primary of *T2* and the secondary of *T1* (through diodes *D1* and *D4*) are out of phase so that no carrier signal is developed in the secondary of *T2*. When the encoding carrier is negative going, the same thing happens as the current flows through diodes *D2* and *D3*. Thus none of the encoding carrier gets through output transformer *T2*.

When speech is applied to the primary of *T1*, the audio voltage across the secondary of *T1* unbalances the diode modulator. The resulting signal across the secondary of *T2* consists of a series of pulses whose polarity and repetition rate are determined by the carrier voltage and whose amplitude is determined by the instantaneous amplitude of the speech signal. If this output is viewed on a spectrum analyzer, it is seen to contain only an upper and a lower sideband.

If the encoding carrier is assumed to be a 3000-Hz tone and the speech frequency is assumed to be a 100-Hz tone, then the output would contain both a 3100-Hz upper sideband and a 2900-Hz lower sideband. If a filter is used to cut off signals above 3000 Hz, then only the lower sideband remains. When the input speech frequency is changed to 200 Hz, the output will be 2800 Hz. Thus the modulator inverts the incoming speech frequency, making it completely unintelligible to the unwanted listener.

Decoding uses the same circuit as encoding, and the system works as long as the same carrier signal is used at both ends.

in Fig. 1. The four diodes in each half of the circuit may be either individual units or an RCA CA3019 integrated circuit.

The actual size foil pattern for the printed circuit is shown in Fig. 2 and component installation is shown in Fig. 3. If you are using the commercial telephone amplifier, most of the required components can be removed from the built-in amplifier including the transistors, volume control, and on-off switch, to be used in the scrambler. The driver transformer for the push-pull output stage can also be salvaged and used as *T2*. If you do not choose to use the PC board, perf-board construction may be used, making sure that the overall board will fit within the enclosure.

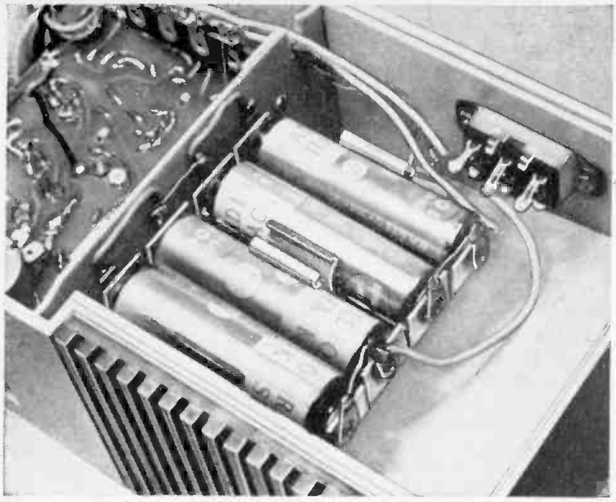
The completed board is mounted on standoffs within the homemade cabinet or on the existing standoffs in the commercial unit. Once the board has been installed, drill a hole in the side of the enclosure large enough to pass the four-lead cable from the project phone. In most phones, the two white leads are from the earpiece, while the black and red leads are from the phone microphone.

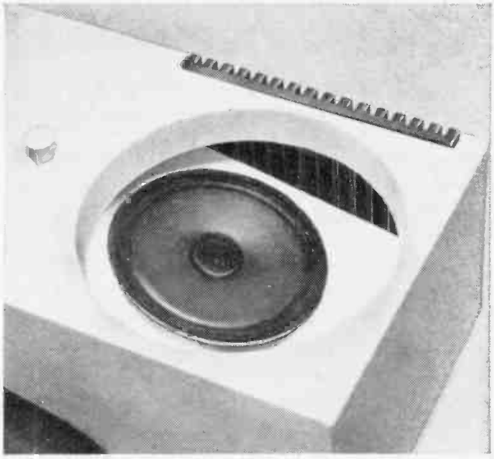
The 9-volt battery is mounted as it comes in the commercial unit, while a pair of C-cell holders are placed within the microphone chamber. A small s.p.s.t. on-off switch is also mounted within the mike chamber. In the homemade version, mount the batteries where convenient.

Testing. The scrambler can be tested without using the house phone. Disconnect both leads supplying the project phone mike to input transformer *T1*. Connect the loudspeaker output from any radio to the input terminals of *T1* and tune the radio to an "all news" station—or one that has more speech than music. If you use a conventional radio, disconnect the speaker connections to the output transformer secondary and use the secondary to supply *T1*. If you are using a transistor radio, use the earphone jack that usually is provided. When the earphone connector is plugged into its jack, the internal speaker is automatically disconnected. Remove the earphone and connect the cable ends to the input of *T1*. Turn the radio volume down.

Connect a conventional audio sine-wave generator through a transistor radio earphone plug and cable to the coder input jack on the scrambler, making sure the feed is properly grounded. Set the audio generator to about 1 kHz, 1 volt. Turn on the scrambler power switch *S1*. Slowly turn up the radio volume. Garbled speech will be heard from the built-in speaker.

By adjusting the radio volume control or the signal generator output level control, the garbled speech can be heard at its best "quality." If you adjust the signal generator frequency to about 3 kHz,





In the PC board version of the scrambler, four AA cells were used in place of the two C cells as microphone power. The speaker that came with the commercial unit (8-ohms) was used in conjunction with the output transformer that came with the built-in amplifier. The speaker is mounted on a piece of heavy cardboard at an angle to make good acoustical contact with the house phone microphone. The use of a PC board, and the smaller AA cells, enabled mounting all batteries within the plastic housing. The 9-volt battery is mounted in the same position as it was in the commercial unit, under the cover at the bottom.

the garbled speech will change. As you will soon notice, the best scrambling for the human voice takes place at about 1 kHz.

To test the unscrambler, connect the radio to the project phone earpiece leads and a transistor radio earpiece to the secondary of *T3*. When the project phone is placed in its correct position with the earpiece in the proximity of (or attached to) *L1*, scrambled speech will be heard in the radio earpiece. If audio tone breakthrough is encountered, connect a capacitor across the speaker to reduce the level of this unwanted signal.

Once both halves are working properly, connect the circuit up for operation as shown in Fig. 1.

Use. Obviously, to use the scrambler, two units must be made—one for each end of the conversation.

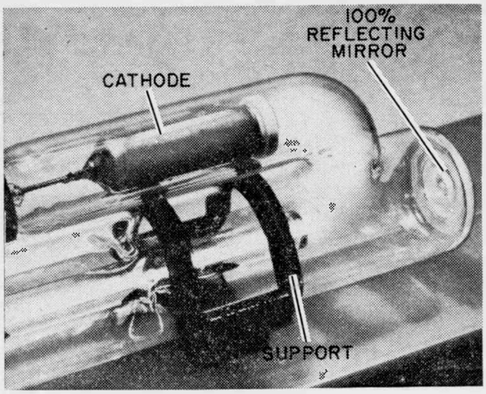
Using the house phone normally, dial the desired number and instruct the other end to "scramble." Make sure you have pre-arranged with him the audio frequency to be used on the signal generators. Each end then places the house phone on the housing with the holes correctly located. Either party can readjust his audio-generator frequency to clear up the speech at his end. –30–

EXPERIMENTERS' LASER

(*Continued from page* 14)

tinuously. If you are using the switched power supply, depress the pushbutton and then release it to start the laser.

Troubleshooting. If all instructions have been followed carefully, the laser should start immediately. During operation, the glass tube will have the characteristic red glow of a neon lamp. If there is no glow, check the power supply



At cathode end of the laser tube, the mirror is 100% reflective to keep light from escaping there.

operation by removing the laser tube and replacing it with a load made up of five 33,000-ohm, 2-watt resistors connected in series. Insert a 10-mA d.c. milliammeter in series with the substitute load. If the power supply is operating properly, there should be a load current of 5.5 mA. If not, check the power supply.

If the supply is OK, replace the laser tube, turn on the power, and turn the room lights out. See if there is a periodic red-orange glow discharge through the capillary tube. If the glow is there but the laser tube does not lase, short out either *R5* or *R18* in the supply. It is pos-

(*Continued on page* 152)

HOW IT WORKS POWER SUPPLY

The 1600 volts required to drive the laser is developed in a conventional voltage doubling circuit. In the automatic firing circuit, as capacitor *C1* charges up, and before any current flows through *R5* and *R6* (the laser has not yet fired), capacitor *C5* begins to charge through *R7*. The voltage across neon lamp *I1* is the same as that across *C5*. When this voltage reaches the firing point of *I1* (approximately 130 volts), current flows through *R9* triggering *SCR1* on. Capacitor *C5 then* discharges through the primary of the 100:1 ignition transformer *T1*, generating a high voltage at the secondary. This fires the laser. Current flows through *R5*, *R6*, *R10*, and *R11* to keep the laser lit, simultaneously keeping the voltage across *C5* low enough so that *I1* does not fire. Therefore, as soon as the laser fires, the automatic circuit stops operating.

THE LOW-COST LASER TUBE

The outer glass tube (1" diam) contains a mixture of 85% helium and 15% neon. Although lasing takes place within a 2-millimeter precision-bore capillary tube inside the larger tube, the large tube provides a reservoir of gas to improve reliability. After several thousand hours of operation, some helium starts to diffuse through the tube walls and some neon is absorbed by cathode sputtering. Hence, the larger the volume of gas, the longer the tube life. Another function of the large tube is to provide rigid support for the carefully aligned and sealed mirrors.

There is an electrode at each end of the tube. The cathode, a cold cathode made from a nickel-plated iron shell, is coated on the inside with barium carbonate, a low-work-function electron emitter. With this type of cathode, the laser starts instantly. The anode is a simple stub of nickel wire.

The two mirrors are not conventional. They are made from an uneven number of quarter-wavelength layers of dielectric. Alternate layers are made of a material having a high refractive index (zinc sulfide or titanium oxide); the other layers have a low refractive index (magnesium fluoride or sodium oxy-fluoride). The 100% reflecting mirror is 23 layers thick and the transmission mirror is 13 layers thick. Only in this way can reflectances of 99.9% be achieved for the one mirror. By contrast, the best aluminized mirrors have only about 90% reflectance.

The voltage-current characteristic of the laser tube is not unlike that of a conventional neon voltage regulator tube. The capillary tube gives the laser a high voltage drop and a larger negative resistance. A trigger pulse, over 2500 volts, must be applied to fire the laser. The voltage across the tube then drops into the operating region. Because of the negative resistance in the operating range, a large-value ballast resistor must be used. In the equipment described here, this resistance is about 120,000 ohms. Thus, the power source must provide about 950 volts for the tube and 700 volts for the ballast resistance under operating conditions.

The glass tube itself is made of annealed, high-temperature borosilicate glass. Although it is rugged, it should be handled with care, especially around the metal-to-glass seals at the electrodes. The tube can be mounted in any position and even works underwater if the high-voltage leads are properly insulated.

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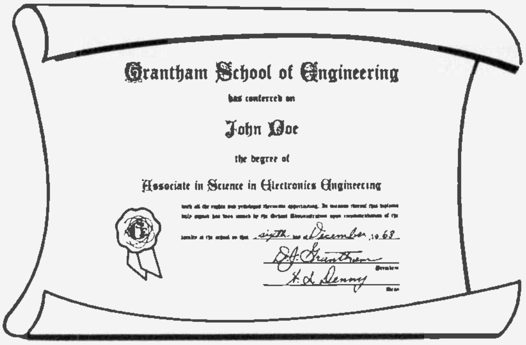

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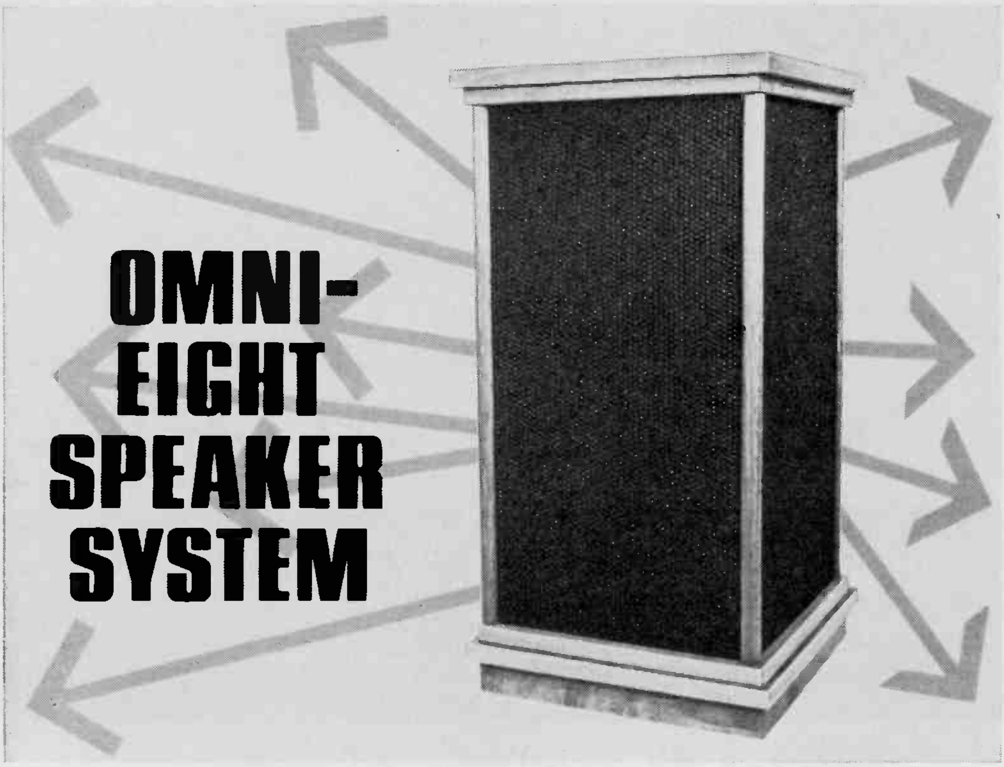


OMNI-EIGHT SPEAKER SYSTEM

MULTI-DIRECTIONAL LOW-COST SOUND

BY DAVID B. WEEMS

THE GENERATION GAP has reached stereo speaker systems. Last year, a floor-standing speaker was invariably placed near a wall or in the corner of a room. Those positions gave better "loading" at the important bass frequencies. Now, suddenly, there are free-standing, column-type speaker systems everywhere —even standing in the middle of the room. Old-timers shake their heads and mutter comments about doing things the hard way. But advocates of the new systems counter with talk about "multi-directional sound," "reflection ratios," and the elimination of "standing waves."

Although some of the current approaches are new, the history of hi-fi is littered with memories of multi-directional speaker systems. One early example was the Columbia "360", a compact monaural phonograph with two opposing 6" speakers. The name was derived from the idea of a full 360° of sound dispersion, realized mainly in the low frequencies.

Another ploy, recommended by G. A. Briggs, the English authority, was to face the speaker upward, directing the sound onto a diffusing cone or spherical reflector. These upturned speakers were usually located at the top of a 4' ported column. They produced true omnidirectional sound, but the low frequencies from the bottom port and the treble notes from the high reflector were sometimes noticeably divided.

The first of a new breed of column-shaped enclosures (still with us) puts the woofer at the base, facing downward. The mid-range speaker and the tweeter are more conventionally located on one side. The moderate height of this enclosure makes it more acceptable to the lady of the house, and the sound is better integrated than that possible from the tall columns. However, only the bass range is completely omnidirectional.

The latest development in the "sound-all-around" game places multiple speakers facing outward in several directions.

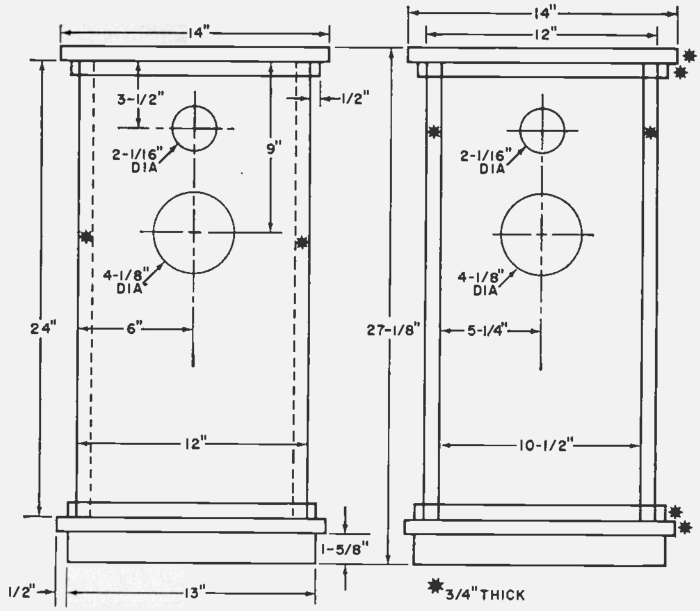


Fig. 1. While only front and one side are shown in drawings, opposite sides are identical in dimensions; ¾"-thick plywood is used for sides.

These systems produce multi-directional, full-range sound that reaches the listener largely by sound waves reflected from room surfaces. These new speaker systems appear to have some distinct advantages over conventional systems—enlargement of the optimum listening area for stereo effect, for example, and a feeling of "depth" imparted by the reflected sound.

There are several possible ways of producing an omnidirectional speaker system. One is to use a collection of full-range speakers; another is to couple an omnidirectional woofer to multiple mid-range speakers and tweeters. Or several small woofers can be used in conjunction with the multiple high-frequency speakers. The choice depends on such factors as cost and the amount of space that is available. For a relatively low-price system—and one that takes up very little floor space—you will want to try the "Omni-Eight."

About the System. The Omni-Eight speaker system uses the multiple-woofer approach to multi-directional sound. It

BILL OF MATERIALS

*4—5" woofers (Olson No. S-845)**
*4—2 ⅜" horn tweeters (Olson No. S-846)**
*1—Two-way crossover network (Olson No. HF-102)**
*1 pkg.—Acoustical fiberglass (Olson No. HF-17)**
2—24" x 12" pieces of ¾" fir plywood for sides
2—24" x 10½" pieces of ¾" fir plywood for sides
2—14" x 14" pieces of ¾" hardwood plywood for top and bottom
4—13" x 1 ⅝" pieces of ¾" hardwood plywood for foot pieces (miter cut ends to 45°)
1—9' length of ¾" x ½" trim for top and bottom (see text)
1—8' length of ½" outside corner hardwood molding for corner trim
1—144" length of ¾" x 1/48" wood veneer (Shurwood wood tape or similar) for plywood edges
4—10½" length of 1" x 2" pine for top and bottom cleats
4—7¼" lengths of 1" x 2" pine for top and bottom cleats
Six-penny finishing nails for attaching sides
Three-penny finishing nails for attaching trim
32—#8 x ¾" panhead sheet metal screws for mounting speakers
8—#8 x 1¼" flathead wood screws for attaching top
8—#10 x 2" flathead wood screws for attaching foot pieces
Misc.—Grille cloth (see text); wood glue; flat black paint; stain; sandpaper; wire; solder; etc.
**Olson Electronics, Inc., 260 S. Forge St., Akron, Ohio 44308*

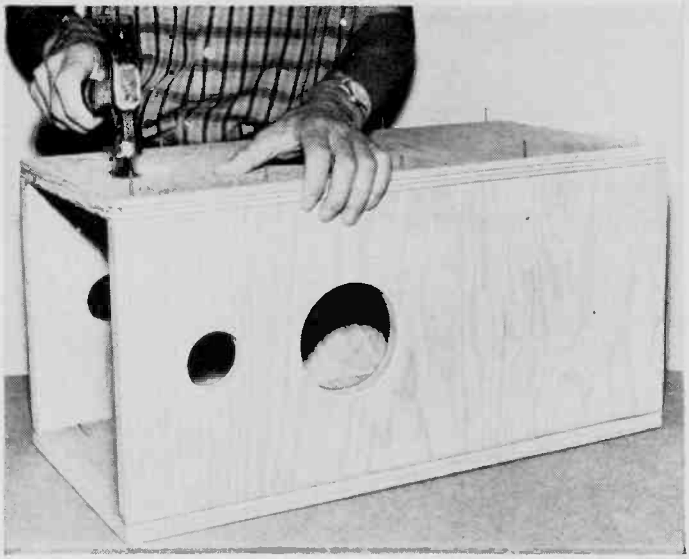


Fig. 2. Start construction of column by gluing and nailing together front, sides and rear. Note that speaker cutouts must all be in a common direction.

has four woofer-midrange speakers connected through a 3000-Hz crossover to four horn-type tweeters. Thus a woofer-tweeter pair faces each of the four walls or the corners if desired. The use of four small woofers results in an enclosure of modest dimensions that occupies only about $1\frac{1}{3}$ sq ft of floor space. A control on the bottom-mounted crossover network balances the tweeter output to that of the woofers.

The bass response of the Omni-Eight is clean and true, due to the 50-Hz free-air resonance of the woofers. It isn't the same kind of bass response you get from a 12" woofer, but you will find a degree of naturalness not present in many large speaker systems. The sound quality of the Omni-Eight can be described simply as "refined."

The total effect of the system is one of diffused sound, due to the multi-direc-

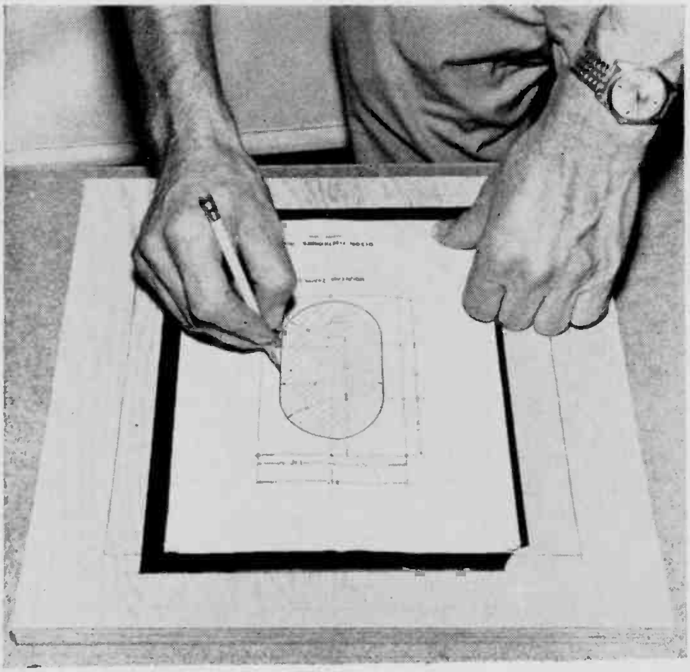


Fig. 3. Provided with crossover network is template that determines dimensions of cutout on bottom of enclosure. Use carbon paper to transfer dimensions to bottom plate.

tionality. The ear can still identify the location of a multi-directional speaker due to the fact that direct sound reaches the ear before the reflected sound; but the placement of the column is less critical than that of conventional systems.

The music power rating of the Omni-Eight is on the order of 30 watts, but it can be driven to good room volume by a 10-watt amplifier.

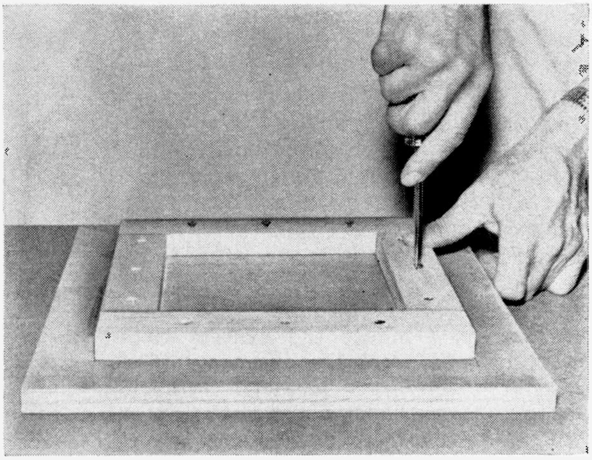


Fig. 4. Prior to mounting top plate on column, attach 1⅝" x ¾" pine cleats as shown in photo.

Construction. The enclosure can be built with common hand tools, though 45° miter cuts for the "foot" pieces and trim will improve the appearance. Cut out the parts to the dimensions shown in Fig. 1. In addition to the speaker cutouts, drill two guide holes for screws through each side piece about ⅜" from the top edge and 5" apart. Glue and nail together the sides to form the column as in Fig. 2. Then coat the exterior surfaces of the column with a flat black paint.

Prepare the 14" square top and bottom pieces. Use the template supplied with the crossover network and a piece of carbon paper to make the cutout for the crossover on the bottom (see Fig. 3). Remove the cutout with a sabre or keyhole saw. Center the top and bottom on the open-ended column and outline the position of the sides against the end plates with a pencil.

Attach 1" × 2" cleats with glue and #8 × 1¼" flathead wood screws on the interior surfaces of the top and bottom plates as shown in Fig. 4. The cleats should fit within the space outlined by the pencil marks to allow screws to be driven through the enclosure sides into the cleats.

Next, cover the plywood edges of the top and the bottom with wood veneer edging to match the veneer on the plywood. Use a razor blade to cut a piece of ribbon veneer slightly longer than the panel. Coat the plywood edge and the rear surface of the veneer with contact cement. Allow the cement to dry for 10 to 20 minutes until it is tacky but does not stick to your finger. Then apply the veneer, but don't let the surfaces touch until the veneer is in exact position. The cement will adhere on contact; but to make sure the entire surface is tightly bonded, place a small block of wood against the veneer and tap with a hammer. Move the block and tap it along the entire length of the veneer. With a razor blade, trim the ends of the veneer to the proper length. Then sand the edges, using a small wood block covered with fine (4/0) sandpaper, slightly rolling the top edge to blend the grain of the veneer with that of the plywood.

Coat all matching surfaces between the bottom cleats, the bottom plate, and the bottom edges of the column with wood glue. Attach the bottom by driving

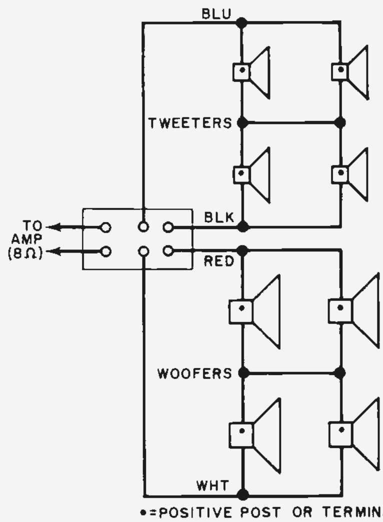


Fig. 5. Tweeters and woofers are wired in series-parallel to present 8-ohm impedance to amplifier.

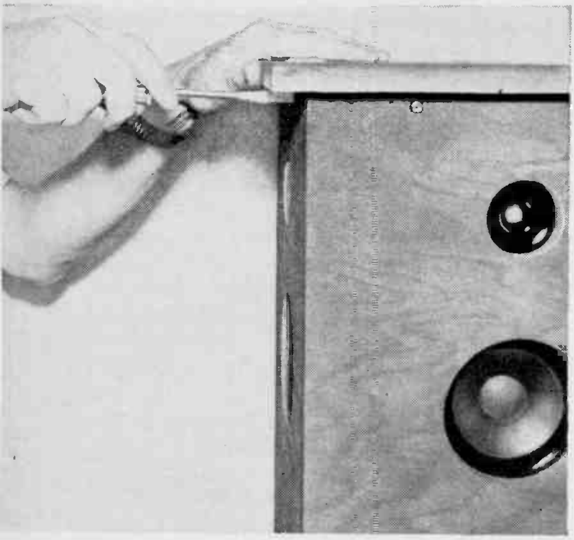


Fig. 6. Screws driven through column walls and into cleats secure top plate in place on enclosure.

nails through it into the lower edges of the four sides. If you have a good fit between the parts, the glue will be sufficient for proper sealing. If not, add screws through the sides into the cleats. Then check for air leaks and caulk the corner joints if necessary.

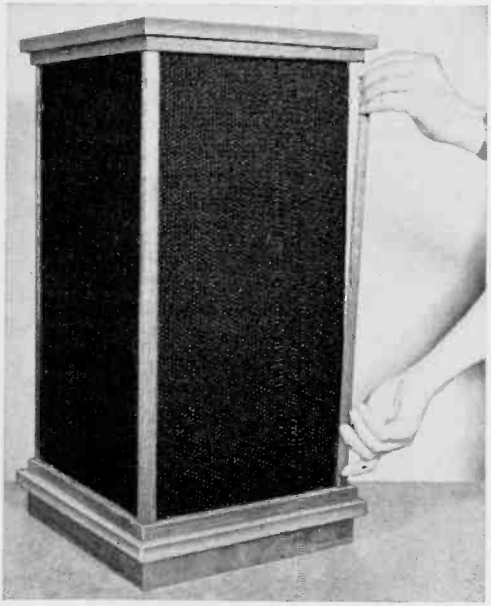


Fig. 7. Staples or tacks securing grille cloth at corners of column are hidden by corner molding.

Install the four miter-edged foot pieces on the bottom plate with glue and eight #8 × 2″ flathead wood screws. Feed the wires from the crossover network into the enclosure and install the network on the bottom, using the ten screws supplied with it.

Now mount the woofers with #8 × ¾″ panhead screws. Locate the positive terminal of each woofer (may be identified by a red insulating washer between the terminal and the speaker frame; negative terminal has white washer). Wire the woofers according to Fig. 5. Then check the polarity of the system by connecting a flashlight battery to the crossover terminals. For proper phasing, all woofer cones should move together in one direction, either outward or inward.

Next, mount the tweeters with panhead screws; wire them according to Fig. 5; and follow the instructions supplied with the network to complete the speaker hookup. Connect the system to an amplifier and check the operation of the tweeter control; clockwise rotation should increase the sound level of the tweeters.

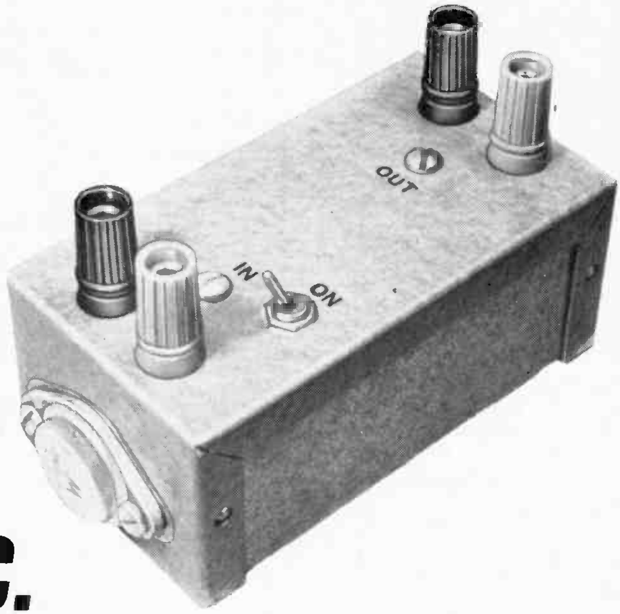
Fill the enclosure with loose fiberglass. One 72″ × 18″ sheet of Olson fiberglass is the minimum amount that should be used. Cut the batting into pieces about 18″ × 10½″, and insert them through the openings at the corners of the enclosure to fill the lower part up to the woofers. Then cut smaller pieces, about 3″ × 10″, to fit in the space between the woofers. The level of the fiberglass should extend to the level of the tweeters.

Set the top in position, and mark the correct positions for screws on the inside cleats. Remove the top and drill ⅛″ guide holes in the cleats. Cement a thin gasket of polyfoam or felt along the top edges of the sides. Then replace the top and anchor it with screws driven through the sides and into the cleats as in Fig. 6. The screws will be in the proper position to draw downward on the top, compressing the gasket. If necessary, weight the top to bring the guide holes in line with the screws.

A piece of grille cloth 2′ × 4′ will fit the enclosure column, wrap-around style. However, if the grille cloth you select does not have a strong vertical or horizontal pattern, you might be able to

(*Continued on page* 152)

BY JON COLT



BUILD A D.C. TRANSFORMER

HIGH VOLTAGE FOR THE NON-SEMICONDUCTORS

WHILE IT IS TRUE that many 1971 electronic devices involve low-voltage circuits, there are still quite a few high-voltage circuits and components around. If you don't believe it, try to fire a neon lamp or a flashtube with a 9-volt battery. You might as well use a match—at least you will make the lamp or tube warm.

The next time you want to power a neon-lamp multivibrator or even rediscover vacuum tubes (they are fascinating, by the way), the d.c. "transformer" might be just what you need. It is called a transformer because it accepts a wide range of input voltages (3-15 volts d.c.) and delivers anywhere from 80 to 425 volts d.c. output with an efficiency of approximately 70% with higher loads. Best of all, the d.c. transformer uses standard, low-cost components—no expensive, hard-to-locate inverter transformer.

The d.c. transformer is so simple in design (see circuit in Fig. 1) that it can be assembled, checked out, and put to work in about four hours.

Construction. The prototype d.c. transformer in Fig. 2 is built in a 4″ × 2″ × 2″ metal utilities box. All components are mounted on the top half of the box except for *R1*, *R2*, *C1*, and *RECT1*. Capacitor *C1* is supported by output binding posts *BP3* and *BP4*, while resistors *R1* and *R2*, because of their size, are made self-supporting via their connection points.

Integrated bridge rectifier assembly *RECT1* is mounted as follows: First press two layers of insulating vinyl tape onto

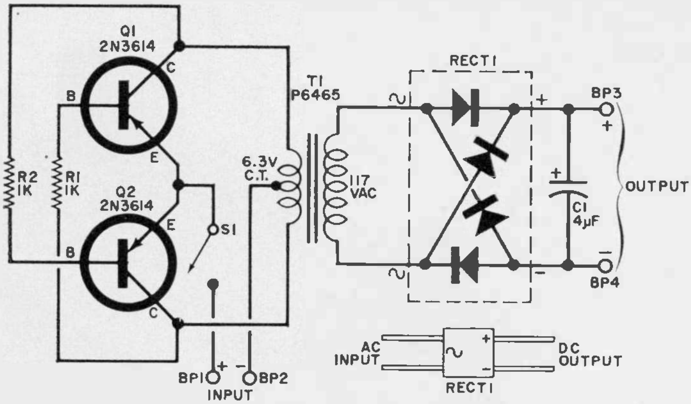


Fig. 1. Multivibrator circuit employs common filament transformer as saturable device. Output is rectified by RECT1, filtered by capacitor.

PARTS LIST

BP1-BP4—Five-way binding post
C1—4-µF, 500-volt electrolytic capacitor
Q1,Q2—2N3614 or Motorola HEP-232 transistor
R1,R2—1000-ohm, ½-watt resistor
RECT1—Integrated bridge rectifier (Motorola No. MDA 920-7, or similar)
S1—S.p.s.t. miniature toggle switch
T1—117-volt primary, 6.3-volt center-tapped secondary at 0.6 ampere filament transformer (Stancor No. P6465)
1—4" x 2" x 2" metal utility box
2 sets—TO-3 transistor insulating and mounting hardware
Misc.—6-32 hardware for transformer mounting; #6 solder lugs (2); vinyl tape; epoxy cement; solder; etc.

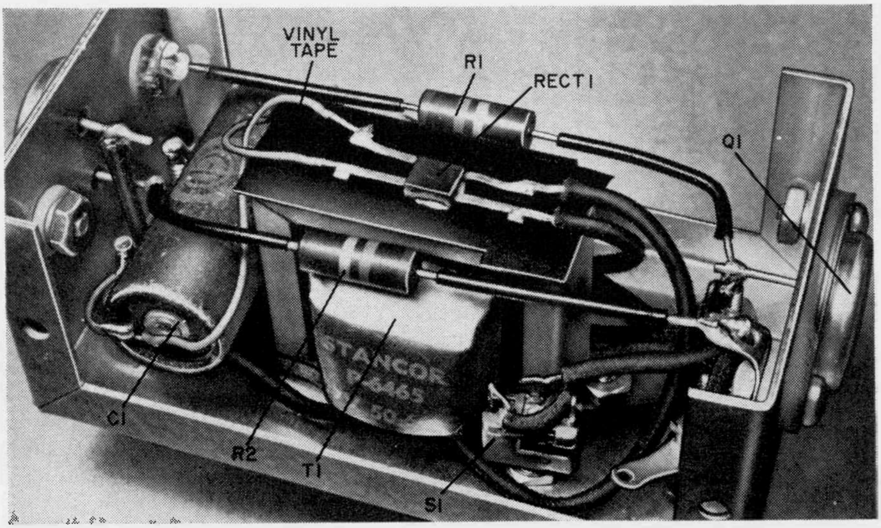


Fig. 2. Transistors are mounted on opposite ends of small utility box. Note that RECT1 is mounted on and insulated from transformer frame with daub of epoxy cement and vinyl tape.

the top of the transformer's frame. Then use epoxy to cement *RECT1* directly to this tape. Also, for insulation purposes, cut out Fig. 3 (or make a copy) and tape this to the inside of the bottom half of the utility box to prevent the rectifier assembly from shorting out against the case. Besides providing insulation, the chart gives you a handy reference for the d.c. transformer's transfer characteristics.

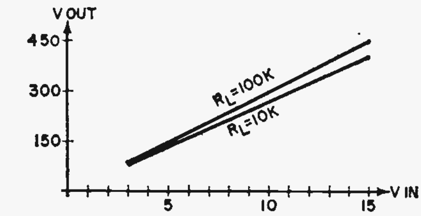


Fig. 3. Graph shows typical transfer characteristics for d.c. transformer when load resistance is 100,000 ohms and 10,000 ohms.

Transistors *Q1* and *Q2* are then mounted at the ends of the case with insulating shoulder washers and TO-3 mica insulators. Put a solder lug on one of the hold-down screws on each transistor to provide collector connection points. Remember to provide adequate clearance when drilling the holes for the base and emitter pins, and heat-sink these pins when soldering to them.

How To Use. As can be seen from Fig. 4, the output of the d.c. transformer starts to drop at any voltage with a

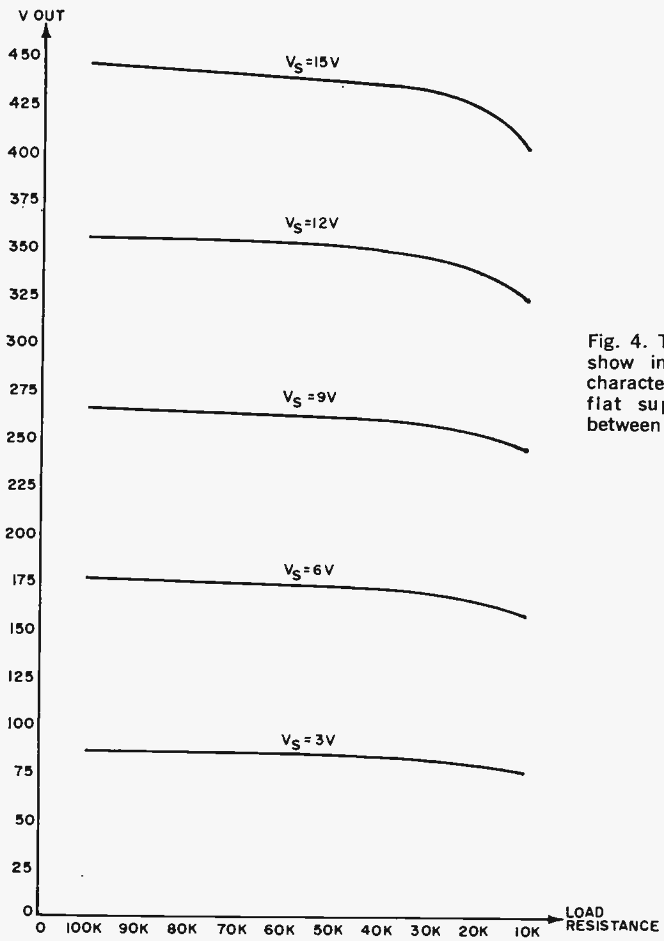


Fig. 4. These operating curves show input voltage vs. load characteristics. Note the fairly flat supply voltage curves between the load extremes.

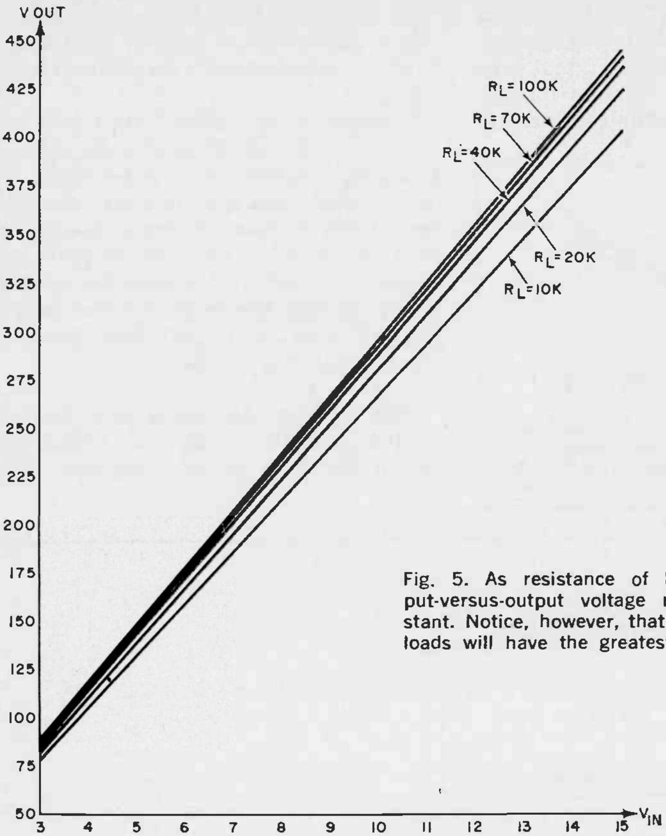
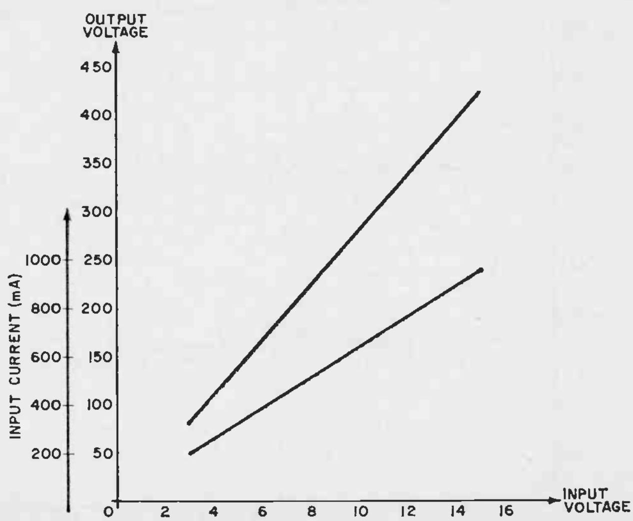
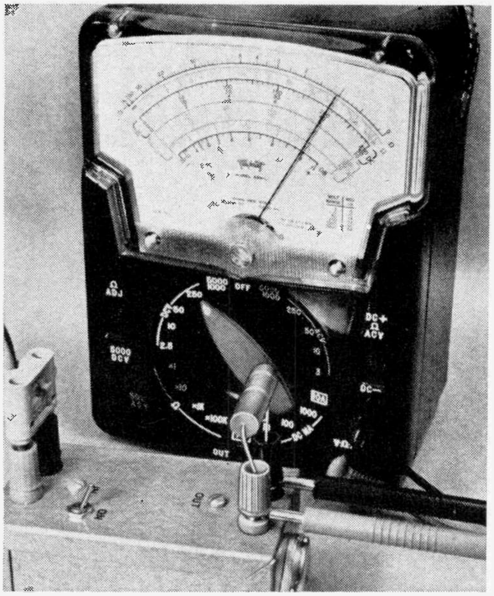


Fig. 5. As resistance of load decreases, input-versus-output voltage remains fairly constant. Notice, however, that very low resistance loads will have the greatest inefficiency effect.

Fig. 6. Graph shows relationships between input voltage and output voltage/current for 20k load on the d.c. transformer.





Proper output voltage is obtained by measuring potential across equivalent output load resistor.

for inputs higher than 15 volts, the voltage ratings of *RECT1* and *C1* become the limiting factors. Even if you decide to experiment with higher output voltages by replacing *RECT1* and *C1* with

HOW IT WORKS

The d.c. "transformer" is built around a magnetically coupled astable multivibrator circuit (stages *Q1* and *Q2* in Fig. 1). What is different about this circuit is the use of a common filament transformer, rather than a special inverter transformer, as the saturating device.

Transformer *T1* is connected so that the low-voltage supply is across the 6.3-volt, center-tapped winding with high-voltage a.c. pulses across the 117-volt winding. The high-voltage pulses are then rectified by bridge rectifier *RECT1* and filtered by capacitor *C1*. Because the output of an inverter is essentially a square wave, much less filtering is needed than would be required for a rectified sine wave.

Inputs between 3 and 15 volts d.c. are applied between *BP1* and *BP2*, triggering the multivibrator circuit. Once rectified and filtered, the output d.c. voltage (with slight a.c. ripple superimposed on it), is available at *BP2* and *BP3*.

10,000-ohm load. The converter, in fact, will not start at all when a 5000-ohm load is connected to the output. A good rule to follow is: do not try to drive loads which are equivalent to less than 10,000 ohms. For example, from Fig. 5, you can see that the output will be about 135 volts for a 5-volt input to *BP1* and *BP2*.

According to the rule, you cannot draw more than 13.5 mA (135 volts/10,000 ohms, by Ohm's Law) from the supply. But don't be misled into thinking that the supply is not powerful. With 15 volts input and a 10,000-ohm load, output current is greater than 40 mA, representing a power output of 16.25 watts.

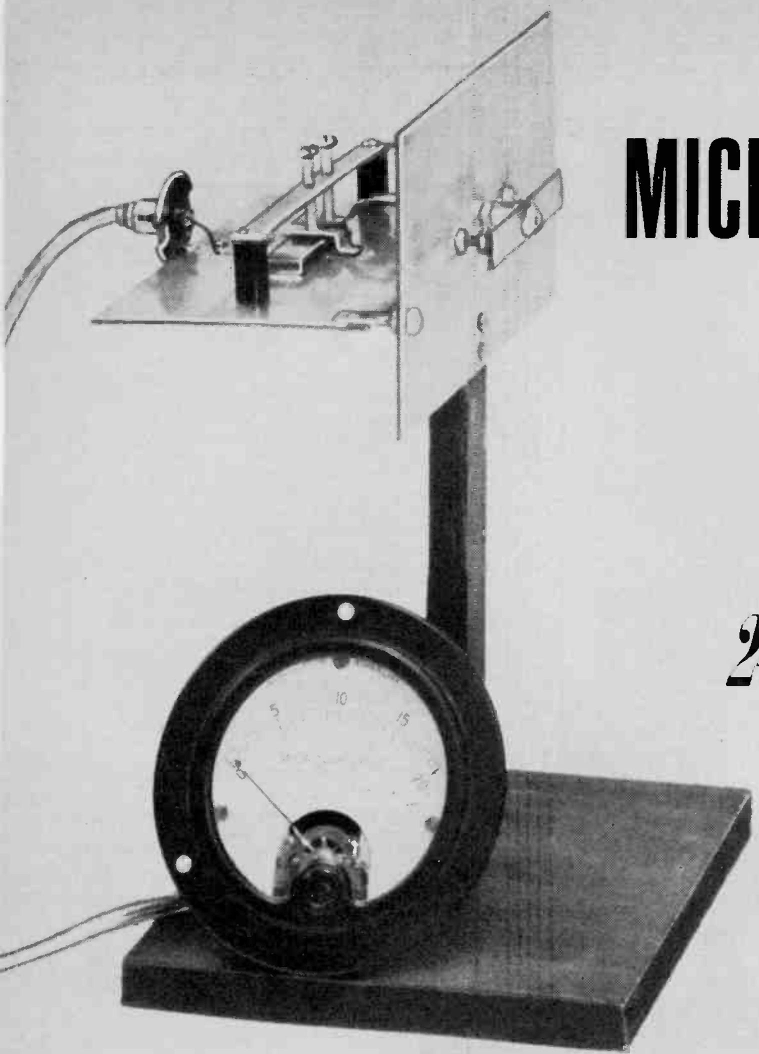
Because the converter's current drain, like its output voltage, varies linearly with respect to supply voltage (see Fig. 6), operation from a supply made up of ten D cells is not out of the question for short periods of time. A 6-volt d.c. input results in an output of 165 volts to a 20,000-ohm load, representing an 8.25-mA drain, while the converter draws about 380 mA from the supply.

The input voltage range was not chosen arbitrarily. For inputs lower than about 3 volts, the converter will not start. And

appropriately rated devices, the breakdown voltage of *Q1* and *Q2* will limit the maximum voltage applied to *BP1* and *BP2* to about 20-25 volts.

One more thing: don't let the converter's small package fool you. High voltage *does* come in small packages; and under the proper conditions can be just as dangerous. Treat high voltage with respect.

—30—



MICROWAVES FOR

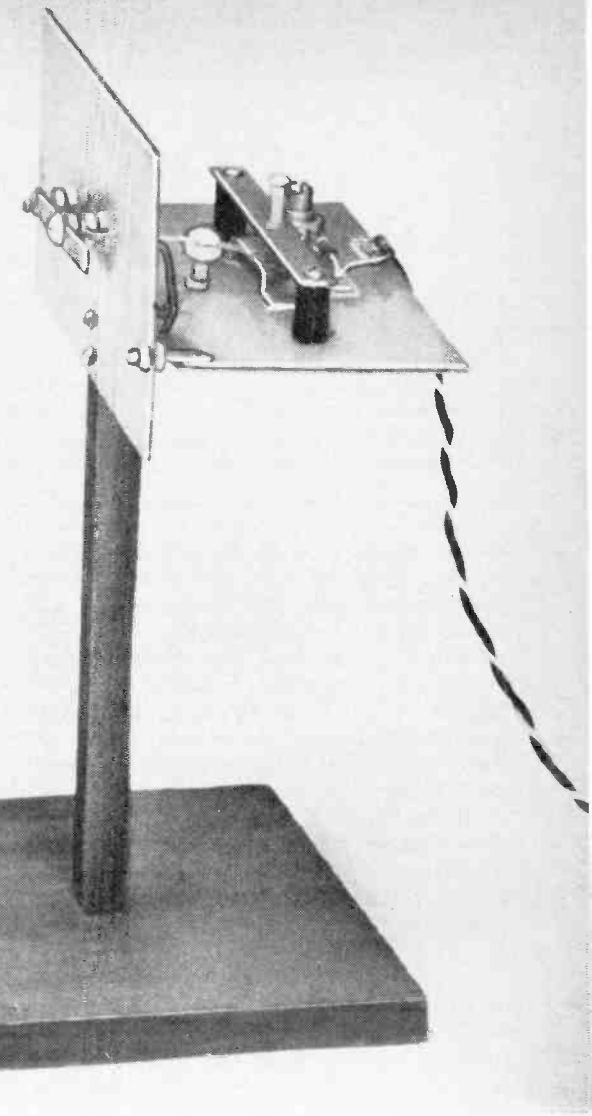
Experiments with a 2400-MHz System

AS AN ELECTRONICS hobbyist or ham operator, you have probably built or experimented with receivers and transmitters in all of the usual frequency ranges—up to the top of the 450-MHz ham band. Isn't it about time you tried microwaves? In the past, this has been difficult—special vacuum tubes or solid-state devices that operate in the microwave region were expensive and some of the metal-working (plumbing) required was difficult.

The microwave system described here —including transmitter, antenna, and receiver—can be built at a moderate cost, with a small amount of hardware work. It operates in the S band from 2300 to 2450 MHz; and although the transmitting power and range are very low, building and experimenting with this system will give you a good insight into how microwaves are generated, propagated, and detected. In principle, the system behaves just like its big brothers in telephone and TV distribution.

In most microwave work, it is customary to use a technique known as "stripline" in constructing the tuned circuit. Stripline consists of a lamination of a copper ground plane, a layer of insulation, and then a thin strip of copper to conduct the r.f. energy. Unfortunately, making stripline requires a precision layout and chemical etching, and it is

THE BEGINNER))))



BY WILLIAM F. HOISINGTON, K1CLL

not easy to tune. The construction technique used in this project results in a tuned circuit that is electrically the same as stripline but it is easier to build and tune. In this case, we use a ground plane, air and nylon for insulation, and ordinary thin copper strips for the r.f. conductors.

Transmitter. The schematic of the transmitter is shown in Fig. 1, while Figs. 2, 3, and 4 show the method of construction. The ground plane is a piece of conventional copper-clad PC board measuring about 4½″ × 3″.

The tuned circuit, *L1*, is made from a piece of thin (about 0.024″) copper 7/16″ wide × 1 9/16″ long. Bend a ⅛″ lip at each end, then make another bend 5/32″ from each lip. The ⅛″ lips are used to solder the inductor to the ground plane, so that the inductor is 1 1/16″ long and stands 5/32″ from the ground plane. Apply heat to the lips and coat the bottoms with solder. Center the inductor on the copper foil of the ground plane and tin the area under each lip. Then solder the inductor to the copper foil. Pick one side of the ground plane to be the front and the other side the rear.

Make up bypass capacitor *C1* using a thin sheet of copper or brass ½″ square. Deburr the edges, and drill a small hole in the center to accommodate a small

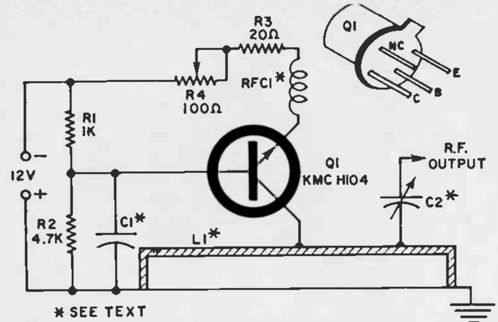


Fig. 1. The transmitter uses a special microwave transistor as a very low-power oscillator.

PARTS LIST TRANSMITTER

C1, C2—See text
L1—See text
*Q1—KMC H104 high-frequency transistor**
R1—1000-ohm, ½-watt resistor
R2—4700-ohm, ½-watt resistor
R3—20-ohm, ½-watt resistor
R4—100-ohm potentiometer
RFC1—Five turns of #30 wire, on $\frac{1}{16}$" diameter
Misc.—4½" x 3" conventional copper-clad PC board (2), thin brass sheet for C1 and C2, nylon screws and nuts (available at hobby shops), thin copper strip for L1 and antenna, metal hardware, solder, etc.

**An H104 transistor is available from Mr. Bill Ashby, Box 332, Pluckemin, NJ 07978, for $5.*

screw—either metal or nylon. Drill a similar hole through the ground plane at approximately the center of *L1* and about ⅓ of the way from the edge of *L1* to the rear edge of the ground plane. If you use a metal mounting screw, scrape away a small area of copper around the ground plane hole so that the screw will not make electrical contact with the ground plane.

Cut a piece of mica (a power transistor mounting insulator will do) or a small piece of 3-mil fiberglass slightly larger than the plate of *C1*. Mount the capacitor on the insulator and secure it in place with one edge of *C1* parallel to the length of *L1*. If you use metal mounting hardware, use an ohmmeter to make sure the capacitor plate is not making contact with the ground plane.

Using Fig. 2 as a guide, drill a hole at the rear corner of the ground plane large enough to accommodate the shaft of potentiometer *R4*. Scrape out an island in the foil near the *R4* shaft to form a terminal for the 12-volt connection, one end of *R1*, and a lead to *R4*.

To make antenna coupling capacitor *C2*, cut a piece of thin brass so that it is about 1 inch long and very narrow except for a ¼" square tab at one end. This is the capacitor plate. Glue a mica or fiberglass insulator sheet, slightly larger than the capacitor plate, to the top of *L1*, centered about ¼" from the end of *L1* (see Fig. 3). Drill a hole in the ground plane about half way between *L1* and the front of the ground plane large enough to accommodate a nylon screw. Then following Fig. 3, affix the thin end

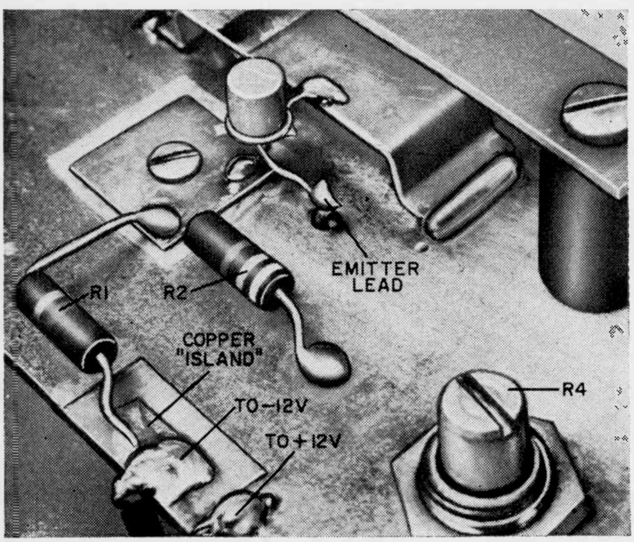


Fig. 2. The emitter of Q1 couples to RFC1 via an insulated wire fed through a hole in the PC board. Use a sharp blade to create an insulated "island" for the −12-volt feed. Don't forget the mica insulator underneath bypass capacitor C1.

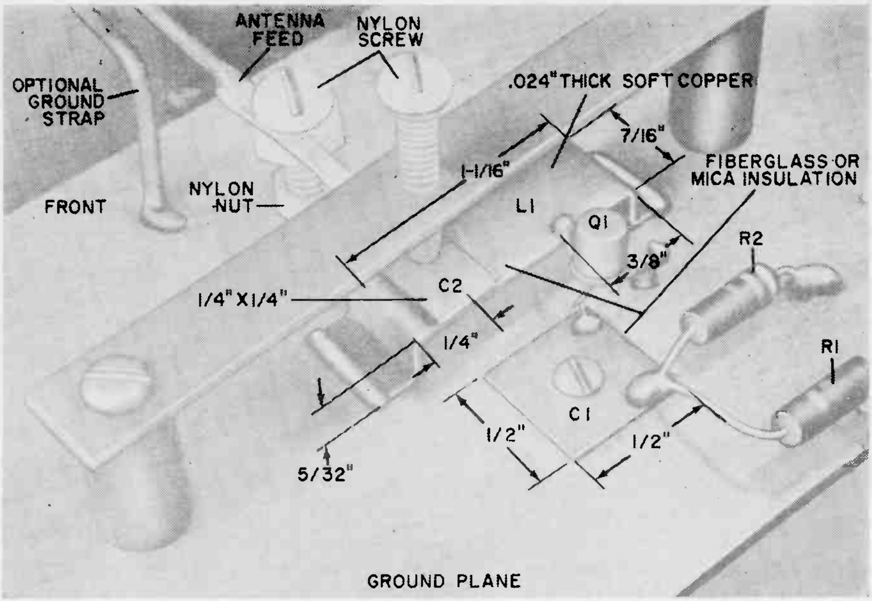


Fig.3. Mechanical construction of the transmitter. Antenna coupling capacitor C2 has its thin lead wedged between the nylon support screw head and a nylon nut. Use a piece of scrap PC board to make the tuning screw support bridge, using a metal screw to tap the C2 hole.

of the capacitor lead to this screw using a nylon nut and making sure that the plate end of the capacitor fits directly over the insulator on *L1*.

Using a piece of scrap plastic and standoff insulators, make a "bridge" over *L1* as shown in Fig. 3. Mark off a point directly over the plate of *C2* and drill a small hole in the bridge. Use a metal screw to tap the hole and insert a nylon screw (having the same pitch) in the bridge so that it touches the capacitor plate and can be used to adjust the spacing between the capacitor and *L1*.

Note where the collector of transistor *Q1* is to be soldered to *L1* as described in the next paragraph. Directly under where the emitter lead will be, drill a small hole to accommodate a length of insulated wire.

Using a heat sink on the transistor lead to protect the device from heat, solder the collector lead to a point ⅜" from the end of *L1* and the base lead to the metal bypass capacitor *C1*. Bend the emitter lead toward the hole drilled in the preceding paragraph. The fourth lead on the transistor is not used and can be cut off short. Connect *R1* and *R2* into the circuit.

On the underside of the ground plane (see Fig. 4), connect one end of *R4* to the −12-volt terminal. Connect *R3* to the other end and the rotor of *R4*. Choke *RFC1* is made by winding five turns of number 30 DSC wire around any 1/16" form. You can impregnate it with coil dope or wax to make it retain its shape. One end of *RFC1* is fed through the hole in the ground plane and soldered to the transistor emitter lead. The other end is soldered to *R3*.

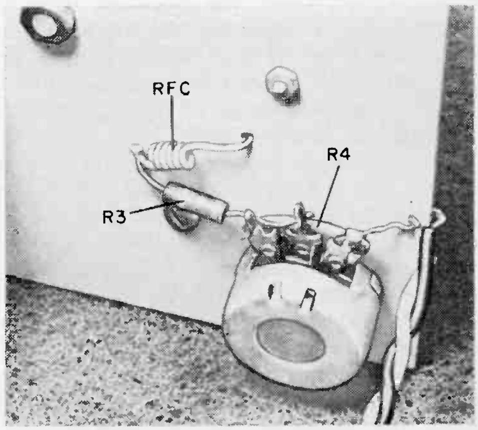


Fig. 4. Underside view of the transmitter showing the location of the RFC and R3. One end of the RFC feeds through a hole and contacts Q1 emitter.

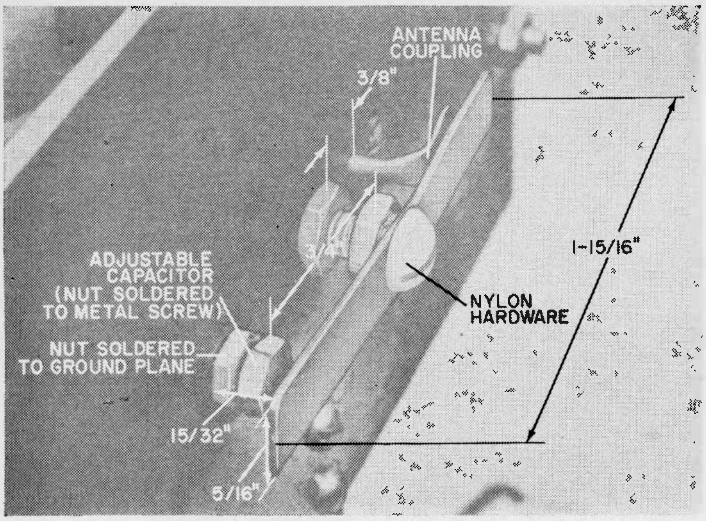


Fig. 5. The antenna coupling (from C2 on the transmitter) is made by creating a flat on one end of a piece of soft-copper bus bar. To install it, rotate the antenna by 90-degrees. After installation, the antenna coupling should be close, but not touching the antenna proper.

Antenna. The ground plane for the antenna is the same physical size as that used for the transmitter. To make the actual antenna (see Fig. 5) cut a piece of thin copper sheet 1$^{15}/_{16}$" × $^{5}/_{16}$". Drill a hole in the center of the copper and in the center of the ground plane so that the antenna can be mounted using nylon hardware.

The antenna is tuned by a small nut soldered to the end of a conventional 6-32 metal screw. Drill a hole in the ground plane ¾" from the antenna mounting screw hole and on the same center line. Solder a 6-32 nut to the copper foil of the ground plane so that it is centered on the hole just drilled. Thread a 6-32 metal screw an inch or so long into the nut from the back so that it protrudes to a maximum on the antenna side. Put a metal nut on the screw so that the nut is flush with the end of the screw. Solder the nut to the screw and file the end surface flat. This screw is now a variable capacitor, with the flat end of the nut-screw combination capable of being adjusted with respect to the antenna (when it is installed). On the other side of the antenna mounting hole, about ⅜" away and still on the antenna center line, drill a hole large enough for a piece of round copper bus bar. Trim the copper foil away from the perimeter of the hole to avoid accidental grounding when the antenna feed is installed.

Take a piece of soft-copper, round bus bar and, using a hammer, make a ¼" × ¼" flat on one end. This will be the antenna feed.

Solder a small L-bracket at each corner of the front of the transmitter ground plane. Hold the antenna ground plane at right angles to the transmitter and adjust the height so that the antenna feed hole is in line with the slim metal lead on the antenna coupling capacitor (*C2*) secured in the nylon screw.

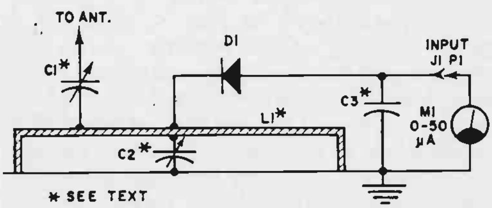


Fig. 6. Because of the very high frequencies used, a special microwave diode is used in the receiver. The diode can be inserted with either polarity to L1, as long as it matches the polarity of meter M1.

PARTS LIST
RECEIVER

C1, C2, C3—See text
*D1—PDO82Z diode**
J1—Phono jack
L1—See text
P1—Coaxial phono plug
Misc.—4½" x 3" conventional copper-clad PC board (2), thin brass sheet for C1, C2, and C3, nylon screws and nuts (available at hobby shops), thin copper strip for L1 and antenna, metal hardware, solder, etc.
**PDO82Z Schottky barrier diode is available from Parametric Industries, Inc., 742 Main St., Winchester, Mass., 01890 for $2.75.*

Attach the antenna ground plane to the L-bracket so that a continuous ground is made from the transmitter ground plane to the antenna ground plane.

Once the two ground planes are fastened, pass the antenna-feed bus bar through its hole in the antenna ground plane so that the tab is approximately 15/32" from the ground plane and bent out toward the end of the antenna. Be sure the feed line does not touch the ground plane. Cut the other end of the bus bar so that it can be soldered to the end of *C2* in the transmitter. Rotate the antenna tuning capacitor (on the antenna ground plane) so that the soldered-on nut is touching the nut on the ground plane.

Slide, or thread, the actual antenna onto an inch-long nylon screw until it touches the head of the screw and secure the antenna in place with a nylon nut. Place another nylon nut on the screw and place the screw into its hole so that the antenna is 15/32" off the ground plane (about 1/5 of a wave-length). Secure the antenna in place with a metal (or nylon) nut at the rear of the board. Position the antenna feed so that it is close to but not touching the antenna.

The antenna-transmitter combination can be mounted on a wood base. Connect a wire to the −12-volt terminal "island" and another wire for the +12-volt connection to the main foil of the transmitter ground plane.

Receiver. The schematic of the receiver is shown in Fig. 6. Inductor *L1* and bypass capacitor *C3* are fabricated just as they are for the transmitter and are shown in Fig. 7. The receiver has a tuning capacitor (*C2*) made up of a piece of thin brass sheet, 1/4" wide, bent so that a small lip can be soldered to the ground plane at the center of *L1*. Another lip on the top straddles *L1* but is separated from it by an insulator. The antenna coupling capacitor *C1* is similar to that in the transmitter. Nylon screws for adjusting *C1* and *C2* are supported in the plastic bridge over *L1*.

Diode *D1* is soldered to the center of *L1* (either polarity) and to the bypass capacitor. A phono jack with the shield pin soldered to the ground plane and the center pin connected to the bypass capacitor serves as a meter connector. The antenna for the receiver is constructed in the same manner as that for the transmitter.

A 50-microampere meter is used to measure the signal level of the rectified signal output from *D1*. The meter can be connected through a length of twin-conductor cable and a suitable plug and placed for easy viewing.

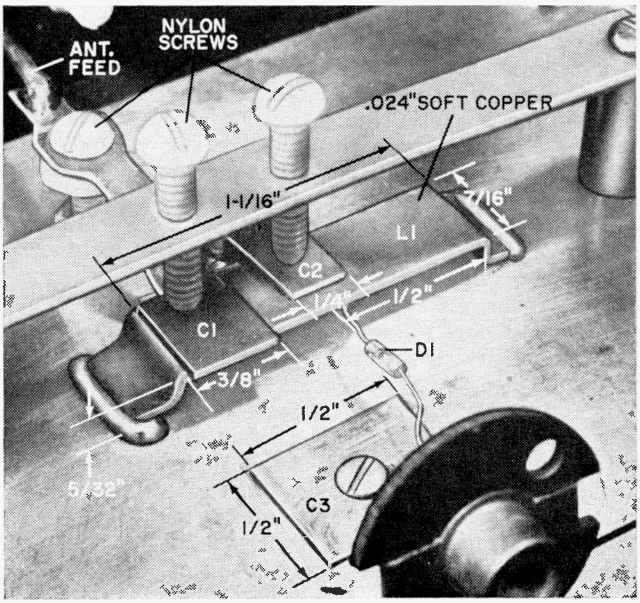


Fig. 7. Construction details of receiver. Strapline L1 is the same as used in the transmitter. Be sure to install mica insulators under capacitors C1, C2, and C3. Receiver uses the same antenna construction as that used with the transmitter.

HOW IT WORKS
TRANSMITTER

In the tuned circuit, the r.f. is bypassed by capacitor *C1* and bias is determined by the network of *R1* and *R2*. The base of *Q1* is 180° out of phase with the oscillator collector r.f. voltage. This is the necessary condition for oscillation. The emitter of Q1 is r.f. decoupled from the power supply by *RFC1* and the transistor current is determined by the setting of potentiometer *R4*. There is an internal in-phase feedback from collector to emitter.

The tuned circuit, *L1*, is a half-wave line grounded at both ends. At one instant, the center of *L1* (collector connection) goes r.f. positive, while the base and the ground plane are negative. One half-cycle later, the polarities of both points are reversed. If the Q (figure of merit of *L1* and the circuit as a whole is sufficiently high, the circuit will oscillate at a frequency determined by the physical dimensions and distance from the ground plane of *L1*.

The amateur band of 2300 to 2450 MHz has been picked for this experimental microwave oscillator because that region is approved for experimental amateur purposes. Changing the dimensions of *L1* and its proximity to the ground plane permits tuning the transmitter to any frequency within the band.

Increasing the emitter current by varying *R4* increases the transmitter output power. Resistor *R3* is a safety resistor which prevents *Q1* from burning up from too much current. Trimmer capacitor *C2* couples the r.f. output to the antenna.

Operation. To tune the receiver to the transmitter, place the two units a short distance apart on the workbench, with the antennas facing each other. Supply power to the transmitter from a 12-volt d.c. source being careful to observe the correct polarity. Set *R4* between half and ¾ resistance. The receiver meter may or may not show an indication of output. Gently adjust *C2* on the receiver, looking for a meter indication. Tuning may be sharp, so be careful. If the two units are close together in frequency, the meter should show a signal somewhere in the course of tuning *C2*.

Once a signal is detected, adjust the transmitter antenna coupling capacitor *C2*, the transmitter antenna tuning capacitor and potentiometer *R4* for maximum signal. With the transmitter rough tuned, adjust the receiver antenna coupling capacitor *C1* and the receiver antenna tuning capacitor for maximum signal. Once these have all been adjusted for a maximum signal, trim the transmitter and receiver coupling tabs for maximum signal and recheck all variable adjustments. As the received signal strength increases, it may be necessary to separate the two devices by a couple of feet more.

Frequency Measurement. Once the microwave system is operating, a frequency check must be made to make sure that it is operating within the 2300-2450-MHz band. The approach (see Fig. 8) is called "interferometry" and was first used over a century ago to measure the frequency of light waves. (Heinrich Hertz used it in 1887 to measure the first electromagnetic waves ever generated.)

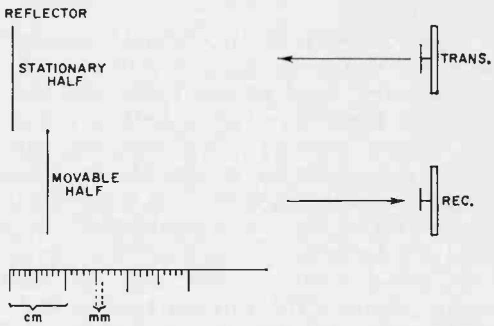


Fig. 8. Basic interferometer is used to measure frequency. As the movable half of the reflector is brought closer to the antennas, a series of "nulls" will be seen on the receiver meter. You measure the distance between nulls to determine frequency.

Place the transmitter and receiver side by side so that their antennas are facing in the same direction. Place a ruler calibrated either in inches or centimeters at 90 degrees to the plane of the antennas and about 2 feet in front of them.

Make two flat metal reflectors (several inches on a side) and place them in front

HOW IT WORKS
RECEIVER

The tuned circuit of the receiver is similar to that of the transmitter. Trimmer capacitor *C1* couples the antenna to the tuned circuit. The rest of the circuit is a conventional crystal detector with a microammeter as the readout. Because of the very high frequencies involved, a Schottky-barrier diode must be used. Unlike conventional diodes, this device is especially made to operate efficiently at microwave frequencies. Capacitor *C3* is an r.f. bypass for the meter.

of the two antennas at the zero mark of the ruler. The butting edges of the two reflectors should be approximately centered between the transmitter and receiver antennas. Make one of the antennas fixed; leave the other movable. Turn on the power at the transmitter and observe that the receiver readout indicates upscale. This proves that r.f. energy radiates from the transmitter, hits, and is reflected back from, the metal sheets, and produces a reading on the receiver.

Slowly slide the movable reflector toward the antennas. You will soon reach a point where the received power drops to a null and then rises again. This is the half-wave point where half of the transmitted r.f. is being supplied to the receiver out of phase with the signal from the fixed reflector. Carefully note and record the position of the movable reflector as indicated by the ruler. Keep sliding the movable reflector in toward the antennas, recording the exact points where nulls occur.

Calculate the centimeters or inches difference between each ruler indicated, add them up and divide by the number of nulls measured. This will give the average half wavelength. Double the value to obtain the full wavelength.

For the band being used here, full wavelength for 2300 MHz is 13.04 cm or 5.13 in.; and for 2450 MHz, 12.24 cm or 4.81 in. If your wavelength is not within these limits, bend tuning inductor *L1* to change the frequency. Retune the receiver to the transmitter either with *C2* (if the frequency difference is not too great) or by bending *L1* in the receiver.

Microwave Experiments. Once your microwave system is operating on frequency, you can experiment with various types of antennas and reflectors. For instance, with the transmitter and receiver facing each other a couple of feet apart, note that placing a metal sheet above the transmission path will greatly boost the signal. This is similar to the way the ionosphere reflects low-frequency r.f. signals.

Placing a pair of metal sheets near either antenna so that the antenna is at the apex of a right angle also boosts the signal. This is a basic horn antenna. It can be used at either the transmitter or the receiver, or both. The signal strength can be vastly increased by various antenna configurations, even though the transmitter power remains unchanged.

To demonstrate this further, make a dipole as shown in Fig. 9. Connect the center feed to the thin coaxial cable to the transmitter antenna coupling capacitor *C2* and the shield to the ground plane. Disconnect the regular antenna. Now you can add directors and/or reflectors to the basic dipole to experiment with beam arrays. A couple of things will become apparent as you experiment: First, as gain goes up, directivity increases; second, to double the range (distance), you must have four times the power. The latter can be proved by using the potentiometer on the transmitter to vary the power. A milliammeter can be inserted in the 12-volt line to measure the transistor current.

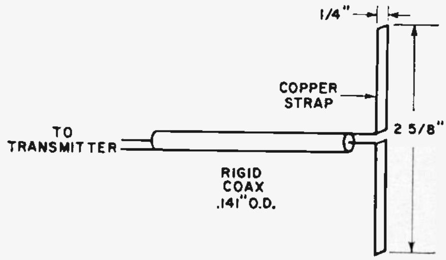
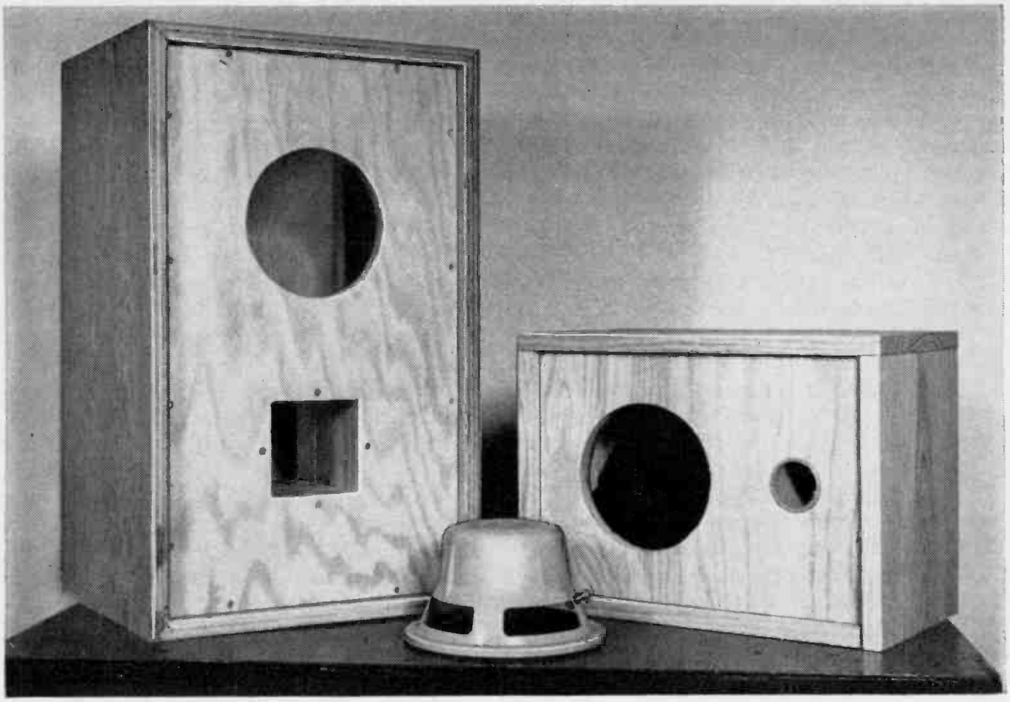


Fig. 9. This simple dipole can be used to perform experiments with various antenna arrays. These can include beams, horns, or parabolic systems. Remove the old antenna and ground plane and install this.

In experimenting with various horns and arrays, remember that, to get about 20 dB of gain, the antenna aperture should be at least six wavelengths square (or 36 square wavelengths) at the aperture.

The transmitter can be audio modulated by conventional techniques and such a system makes a very interesting Science Fair project. Microwave signals can be "bounced" around corners and over other intervening objects, by means of simple metal reflectors. When a hand is placed in the beam path, the signal level changes, showing that the microwave r.f. is actually carrying the signal. -30-



Rally Round the Reflex

BY DAVID B. WEEMS

Proper enclosure tuning gives maximum enjoyment

MAN YOUR sabre saws, reflex partisans, and look to your ports; the much maligned bass reflex is again under attack! Let's start a campaign to take the boom out of the boom box and preserve it from extinction. The hi-fi system you save may be your own!

Few people will argue that the idealized bass reflex enclosure is so efficient that you can readily obtain ear-shattering sound from only a few watts of audio power. The "boominess" of the home-made bass reflex results from either the lack of know-how or the inability to tune the enclosure properly.[1] Any solution to the boominess and size problems will depend upon whether you want to emphasize transient response or clean low-frequency reproduction and bass efficiency.

All enclosure designers must make a compromise at some point or another in building a bass reflex. Presumably each manufacturer makes the decision which best complements his loudspeakers, but he may have been influenced by what he believes most customers want. If you prefer the satisfaction of doing the job yourself or just want "something differ-

1. The author attempted to answer these questions in his article, "Tune Up Your Bass Reflex," 1969 Spring ELECTRONIC EXPERIMENTER'S HANDBOOK. *Unfortunately, while answering one question he emphasized the puzzling problem of how big to make the enclosure. (Editor)* ent," here are some guides to help you. Anyone can use the chart design method, but those with test equipment will want to apply the impedance checks. For easy tuning we shall stick to enclosures with ordinary ports which can readily be adjusted after completion.

Reflex Working Principles. In order to consider enclosure size and other questions, let's take a quick look at how the ported enclosure works. A speaker in a closed box acts like a piston, compressing the air in the box as the cone moves in, lessening the pressure in the box as the cone moves out. Add a port to the box so the pressure can be relieved and you have an adaptation of a Helmholtz resonator. The term "resonator" indicates that the air in the box is resonant at a certain natural frequency. The frequency of the resonance is determined by the enclosed volume of air and the size of the port.

You might think of the air in the box as a large spring, compressing and expanding, with a piston at each end. One piston is the air in the port, and the other piston is, of course, your speaker. At resonance, both pistons act to compress the spring at once, another way of saying that the two pistons are in phase.

What effect does this have on the speaker? A speaker cone in free air, or in a closed box, vibrates at increasing amplitude as the signal goes down in frequency (below 200 Hz) with the exception of the resonant point where there is a peak in amplitude. Because of this, speakers used in small sealed enclosures are designed with long-throw voice coils so that the voice coil can move over a comparatively large distance and still remain in the region of uniform magnetic field. Such speakers are relatively inefficient.

Speakers designed for large ported enclosures are high in efficiency. When one of these speakers is mounted in a ported box, and the system is working at resonance, the air in the enclosure (being under compression when the speaker moves in and at a partial vacuum while the speaker cone is moving out) acts on the cone in opposition to its movement. This damping reduces cone

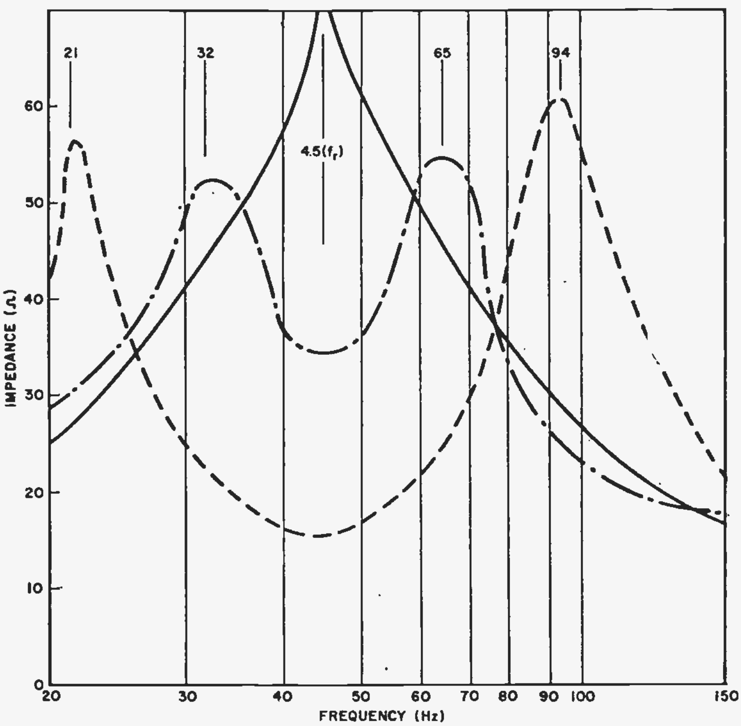


Fig. 1. Graph at left shows speaker's free air impedance (solid line), impedance in 1300 cu in. tuned enclosure (short dashed line), and impedance in 8600 cu in. tuned enclosure (long and short dashed line).

travel at resonance, resulting in significantly lower distortion at low frequencies. And the sound output is augmented by the supplementary "piston"—the air in the port. In a properly designed system, port radiation is at a maximum in the frequency range where it is most needed to compensate for natural bass loss.

Enclosure Size. Your choice between moderate, large, or colossal enclosure size may depend on whether you want to emphasize low frequency reproduction, transient response, or peace in the family. The design chart, Table I, shows that the volume determines the tuning frequency for a given size port. Or stated differently, the larger the enclosure, the larger the port for a given frequency. And the larger the port, the greater the radiation from the port—up to a certain point. Beyond that, as the port becomes larger, the enclosure is changed from a box with a hole in it to a box with one side missing and the air behind the speaker ceases to act on the speaker. A useful rule of thumb is to set the upper limit of port size equal to the effective cone area of the speaker. In other words, the box should be no larger than that which allows you to tune the enclosure at the desired frequency with such a port.

Even this may be too large for optimum performance, particularly if you like "tight" bass. The goal then is to choose an enclosure volume that is large enough to yield a port area that is sufficient to be effective without ringing or sounding "mushy."

At the other end of the size range, a ported enclosure that is too small has several undesirable characteristics. Small enclosures demand small ports, and a tiny port may produce more whistling noises than bass notes. Similarly, avoid a slit port unless you are using several of them as an acoustical resistance. If you find that the correct port area for a given situation is only a few square inches, use a duct instead of a simple port.

Another disadvantage of the too small box is the greater tendency to boom. And the low bass notes are cut off. Even ducts can't alleviate these faults satisfactorily.

If you have no audio test equipment, you must resort to design charts. One rule of thumb is to look at the chart and choose an enclosure volume that will require a port area from 30 to 100% of the effective cone area of your speaker for proper tuning (more about this later). The range in square inches is:

Rated Speaker Diameter (in.)	Port Area (sq. in.)
8	9 to 28
10	15 to 50
12	24 to 78
15	40 to 133

You can choose your enclosure volume within the limits determined by the port areas given above in relation to the space you have available.

Here is an example. You have an 8-inch speaker that requires an enclosure tuned to 45 Hz. From Table I you see that the largest recommended enclosure volume is 6 cu. ft., requiring a port area of 28 sq. in. The smallest recommended volume is 3.5 cu. ft. with a port of 11 sq. in. Note that these values are given for simple ports; ducts must be used for smaller enclosures.

TABLE I—DESIGN CHART FOR ENCLOSURES WITH SIMPLE PORTS

VOLUME (cu ft)	PORT AREA (sq in.)				
	PORT FREQUENCY (Hz)				
	35	40	45	50	60
12	38	52	90	130	**
11	34	48	84	120	**
10	30	40	64	90	**
9	26	36	56	80	**
8	24	30	50	74	145
7	18	24	36	50	110
6	12	18	28	36	75
5	9	14	20	30	50
4	*	10	15	20	36
3½	*	*	11	16	28
3	*	*	8	12	22
2½	*	*	*	8	16

The figures given are approximately correct for simple square or circular ports. For rectangular ports (length:width ratio = 4:1) the port should be reduced in area to about 75% of that shown here.
**Use ducts.*
***Close port.*

To choose the best enclosure volume for your speaker system, you should use every aid available, including all the information supplied by the manufacturer. With test equipment you can also run an impedance curve for the speaker.

Use of Impedance Curves. The impedance of a speaker is usually rated at 4, 8, or 16 ohms at X Hz. Because the impedance of a voice coil is made up of its d.c. resistance plus both capacitive and inductive reactances, which change with frequency, it varies widely over the audible spectrum.

Figure 1 is a typical graph of impedance vs frequency to show something of the effects of an enclosure on a speaker. A speaker operating in free air has a single low-frequency peak in its impedance curve. The peak occurs at the fundamental resonance point. Put the speaker in a closed box and the peak is still there, but now it's higher in frequency. Port the box and there will be two peaks with the valley between them located at the frequency to which the system is tuned, usually at the free air resonance of the speaker.

Don't try to equate impedance curves with frequency response. As James F. Novak, Senior Design Engineer for Jensen, says, "Any amplifier of reasonably high quality has a damping factor good enough to make it a constant voltage source. With this type of amplifier, the speaker/enclosure response is independent of the impedance variations. If the amplifier were constant current, the response would follow the impedance curve."

Nevertheless, the impedance curve does provide useful information. As mentioned earlier, it tells you to what frequency your system is tuned. And it tells you the frequency of the upper peak, the greatest danger zone for boom in ported enclosures. If this peak occurs above 100 Hz, into the male voice range, announcers and some singers may sound as if their microphones were located in the bottom of a barrel.

The impedance curves shown in Fig. 1 demonstrate the effect of enclosure size on impedance. These curves are for a good quality 8-inch speaker in two enclosures (the smallest and largest recommended sizes), each tuned to 45 Hz, the free-air resonance of the speaker.

It is evident that the small enclosure has the greater effect on the impedance of the speaker. Stated differently, the smaller enclosure is more closely "coupled" to the speaker. The speaker impedance is much lower at resonance in the small enclosure than in the larger enclosure. This indicates that the smaller enclosure is doing more effectively what a tuned enclosure should do—control the cone movement at resonance. But it is impossible to say, just looking at the impedance curves at resonance, what enclosure volume is optimum.

However, you can get some idea of the frequency response range of the two enclosures. The bass output from ported enclosures cuts off at some point below the frequency of the upper impedance peak. Looking again at the curves, you will see that the small enclosure will cut off somewhere below 94 Hz. But the larger enclosure will cut off somewhere below 65 Hz. This difference would be noticeable, particularly in the reproduction of musical tones of large instruments.

Another difference in the impedance curves produced by the large and small enclosures is the frequency span between the impedance peaks. Note that the twin peaks of the large enclosure are much closer together in frequency than the peaks of the smaller enclosure. A useful term of reference in measuring this span is to divide the frequency of the upper peak by the frequency of the lower peak. The quotient is then simply the ratio of the upper frequency peak to the lower frequency peak, a convenient small number. For the enclosures referred to in Fig. 1, the ratio is 2 (65/32) for the larger enclosure and 4 (94/21) for the smaller enclosure. The larger the enclosure, the closer together will be the twin peaks and the lower the ratio.

The ratio should fall within certain limits for enclosures of proper volume. For conventional loudspeakers of the 1950's, the limits were between 1.5 and 2.4.[2] These low values would result in extremely large enclosures by today's standards. One reason for larger enclosures in those days was that many high-fidelity loudspeakers then had a resonant frequency of about 60 to 70 Hz. It was necessary to use a large enclosure so that the upper peak would be below 100 Hz. For today's low-resonance speakers a more reasonable range might be from about 2 to 3.

2. *F. Langford Smith*, Radiotron Designer's Handbook, *4th ed.; Radio Corp. of America, 1953, p. 847.*

James F. Novak has suggested the precise ratio of 3.13 which he says produces optimum transient response. It yields rather compact enclosures except in the case of very-high-compliance, low-resonance speakers. For the latter, simple rules of thumb do not apply, and some reduction of interior volume will give excellent results with ducted ports even when the peak:peak ratio is somewhat greater than 3.13.

You can use this ratio as a rough guide to estimate whether your enclosure is at the large or small end of the scale for your particular speaker. Listening tests conducted with three enclosures of various sizes with peak:peak ratios ranging from 4 to about 2 indicated that the average listener preferred a ratio of 2 (the largest enclosure) by a wide margin. Several listeners greeted the sound with the peak:peak ratio of 4 with sarcastic comments.

Unfortunately, it is difficult to predict in advance what the ratio will be for a particular speaker/box combination. Novak has described a useful method of estimating the preferred values for his optimum volume enclosures (with a peak:peak ratio of 3.13) by measuring the free-air resonance of a speaker and then measuring its resonance in a "standard" box.[3]

If you test your present enclosure and find that it is too small or too large by these standards, there are possible cures without major surgery. For the small box, a collar of damping material, such as fiberglass, over the speaker will often help. And for the rare large system that has too much port output, a cloth stretched tightly across the port will usually be sufficient.

If you are designing an enclosure, you should consider its shape as well as its volume because the shape will have some effect on frequency response and impedance. Try to avoid extreme shapes, such as a cube or a pipe. A good general rule is to make each inside dimension slightly different, but limit the longest inside measurement to less than 3 times as great as the shortest. Some manufacturers select precise ratios for these dimensions. For example, John Gilliom at Electro-Voice states that the optimum dimension ratio is 1: 1.44: 2.08 (see Fig. 2). In other words, a typical bookshelf enclosure might have an inside depth of 1 ft., an inside height of 1.44 ft. (about 17¼"), and a length of 2.08 ft. (about 25"). Or the 5 cu ft "universal" enclosure shown in Fig. 3 would have approximate inside dimensions as follows: A 30"; B 21"; C 14½".

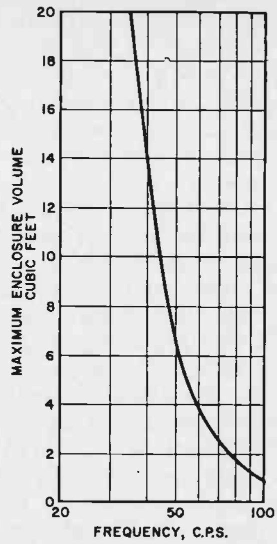


Fig. 2. Graph shows maximum volume vs. frequency for a Helmholz resonator in the shape of a rectangular box with the dimensions in the ratio of 1:1.44:2.08.

Tuning the Ported Enclosure. Tuning an enclosure to a specific frequency is not very difficult (see EXPERIMENTER'S HANDBOOK, Spring '69, for an easy method), but choosing the frequency may not be so simple. The traditional goal, almost universal in articles and books about ported enclosures, is to tune the box to the free-air resonant frequency of the loudspeaker. Theoretically, the tendency of the speaker cone to undergo excessive movement at resonance would be controlled by the resistive action of the air in the box as described earlier. Although the practice is still followed by some companies, there are certain situations in which poor bass is the result.

For example, in Table II, the University models 312 and 315C have claimed resonances of 16 and 17 Hz, respectively, and yet are suggested as usable in en-

3. *James F. Novak, "Designing a Ducted Port Bass Reflex Enclosure,"* Electronics World, *January 1966.*

closures that are tuned to 50 Hz. The tuning to 50 Hz was probably the principal decision in the design of these enclosures. The University enclosures listed are the correct size to permit the system to be tuned to 50 Hz with a port area equal to effective cone area. But why 50 Hz? Hugh Morgan, Consultant for Research and Development at University Sound, tells us what would happen if such a system were tuned to the speaker's free-air resonance:

> "Since reflex operation enhances response only 2-3 octaves above resonance, the resultant curve would peak at resonance and then sag badly in the important 70-150-Hz area, above which the main cone output would begin to 'catch up' to the combined speaker-port resonance area output. Musically, this would be a rather un-listenable system. It would appear to have poor bass. This is characteristic of very low-resonance speakers when classically reflexed."

Note that in the design of the reflex enclosures recommended by Hugh Morgan, the old objective of controlling the cone at resonance was secondary to obtaining uniform low frequency response in the musically important ranges. In other words, the output from the port is placed at those frequencies which are most needed to complement the response of a particular loudspeaker. To choose the port tuning on such a basis, the designer should have access to response curves of the loudspeaker.

Another reason for challenging the practice of tuning every enclosure to the free-air resonance of the speaker is given by T. W. Richardson of the James B. Lansing Technical Service Department:

> "For one thing, the resonance changes as soon as the speaker is put into a box. And it is this system resonance that determines where a port should be tuned for maximum bass radiation."

Richardson also mentions that you should know the kind of response your speaker has before deciding where to put the port frequency. He also says that it may be desirable to tune for other purposes than maximum bass radiation.

> "For example, in most JBL bookshelf systems, the port is tuned considerably below the closed-box frequency. In these models we are primarily interested in reducing distortion and limiting cone travel at very low frequencies rather than trying to get maximum bass efficiency."

The Next Step. What course should the builder of speaker enclosures at home follow? Obviously, where they are applicable, he should follow the instructions of the manufacturer. But, if you want to produce an enclosure of unusual size or one that is in any way different from the manufacturer's recommendations, you can improvise and yet be consistent with his practice. First, estimate the tuning frequency of the manufacturer's recommended enclosure by reference to a published chart. Then tune your new enclosure to the same frequency. The results should be on the target—if not right in the bull's-eye.

Of course, these instructions are of no help if you are the owner of a nameless speaker or one that is supplied without enclosure information. Or if you have no test equipment. For you, T. W. Richardson has some advice:

> "If I were a home constructor, building an enclosure for an "orphan" loudspeaker, I would tune the port to about 50 Hz, period! If I had no equipment to

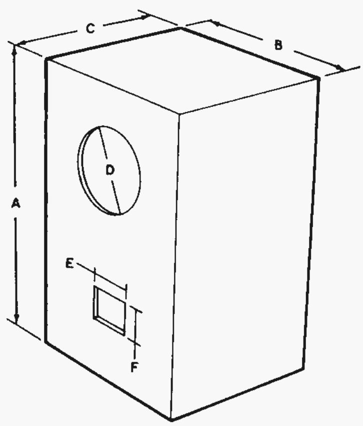


Fig. 3. "Universal" enclosure recommended by T. W. Richardson for "orphan" loudspeakers. Tune enclosure to 40 Hz. Use 3/4" plywood, well braced, and glued and screwed together with glue blocks inside the corners. Volume should be at least 5 cu. ft. Typical values for A, B, and C would be 30", 21", and 14.5" respectively. If tuning equipment is not available, try 4 in. for E and 3½ in. for F.

TABLE II—BASS REFLEX ENCLOSURES FOR POPULAR LOUDSPEAKERS

MANUFACTURER AND MODEL	OPTIMUM VOLUME (cu ft)	TUNING SPECIFICATIONS	RECOMMENDED DAMPING MATERIAL	COMMENTS
Altec Lansing				
All models	Not specified	See comments		Enclosures tuned to free-air resonance of speakers. Complete instructions given in "Speaker Enclosures: Their Design and Use," Altec Lansing, 1515 S. Manchester Ave., Anaheim, Calif. 92803. Price $1.00.
James B. Lansing				
LE8T/PR8	2	Use PR8 passive radiator	Acoustical fiberglass, Kimsul, Tufflex, or felt rug padding.	These values were chosen as "best compromise" between space requirements and optimum-performance larger enclosure. Note: 2 cu ft is maximum for LE8T with PR8. Minimum volumes are: LE8T—0.75; LE12C—2.2; and D130—2.5 cu ft. Information on enclosures of all sizes recommended is given in publication CF802, "Loudspeaker Enclosure Construction Manual," a very useful booklet for use with any PBL speaker. Order from James B. Lansing Sound, Inc., 3249 Casitas Ave., Los Angeles, Calif. 90039. Price 50¢.
LE8T	3 to 5	13 sq in., 3" tunnel 15 sq in., 3" tunnel		
LE12C	4 to 6	15 sq in., 6" tunnel 20 sq in., 5" tunnel		
D130	4.5 to 6	25 sq in. 35 sq in.		
Jensen				
SG80	1 (1775 cu in.)	3" I.D. x 4" long duct	Fiberglass	Enclosures tuned to free-air resonance of speakers. Volume is selected for optimum transient response rather than lowest bass cutoff or maximum output. Information for enclosure construction is packed with each Jensen speaker.
DL220	4 (6940 cu in.)	3" I.D. x 5" long duct		
SG223	8.3 (14,400 cu in.)	4¾" I.D. x 5½" long duct		
University				
Diffusicone 8	8	28 sq in.	Tufflex for lining. Spun glass wool as air space damper.	Models 312 and 315C are not designed for "classical" reflex operation, but enclosures here would give good performance, arbitrarily tuned at 50 Hz (see text). Avoid narrow slot shapes for these ports. Information for smaller enclosures packed with these and other University speakers.
312	10	78 sq in.		
315C	17	133 sq in.		

check port resonance, I would use a published enclosure design—one as large as possible—with preferably 5 cubic feet or more of internal volume."

G. A. Briggs, the English authority, says:

"If the user has no technical equipment for checking resonances and resonance frequencies, I think the best plan would be to have a vent with a sliding panel so the area could be adjusted to the best position on a listening test.

"If we are dealing with small enclosures—about 1 cubic foot—my own preference is for the slotted back, which helps to cut down resonances. And I would prefer a smooth response to resonant peaks which some people like to have as bass improvement."

Mr. Briggs's compact is detailed in Fig. 4, and a "full-size" enclosure such as that recommended by Mr. Richardson is shown in Fig. 3. Listening tests on several speakers in a box tuned to 40 Hz indicated very satisfactory results. In some cases, it appeared to be desirable to tune the enclosure to a slightly high frequency—45 or 50 Hz. To allow for this possibility and follow Mr. Briggs's suggestion of a sliding panel, you might enlarge the port of the enclosure in Fig. 3 to E = 7" and F = 4½". Then install a sliding panel or temporarily screw a panel to the baffle to vary the port size.

The best results in most cases will occur when the area of the port is between 14 and 25 sq in. Note that, if we follow the rule of thumb given earlier to determine enclosure size by port area (port area equal to at least 30% of the effective cone area), this enclosure is as suggested by Mr. Richardson, at the low limits for 12" speakers. Of course, even smaller enclosures may be tuned to 40-50 Hz by means of a duct behind the port.

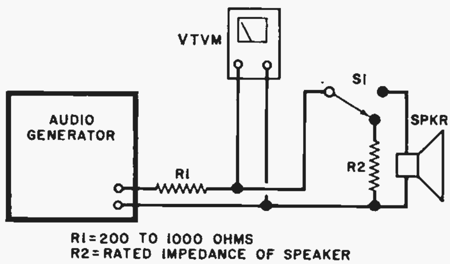
Damping Material. Another decision that the enclosure builder must make is: what kind and how much padding should be used. Here's what the experts say about the kind:

Novak: "The advantage of fiberglass is its ready availability and the fact that it is obtainable in many densities. The acoustic resistance is a function of density.

"Any material consisting of loosely packed or woven fibers will probably work well. The properties of fiberglass have been thoroughly documented and it is, therefore, the material that is most often used."

Richardson: "Almost anything that is absorbent to sound and not too bulky or flaky *can* be used to line loudspeaker enclosures. This includes acoustical fiberglass, Kimsul, Tufflex, felt, rug padding, old blankets, cotton waste, and what-have-you. However, best results will be obtained with the first three items."

Morgan: "We have found Tufflex to perform very well as lining material and spun glass wool to be effective as an air-space damper and volumetric expander."



HOW TO RUN AN IMPEDANCE CURVE.

To run and plot an impedance curve, follow the test hook-up shown in the diagram. Assuming you have an 8-ohm speaker, in which case *R2* should equal 8 ohms, the procedure is as follows.

1. Set the audio generator frequency to 200 Hz.
2. With the switch turned to *R2*, adjust the generator output so that the VTVM (or other a.c. voltmeter) has a reading of 8 or 80 units (for example 80 millivolts). The exact value isn't important, but choose a reading that is about half the meter scale allowing enough switchable range above it for the meter to record the peaks.
3. Switch *S1* from the resistor to the speaker.
4. Maintain constant output and sweep the generator down the scale from 200 to 20 Hz, stopping at the following frequencies to take readings: 200, 175, 150, 125, 100, 90, 80, 70, 60, 50, 40, 30, 20.
5. Repeat the sweep and watch for peaks. Record the frequency and reading for each peak or valley. For example: you may have recorded a reading of 40 at 80 Hz and also at 70 Hz. But on the rerun you note that there is a peak of 50 at 75 Hz. Since the exact position of the peak is of some import, it should be recorded.

Note that although your readings are a.c. voltage readings, you may consider them to be impedance values in ohms.

Mr. Morgan points out that different systems may use padding for different purposes and says that the characteristics of the padding should match the purpose.

As to how much padding to use: the usual purpose of padding is to act as a boundary reflection damper and common practice (as recommended by JBL) is to line a minimum of 50% of the inside walls of the enclosure. T. W. Richardson says:

> "The only function of this padding is to absorb some of the mid-range energy that otherwise might be reflected back through the cone or out through the port opening and introduce unwanted peaks. With 50% lining, you have a padded side facing an unpadded side.
>
> "For example, line the top, back, and side. Once you start using more damping material than that, the mid-range will begin to sound less 'live.' The exact location and amount of padding are not overly critical unless you are a perfectionist."

Some experimenters, utilizing "stuffing" as an air-space damper, have recommended filling a bass reflex enclosure with damping material. Novak, while admitting that the practice smooths the impedance curve, reduces phase shift and improves loading, questions it because it absorbs power. He does recommend acoustic resistance to cure hangover by means of a fiberglass collar over the speaker. Richardson says that hangover almost always occurs at the frequency of the upper impedance peak and points out that damping the port itself will not help this particular problem but only reduces the advantages of the ported enclosure. Morgan is skeptical of the practice for home experimenters, on the theory that overdamping might result from too much stuffing.

If, against the advice of the experts, you want to try "stuffing" on a pure trial and error basis, you should try to compare your system with one that is identical but not stuffed. For example, if you are building a stereo pair, stuff one and use normal padding in the other. Then compare the two using a monaural or combined stereo program in first one and then the other. Too much stuffing will produce a choked effect in the bass.

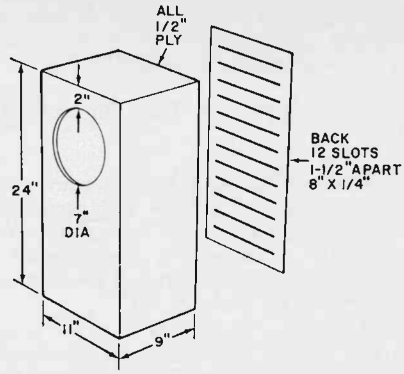


Fig. 4. Compact (1 cu ft) enclosure for 8" speakers has all sides lined with 1" absorbent material. Back is lined with soft cloth. Slots may be made by cutting strips of ½" plywood to proper width and mounting them on a frame width ½" spacing. Or cut a row of 10 holes ½" in diameter to give about the same area as the 8" x ¼" slot.

Sound Is the Thing. No matter how you solve your speaker enclosure problems, there are a few points worth remembering. First, choose the kind of speaker system you want by listening, not by recommendation or from theory. Specifications may be helpful to the design engineer as guidelines, but they won't tell you what will sound good to your ears. As T. W. Richardson says, "*Any* specifications are *not* better than no specifications. What one is purchasing is sound."

Second, don't forget to ask for help from the company that built your speaker. Some companies have useful booklets available for a nominal cost (see Table II), and almost all furnish some kind of information with the speaker. But if, without test equipment, you apply Company A's methods to Company B's speaker, the results may be unpredictable. In fact, you should not even assume that Company A's plans for any one of its 12" speakers are applicable to another of its 12" speakers—unless they say so.

Finally, if you have already built a set of ported speaker enclosures and have broken the rules but like the sound, or if you pushed in some extra stuffing because you thought that made it smoother, don't feel too guilty about it. As G. A. Briggs says, "After all, loudspeakers are made to listen to and not just to conform to theory." And, having made some of the best, he ought to know. —30—

BUILD THE Time Out

TURNS OFF CAR LIGHTS WHEN YOU'RE SAFELY INSIDE

BY JOHN STAYTON

THERE ARE FEW things more aggravating to the motorist than pulling into the driveway at night and having to stumble around in the dark driveway to find the key for the garage or front door. Not only is it inconvenient; it's unsafe if there is snow on the ground, or roller skates or bicycles lying around.

Wouldn't it be helpful if you could leave the headlights on for a while after getting out and not have to go back to turn them off? With a "Time Out" you can do just that. When you have this device installed in your car, the headlights stay on after the ignition is turned off and then go off automatically after a predetermined period of time—from a few seconds to a couple of minutes. If you always park in well-lighted areas at night, the Time Out comes in handy should you forget to turn off your lights.

The Time Out is easily constructed using readily obtainable parts and it is easy to install in your car.

Construction. There is nothing critical about the circuitry of the Time Out (see Fig. 1) and any method of construction may be used. A printed circuit board like the one used in the prototype helps to produce a sturdy compact unit and may be duplicated using Fig. 2 as a guide. When installing the semiconductors be sure you observe the proper polarities and heat sink their leads while soldering.

In the prototype, the circuit board and relay are housed in a 3¾" × 3" × 2⅛" metal utility box. A barrier-type terminal strip mounted on one end of the box is used to make connections to the automobile wiring. The circuit board is mounted on short spacers and is in such a position that the delay adjusting potentiometer (*R9*) is accessible through a hole drilled in the case. Line this hole with a rubber grommet to prevent short circuits when making adjustments with a metal screwdriver.

When selecting a relay, don't scrimp on the current rating of the contacts. In the prototype, both sets of 10-ampere contacts were wired in parallel just to be on the safe side. The same principle applies to the wire used to connect the

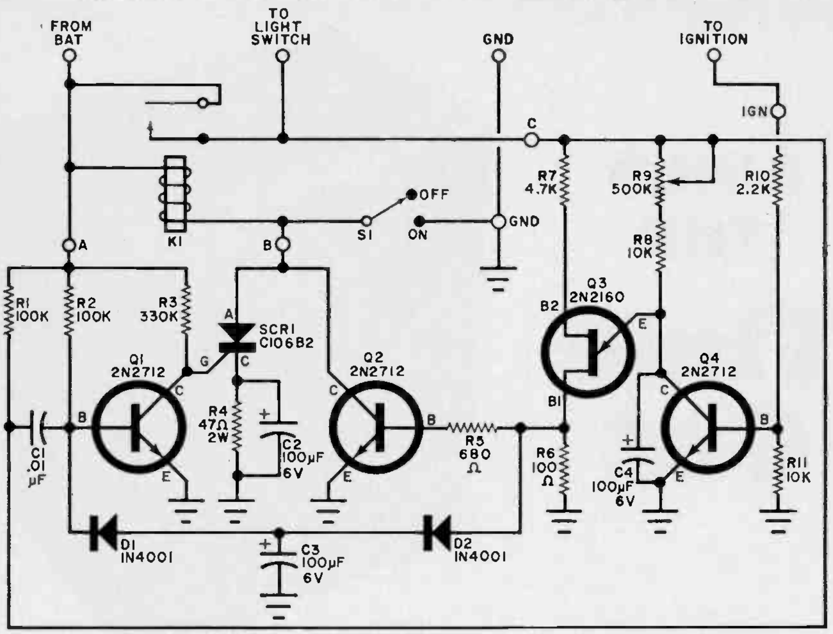


Fig. 1. The UJT turns off the lights by making Q2 appear as a momentary short circuit across SCR1. This causes the relay to open, removing power from lights and timer.

PARTS LIST

C1—0.01-µF capacitor
C2,C3,C4—100-µF, 6-volt electrolytic capacitor
D1,D2—1N4001 diode
K1—6-volt d.p.d.t., d.c. relay, 10-ampere contacts (see text)
Q1,Q2,Q4—2N2712 bipolar transistor
Q3—2N2160 unijunction transistor
R1,R2—100,000-ohm
R3—330,000-ohm
R5—680-ohm
R6—100-ohm
R7—4700-ohm
R8,R11—10,000-ohm
R10—2200-ohm
(All resistors ½-watt, 10%)
R4—47-ohm, 2-watt resistor
R9—500,000-ohm potentiometer (printed circuit board type)
S1—S.p.s.t. slide switch
SCR1—Silicon controlled rectifier (GE C106B2)
Misc.—Four-contact barrier strip, 3¾" x 3" x 2⅛" metal utility box, rubber grommet, spacers, mounting hardware, chassis lettering, mounting hardware, etc.
Note—An etched and drilled PC board for $1.65 and a complete kit of parts including case, PC board, and hardware, for $12.95 are available from PAIA Electronics Inc., P.O. Box 14359, Oklahoma City, OK 73114. Oklahoma residents add state sales tax.

HOW IT WORKS

When the circuit is in its normal, inoperative state, relay *K1* is not energized and no power is applied to either the timing circuit or the headlights. Transistor *Q1* conducts because of the forward bias through *R2*. This holds the gate of *SCR1* near ground potential.

When the vehicle's headlight switch is closed the junction of *R1* and *C1* is grounded through the lights and the charge stored on *C1* creates a negative pulse to turn off *Q1* momentarily. With *Q1* off, a voltage is applied to the gate of *SCR1* turning it on and energizing the relay. Power is thus applied to the headlights and the rest of the timer circuit.

When the ignition switch is closed, the positive potential at the junction of *R10* and *R11* causes *Q4* to conduct and disables the timing circuit by shorting to ground the emitter of uni-junction transistor *Q3*. This condition exists as long as the ignition switch is turned on. When it is turned off, *Q4* stops conducting and a charge builds up on *C4* through *R8* and *R9*. When the charge on *C4* is sufficiently high, *Q3* starts to conduct and a pulse is created on the base of *Q2*, turning it on. With *Q2* conducting, the anode of *SCR1* is shorted to ground. Due to the charge built up on *C2*, *SCR1* is then reverse biased and turns off. The relay is thus de-energized and the headlights are turned off.

When the relay's contacts open, the junction of *R1* and *C1* is once again grounded through the lights and a pulse is created which would begin the turn-on sequence again if it were not for the charge stored on *C3* when *Q3* was conducting. This charge neutralizes the pulse and keeps *Q1* from turning off. Diodes *D1* and *D2* serve to keep the proper polarities in the circuit.

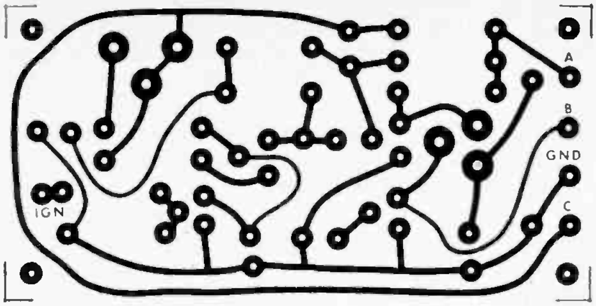
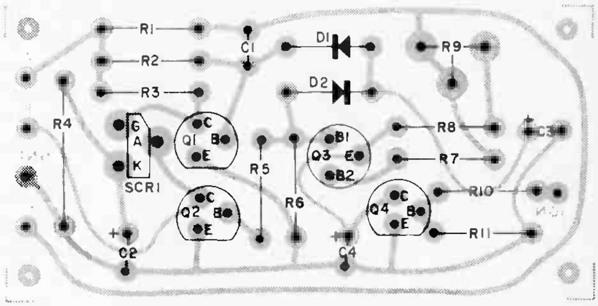


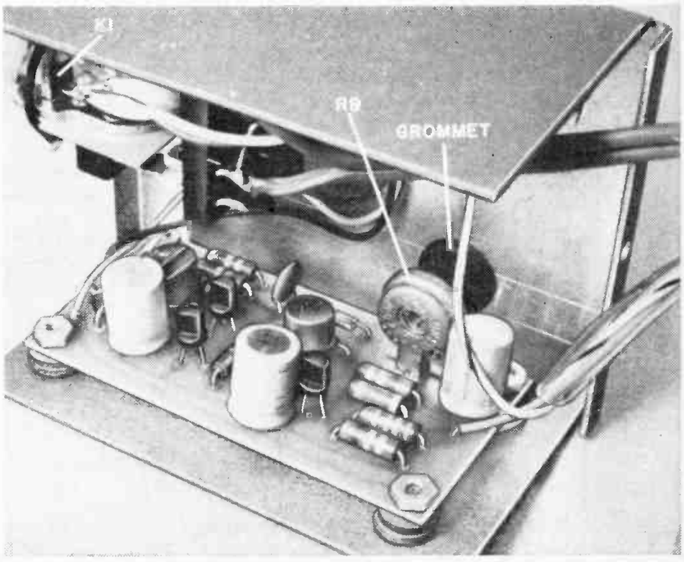
Fig. 2. Actual size foil pattern (above) and component installation (right) for the printed circuit board. Note polarities of semiconductors and capacitors.



relay contacts to the terminal strip—don't use anything smaller than #18 lamp cord or equivalent. The rest of the wiring can be standard #22 hook-up wire. Be sure to leave enough slack in the wires between the circuit and the terminal strip to remove the case.

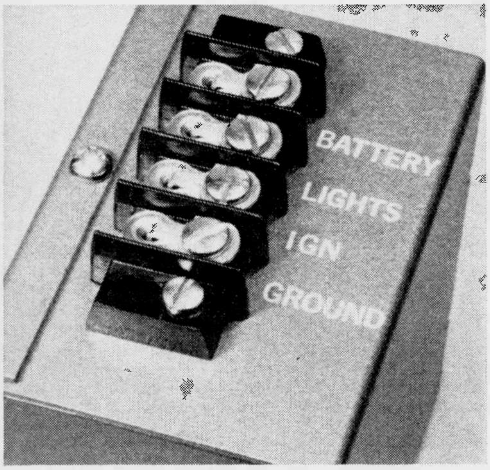
Installation. In selecting a location for the Time Out in your car, bear in mind that you may want to be able to reach the override switch (*S1*) from time to time and that the time delay will have to be adjusted when you first set up the system.

Electrical connections to the car are shown in Fig. 3. Locate the lead from the car's light switch to the battery and cut it. After splicing lengths of lamp cord long enough to reach the Time Out, connect the line which goes to the light switch to the terminal marked LIGHTS on



Relay K1 and override switch S1 are mounted on the metal chassis while the grommetted hole allows screwdriver adjustment of R9. Mount the PC board on four rubber shock absorbers to reduce vibrations.

the timer. The wire that goes to the battery should be connected to the BATTERY terminal on the timer. The GROUND terminal of the Time Out is connected to any convenient ground point such as under the head of an existing screw in the firewall or dashboard. The IGN terminal of the timer is connected to any convenient point which is live only when the ignition is on—such as the radio or heater fan motor. In most cases, the Time Out can be electrically connected at the vehicle fuse block.



Connections to the vehicle wiring are made via a four-terminal barrier strip. Clearly identify the terminals to avoid wiring errors in installation.

Operation. The Time Out does not interfere with the vehicle's conventional lighting and ignition systems. The lights should work normally except that, when the light switch is left on and the ignition is turned off, the timer will hold the lights on for a length of time depending on the setting of the timer and then turn them off. Clockwise rotation of the timer control (*R9*) increases the time that the lights stay on.

When installed as shown in Fig. 4, the Time Out will control both parking and headlights but will not have any effect on the brake lights, turn signals, or emergency blinkers. For emergencies, turn *S1* on so that the headlights will remain lit indefinitely when the ignition is off. Be sure to turn *S1* off when override control is no longer needed. -30-

Fig. 3. Electrical connections for a typical car are shown at the right.

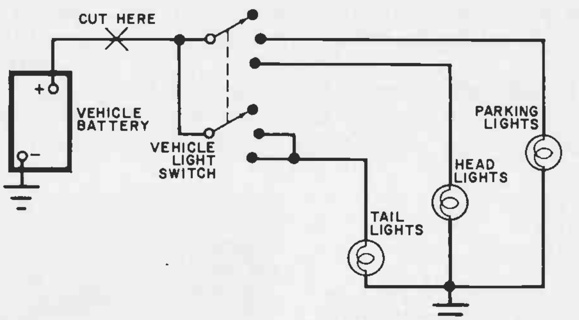
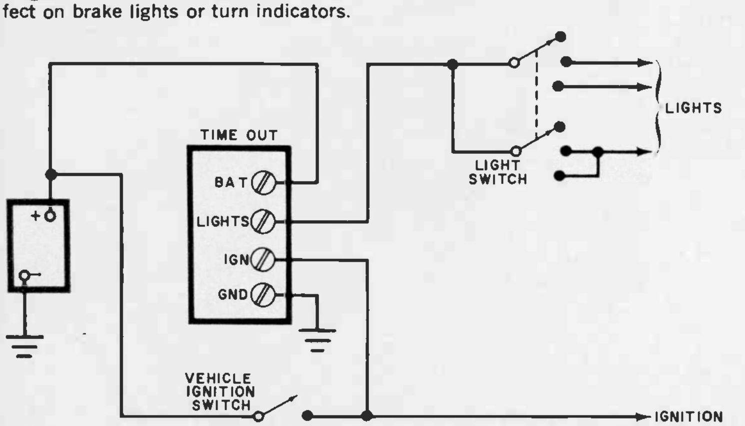


Fig. 4. When installed as shown in diagram below, Time Out has no effect on brake lights or turn indicators.



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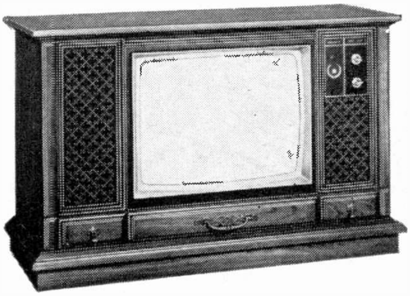

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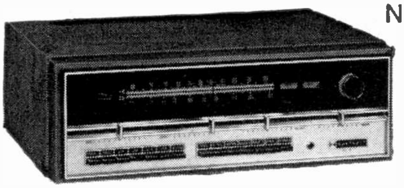

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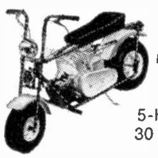

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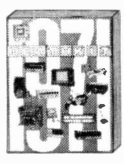

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CIRCLE NO. 8 ON READER SERVICE CARD

Engineering Level Opportunities FOR YOU

HOME STUDY IS THE ANSWER

BY ALEXANDER W. BURAWA, Associate Editor

THE PHENOMENAL PACE at which electronics has developed in the last few years—and the ever-increasing complexity of the technology—have precipitated an unprecedented demand for engineering level electronics technicians. In the aerospace and communications industries, in sophisticated computer centers, and in scientific and medical electronics—all areas where the most lucrative job opportunities exist—training on the level of the radio-TV repairman is no longer sufficient. Technicians in these job situations are actually associate or assistant engineers; and it takes engineering training on the college level to get these jobs—something you can now do with home study.

If you can't take the time or haven't the money to spend for two to four years of college what do you do? Do you know that four nationally accredited *home study schools* are now offering engineering courses on the college level? If you have the prerequisites, two years or less of leisure-time home study could put you well on your way toward one of these engineering technician positions.

The college-level courses offered by home-study schools have gained wide-spread approval in industrial and educational circles. In most cases, the student receives an industry recognized diploma upon completion of one of the courses. One home study school offers the opportunity of earning a degree.

Home study courses in electronics actually started in the 1920's. The earliest courses were highly specialized, tending to focus on certain areas in a technology which was then only in its infancy. Gradually, coverage was expanded and today's home study engineering courses are as up-to-date and cover as much ground (in the technology) as those offered in many technical colleges.

Schools accredited by the National Home Study Council* offering engineering programs are: Capitol Radio Engineering Institute (CREI), 3224 Sixteenth St., NW, Washington, DC 20010; Cleveland Institute of Electronics (CIE), 1776 East 17 St., Cleveland, OH 44114; Grantham School of Engineering (GSE), 1505 North Western Ave., Hollywood, CA 90027; International Correspondence Schools (ICS), Scranton, PA 18515; and National Technical Schools (NTS), 4000 S. Figueroa St., Los Angeles, CA 90037.

**The Accrediting Commission of the National Home Study Council has been approved by the U.S. Office of Education as a "nationally recognized accrediting agency." Its purpose is to establish educational, ethical, and business standards; examine and evaluate private home study schools in terms of these standards; and accredit (only) those schools which qualify.*

Correspondence study has emerged as one of the truly effective methods of independent learning. The millions of people enrolled in correspondence courses in nearly every conceivable subject attest to the great contribution the home-study industry is making to American (and international) education. An increasing number of colleges and universities are recognizing correspondence instruction as equivalent to resident work, and a growing number accept for credit courses taken by students in accredited home-study schools. It seems obvious to most thoughtful educators that correspondence instruction—from engineering to art appreciation—is on the threshold of its greatest years.

Roy W. Poe
President, CREI

Prerequisites for engineering level home study courses are obviously high. The applicant must be a high school graduate (or possess a high school equivalency certificate) and have studied, or had previous job experience in, the electronics industry. Applicants without the electronics prerequisite but who have a firm grasp of theoretical and practical physics and intermediate mathematics are good potential candidates.

There are very practical reasons for setting these high prerequisites. The courses provide studies only in electronics theory; there are no gimmicky training kits or home-built TV receivers. The schools sense that no engineering level home study course can possibly provide the exposure to all the test equipment, circuits, and systems required for a full resident laboratory course. Since home study programs feature low cost, this is a sound principle and the study programs have been adjusted accordingly.

Thus, even though home study engineering courses have no costly kits and training aids, nothing has been sacrificed in the quality of educational materials provided. Such items as tube and transistor manuals, special textbooks, and slide rules are included in the basic tuition.

WHAT IS AN ENGINEERING TECHNICIAN?

The entire technical work force in electronics can be divided into two broad, but not necessarily well defined, categories: technicians and engineers. Technician in this sense refers to the person who operates, maintains, troubleshoots, and repairs electronic gear. Engineer refers to the designer of new devices, circuits, and systems. Between the two categories lies a growing force of engineering technicians (sometimes referred to as associate engineers). The engineering technician's duties and responsibilities overlap both categories.

Engineering technicians usually work directly with scientists and engineers with degrees. They analyze and solve engineering problems and occasionally prepare technical reports. Consequently, the engineering technician must have a thorough grasp of the scientific principles of his particular field and a good understanding of mathematics and physics. Generally, to be entitled to the title of associate engineer, the person is expected to be a graduate of a two-year college. However, the growing recognition of home study by the industry does entitle the home study graduate to apply to his name the title of engineering technician.

The home study concept of education is geared for individual attention. Each lesson is written to provide maximum clarity. But even the clearest written text might confuse some students. So, all of the schools maintain a full-time consultation service, staffed with engineers and educators who are experts in home study problems, to which the student can turn for help. This service is available even after graduation.

Textbooks are broken up into bite-size lessons for easy assimilation and to allow the student to pace his progress. Within each lesson are answer-keyed questions that are designed quickly and immediately to check the student's comprehension of the material covered. At the end of each lesson is an exam which must be completed and sent to the school. All questions asked are of the thought-provoking essay type.

At the school, the student's exams are reviewed and graded by professionals. In grading the exams, several things are looked for: The correct answer, of course, is one, but more important are the techniques used in answering math questions and the method of presentation. If an incorrect method or answer is given, the person grading the exam will supply corrective hints that show where the student went wrong, and refer him to the

"Many people are now realizing that everyone can't go to college; and, more important, many individuals should definitely not seek a college education. Home study is an ideal alternative—not a substitute, but an excellent opportunity to obtain specialized education quickly, effectively, and economically.

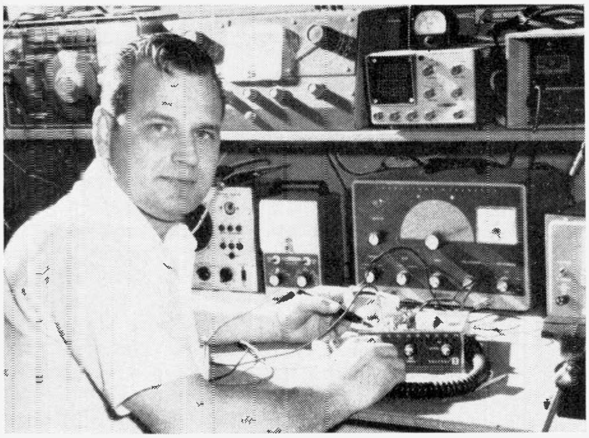
"At CIE, we have some 775 industrial and commercial clients, and this roster is growing daily."

Ralph J. Schmotzer
CIE

Angelo Vaccaro came to the U.S. from Italy 15 years ago and went to work as a machinist. When he enrolled in CREI in 1953, he could hardly speak English, and he gives the lessons credit for helping him learn the language. Today he is Vice President of Columbia Controls Research Corporation in Glen Cove, N.Y. He holds in his name or in the name of the company 15 patents for devices such as an electronic scanner, an electronic tensioning control device, and a reader for a computer system. Some of these devices have been sold or licensed, and negotiations are under way for others.

ON THESE PAGES

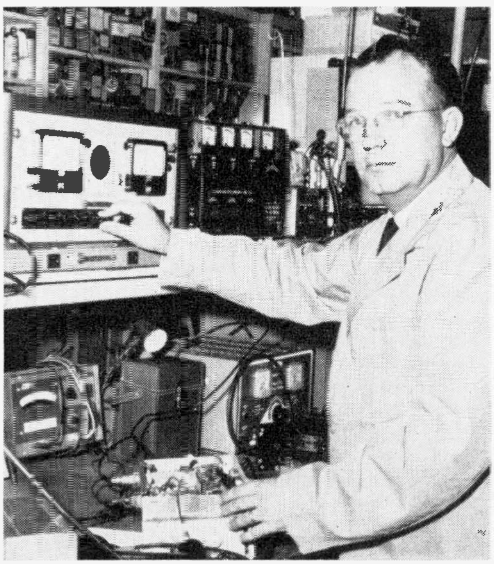
Maurice T. Swinnen graduated from CREI in 1962 shortly after he arrived in the U.S. from Belgium. Not long after graduation, he joined the Division of Neuropsychiatry at Walter Reed Army Medical Center in Washington, D.C. Starting at Walter Reed as an equipment repairman, Mr. Swinnen rapidly rose to electronics technician and, finally, to supervisor of the electronics shop facility of the Division of Neuropsychiatry. He is in charge of seven technical support personnel, two of whom are graduate electronics engineers. He has contributed well over 100 technical reports about the instruments he has devised during the past seven years and more than 20 publications have appeared under his name in both medical research and electronics journals. He is often called upon to attend the various technical and medical conventions around the country—to learn as well as to teach.



Edward Dulaney graduated from CIE and now owns his own two-way mobile radio manufacturing business, Dulaney Electronics Services. Before his training in electronics through home study, Ed was a commercial pilot engaged in crop dusting. Now, his company manufactures two-way radio equipment and has seven fulltime employees on the payroll with dealers in seven states. By going into electronics, Ed states that he has fulfilled his dream and is much better off financially than in his crop-dusting days.

SOME SUCCESSFUL STUDENTS

Dennis Stout, another CIE graduate, performs engineering maintenance on microwave equipment. A few years ago, he was a second-class radio man in the U.S. Navy. Dennis states that if someone had told him then that he would someday own a beautiful home and two cars and have a good income, he would never have believed it possible. He is also convinced that what he is doing now is only the beginning and that the future still has a lot to offer for his chosen career.



August Gibbemeyer was in radio-TV servicing before deciding to upgrade his electronics education through CIE. Presently, he is happily in the two-way radio servicing business (police, fire and cab rigs) and his business is increasing by leaps and bounds. A four-man operation located in an ideal area for marine service work, the business has more than enough work to keep everyone occupied for more than eight hours a day.

"Our home study degree program is relatively new, but already quite a few firms and agencies are paying tuition in this program for their employees. And many others are reimbursing their employees who complete correspondence 'semesters.' Some of the firms and agencies who have paid tuition directly to the School are: Naval Ordnance Station of Indian Head, Md.; the WDL, E&TS, and C&TS Divisions of Philco-Ford; Sprague Electric Co.; Consolidated-Bathurst, Ltd., of Canada; ESSA Research Labs; and NASA Flight Research Center, Edwards, Calif."

D. J. Grantham
President, GSE

page or section in the lesson that should be reviewed.

When the student is through with his course, he must complete a comprehensive examination that touches on every area studied. The end-of-course exams are usually proctored (taken in the presence of a qualified person). Then upon passing the comprehensive exam, a diploma, which is the school's statement of the student's competence, is awarded.

Although basically similar, the exact content of the home study engineering courses offered by the various schools varies.

At CREI, the master, or principal, course on the college-engineering level is the Electronic Engineering Technology Base Program with Major Electives. It has two objectives: to provide a broad basic foundation in electronics and to equip you with specialized knowledge in a particular field of your choice. The Base Program covers the theory and application of advanced electronics in relation to circuits, components, and systems. The electives in which you can specialize include: Communications; Aeronautics and Navigation; Television; Computers; Nuclear Instrumentation and Control; Automatic Control; Missile and Spacecraft Guidance; Radar and Sonar; and Digital Communications.

CIE, ICS, and NTS offer master courses in electronics engineering. No electives are available as such, but the courses are designed to prepare the student for a career in any of a wide variety of specialties in the electronics industry. Typical basic subjects include steady-state and transient network theory, solid-state physics, magnetics, etc.

GSE's program consists of five sections and includes an "incidental" preparation program for an FCC First Class Radiotelephone License with Radar Endorsement. Emphasis is on mathematics and physics (as it is in all home study courses). The course sections are: Basic Electronics with Mathematics; Communications Circuits and Systems; Engineering Mathematics and Computers; Classical and Modern Physics, and Technical Writing; and Engineering Calculus, Electrical Networks, and Solid-State Circuit Design.

A very important benefit of these courses for those students who plan to go on to college to earn their associate and bachelor degrees in electronics engineering is that many colleges allow considerable advance-standing credit for material covered (depending on the college and the results of tests). In addition, Grantham has oriented its program toward the obtaining of a degree. After completing his home studies, the student attends a two-week resident class at the school, for which he earns an Associate in Science in Electronics Engineering (ASEE) degree. —30—

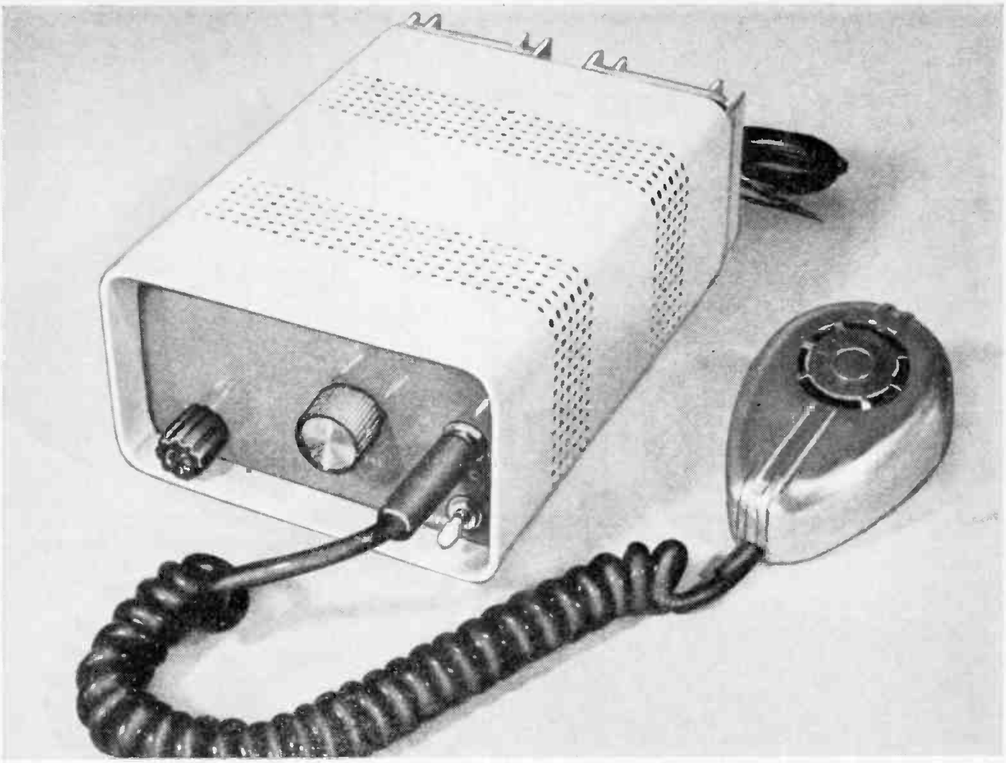
"It has been said that education is the mother of leadership; and by encouraging education, the National Home Study Council helps build leaders to guide America through the tests and trials of this critical and complex time. . . . Never has your mission been more timely or more imperative than now. Your high academic standards promise quality education to all who pursue correspondence study. I commend your distinguished and enduring service to America."

—Excerpt from a telegram sent by President Nixon to the NHSC at its 1969 Annual Conference.

"Recognition of home study programs in direct conjunction with college-level education is distinctly on an upward swing. As an indication that industry does accept home study graduates, our own experience has been that major firms throughout the world have sought and value our graduates.

"Data involving motivational research has proven that self-directed independent study is more effective than resident training. One obvious reason for this is that the home study student must research his own material as sent by the school without someone at his side. While he is guided, supplied with accurate and tested study material, and counseled as needed, he is not spoonfed information, nor is he held back in a class of students with a variety of achievement skills."

Robert Parma
Director of NTS



TEN-WATT PA AMPLIFIER

INTEGRATED CIRCUIT SIMPLIFIES CONSTRUCTION

BY ED FRANCIS

WHEN A NEW electronic component is put on the market for experimenters, it is usually only after the commercial users have exploited it to the full. This is not so of the RCA CA3020 integrated-circuit audio power amplifier. From the moment of its introduction, the CA3020 was available to both commercial users and experimenters. It has been used in scores of applications.

The CA3020's success is due to a blend of small size, low cost, high reliability, ease of use, and a respectable ½-watt output. Even so, it is not powerful enough for public address audio amplifier applications. But, capitalizing on the IC's push-pull output configuration, it is possible to produce a PA system that develops a 10-watt output with the addition of a handful of components.

For maximum appeal, the PA system described here was designed for mobile/home use. All you need do after the project is assembled is connect it to a suitable d.c. power source, plug in mike and speakers, and you're in business.

About The Circuit. The CA3020 IC amplifier has an output stage consisting of two *npn* transistors in a push-pull configuration, requiring a 130-ohm center-tapped load. Since the outputs (taken at pins 4 and 7 of *IC1* in Fig. 1) are 180° out of phase with each other, they are complementary-symmetry coupled to the bases of *pnp* power transistors *Q1* and *Q2* which are also connected in push-pull.

The input impedance of the 2N2869/2N301 transistors specified for *Q1* and

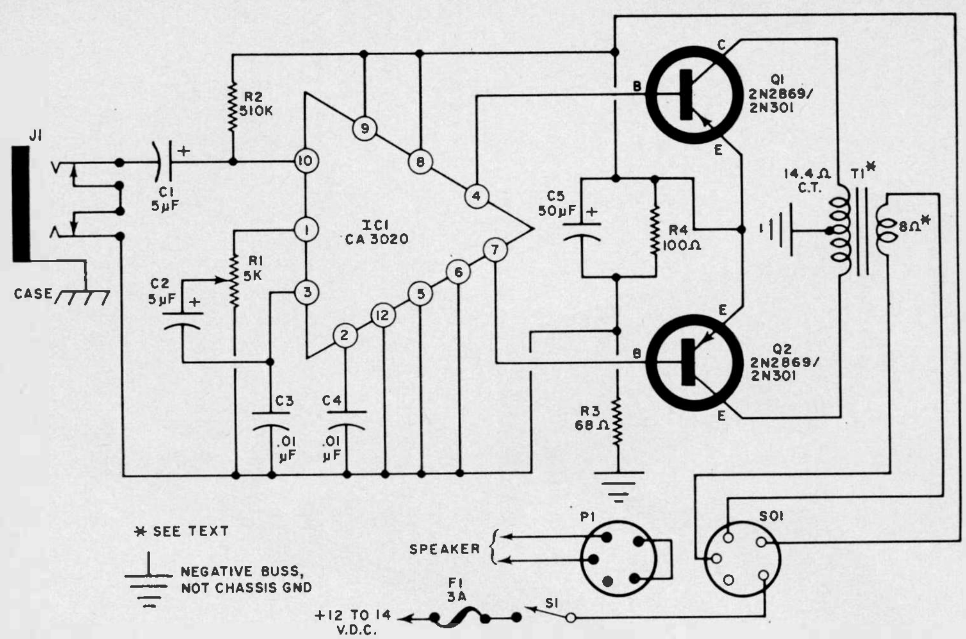


Fig. 1. Because IC1 cannot tolerate more than 9 volts d.c., connections to negative side of power source are actually 4-5 volts positive with respect to negative buss. Only connection made to the chassis is the J1 mounting bushing.

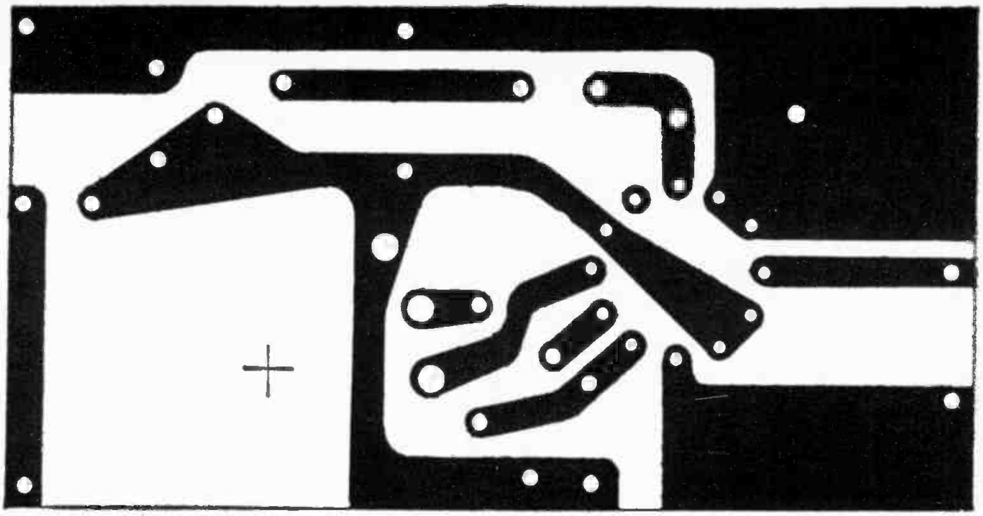
PARTS LIST

C1, C2—5-μF. 12-volt electrolytic capacitor
C3, C4—0.01-μF disc capacitor
C5—50-μF, 15-volt electrolytic capacitor
F1—Standard 3-ampere fuse (NOT slow blow)
IC1—RCA CA3020 ½-watt audio integrated circuit amplifier
J1—Two-circuit control-transfer phone jack
P1—Five-pin molded plus (Amphenol 78-PCG5)
Q1, Q2—2N2869/2N301 power transistor
R1—5000-ohm audio taper potentiometer (IRC 60 137 6507)
R2—510,000-ohm, 5% resistor
R3—68-ohm resistor
R4—100-ohm resistor
} All resistors ½-watt
S1—S.p.s.t. switch (can be part of R1 or a separate slide or toggle switch)
SO1—Five-pin socket (Amphenol 91-MPM5L)
T1—Output transformer (see text)
1—LMB Type CO-3 metal cabinet
2—Heat sinks (Olson Electronics X-951)
Misc.—Transistor sockets, hardware, mica insulators (2 each) for TO-3 case configuration; high-impedance (50,000-ohm) dynamic microphone with two circuit phone plug attached as described in text; 3⅝" x 1¾" printed circuit board; loudspeaker (see text); fuse holder; control knob; three-lug terminal strip; rubber grommets; 1" metal spacers (6); 1½" 6-32 machine screws and matching nuts and lockwashers; coded power cable; hookup wire; solder; etc.

Q2 serves as the necessary center-tapped load for *IC1* and eliminates the need for a driver transformer. Transistors *Q1* and *Q2* feed output transformer *T1*. Since a complementary-symmetry configuration is also used here, no bias arrangement is needed for the power output stage.

The output stages operate on between 12 and 14 volts d.c., but *IC1* cannot tolerate more than 9 volts d.c. Consequently, the voltage divider chain formed by *R3* and *R4* is incorporated into the circuit to provide a safe operating voltage for *IC1*. Because of this arrangement, the common (usually grounded) pins of the IC are actually 4-5 volts above the negative buss reference; so it is necessary to use a two-circuit phone jack for *J1* to prevent shorting *R3*. (Note that with this setup, chassis or case ground is *not* used as the ground reference for the input signal.)

Protection for the output transistors is built-in and the loudspeaker load must be plugged into the amplifier through the *P1/SO1* connectors before d.c. power can be applied. When *P1* is unplugged, the positive input voltage line is broken.



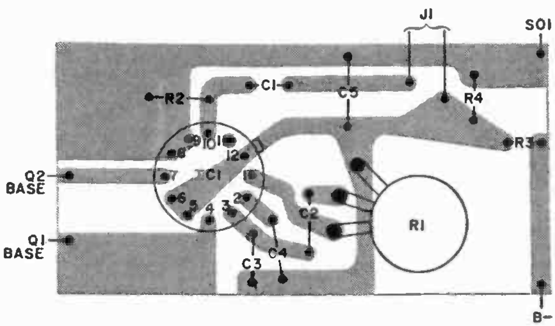
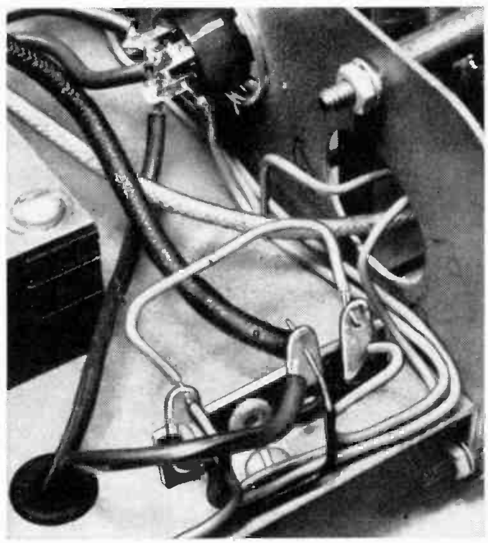


Fig. 2. When making printed circuit board, copy actual-size etching guide exactly as shown above. Then mount components on top of board (see drawing at left), making sure indexing tab of IC1 is located as shown.

No electrical connections are made to the amplifier cabinet, so the system can be used in either positive- or negative-ground mobile electrical systems.

Construction. Apart from the fact that this is one project for which you will have to make your own printed circuit board (if you choose this method of assembly), construction is very easy. Except for the output transistors and transformer, the fuse holder, and the microphone and speaker/power connectors, all parts mount directly on the circuit board. If you prefer, you can assemble the circuit on a piece of perforated phenolic board, but a printed circuit board is recommended (see Fig. 2 for actual-size foil pattern guide and component layout).

Mount the components on the board in the following order: first the resistors, then the capacitors and volume control *R1*, and finally the integrated circuit *IC1*.



Terminal strip, mounted right rear of chassis, simplifies interconnections between power cable, output transformer T1, output transistors Q1 and Q2.

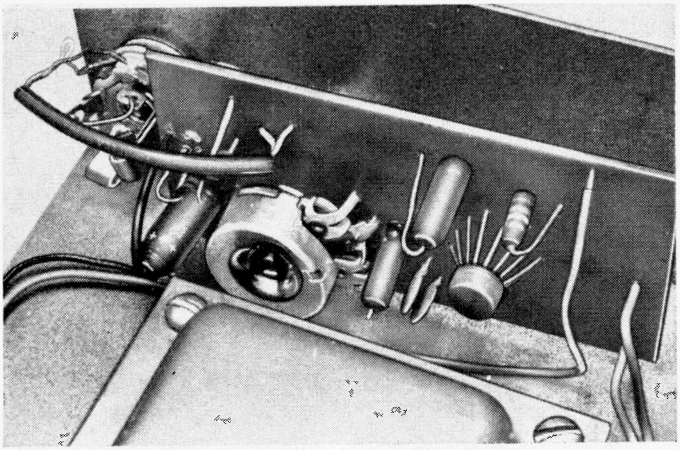


Fig. 3. Circuit board mounts to front of case via long threaded shaft of volume control. Use shielded cable to connect input jack to circuit board as shown.

When mounting *IC1*, leave the leads full length, carefully inserting them into the proper holes in the board. Then, heat sink each lead as you solder it to the foil. Temporarily set the circuit board assembly aside.

The next step is to homebrew an output transformer with specifications to match the circuit. To make this transformer, refer to the instructions provided in the sidebar on next page. Then, mount the transformer inside the amplifier case in a position where it will not interfere with the circuit board or output transistor wiring.

Now mount the power switch (if it is not part of *R1*), fuse holder, and circuit board on the front of the case as shown in Fig. 3. Use two hex nuts and a control lockwasher to secure the extra-long threaded bushing of the potentiometer in place so that it protrudes from the front no more than 3/16", including the thickness of the hex nuts.

The heat sinks, as you get them, will not fit directly onto the rear apron of the case. Hence it is necessary to cut them down to size and file or grind the corners to fit the curvature of the case corners as shown in Fig. 4.

If the heat sinks are not pre-drilled to accommodate the TO-3 transistor and socket, machine them so that they do. Bear in mind, however, that care must be exercised in this operation to insure that, when mounted, the transistor leads or case do not short to the heat sinks. When you are satisfied, mount the transistors and their sockets on their respective heat sinks, placing a mica or teflon insulator and silicone paste between the transistor cases and heat sinks.

Space on the rear panel of the amplifier case is at a premium. Therefore,

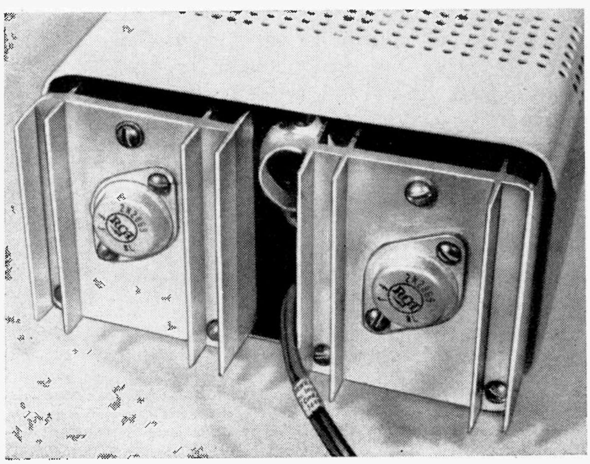
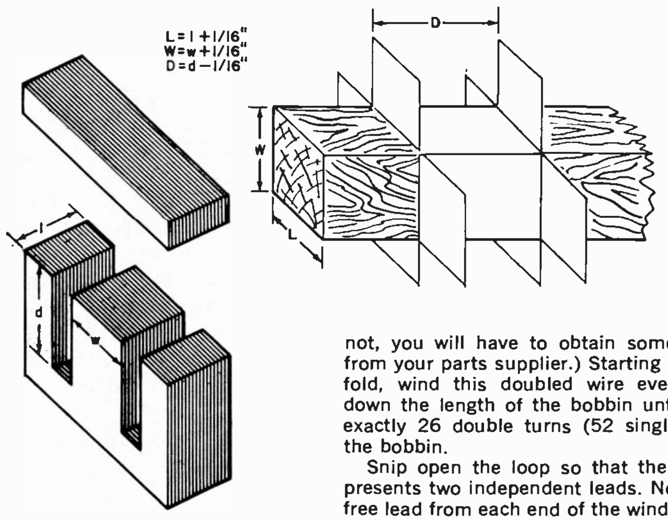


Fig. 4. Heat sinks for output transistors are slightly over size and must be machined to fit within chassis cowling; note rounded edges. They can be mounted to rear of case with spacers and hardware.

carefully select the location for *SO1*. Drill the hole for and mount this five-contact socket. Then solder 6″ lengths of heavy-duty stranded hookup wire to the contacts of each transistor socket, and mount the transistor/heat-sink assemblies on the rear of the case. Use 1″-long metal spacers and 1¼″-long 6-32 hardware.

Now, referring back to Fig. 1, interconnect the circuit board, switch, fuse, power transformers and power transistors. For some of these connections, the job will be easier if you use a terminal



TRANSFORMER CONSTRUCTION

Since the output transformer needed for the PA amplifier is not a standard item, it must be homemade from a transformer that has been salvaged from an old radio or TV receiver. The only requirement is that the salvaged transformer have a core cross-sectional area (l x w in upper left drawing) of approximately 0.7 sq in.

Disassemble the salvaged transformer as follows. First, remove the hardware securing the laminations together at the corners. Next, score through the weatherproofing shellac and remove one set of E and I laminations at a time, taking care not to bend them out of shape. If any of the laminations show signs of rust, clean them with steel wool or very fine emery cloth.

Now, referring to the drawing at the upper right, prepare a bobbin and winding handle. The winding handle can be a piece of scrap wood, while the bobbin material can be lightweight card stock (an index card, for example) or heavy-duty waxed paper, such as the type used for wrapping industrial tools or freezer wrap. Slide the bobbin onto the winding handle.

To insure that the center tap of the primary winding is exactly centered, fold a 20′ length of #16 enameled wire exactly in half. (Check the original windings on the transformer. If the wire is the correct size, you can use it; if not, you will have to obtain some #16 wire from your parts supplier.) Starting 4″ from the fold, wind this doubled wire evenly up and down the length of the bobbin until there are exactly 26 double turns (52 single turns) on the bobbin.

Snip open the loop so that the folded end presents two independent leads. Now take one free lead from each end of the winding, and cut them so that they are just long enough to form a ½″ pigtail when twisted together at the center of the bobbin. Scrape away the insulating enamel from each lead. Then twist together the two leads and one end of a 6″ length of #16 or #14 stranded hookup wire, and solder the connection.

Cut the two remaining leads of the primary winding to the same length, scrape away ½″ of the insulating enamel from each, and solder 6″ lengths of #14 or #16 stranded hookup wire to each. These two leads should have a different color code from the center-tap lead to permit easy identification. Flatten all connections against the windings (do not allow the exposed connections to touch each other) and wrap a layer of electrical tape around the entire assembly.

Next, neatly wind the appropriate number of secondary turns (27 for 4-ohm output; 39 for 8-ohm output; 54 for 16-ohm output) over the tape-wrapped primary winding. Solder 6″-long #16 or #16-stranded hookup wire to the ends of these windings. Then tape the assembly as described above.

To assemble the transformer, slide the entire winding assembly off the winding handle and insert the crossbar of each E lamination into the windings core. Interleave these E laminations; do not insert them all in one direction. This done, slip an I lamination into place at the open ends of the E laminations. Replace the corner hardware. Then apply a coat of shellac to all exposed surfaces of the core laminations to provide a weather seal.

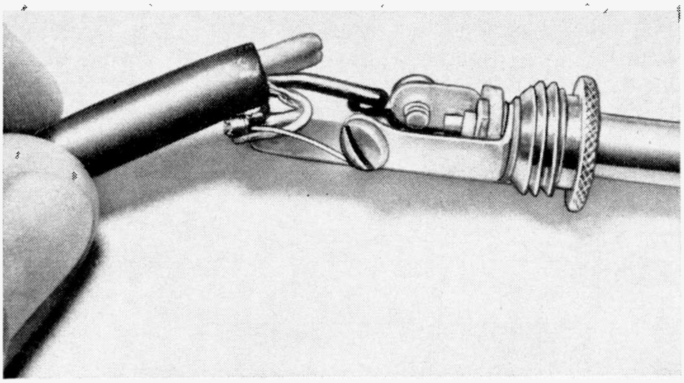


Fig. 5. When connecting plug to microphone cable, use only two shorter contacts. Do NOT allow cables to touch long one.

strip. Now wire *SO1*, and use a length of shielded cable to connect *J1* to the circuit board. Then drill holes through the lower center of the rear panel and inner mounting base of the cabinet, insert a rubber grommet into each hole, and route the power cable through the holes, connecting it to the appropriate points in the circuit. (Note: the power cable should be coded so that the positive lead is clearly identifiable.) Assemble the amplifier case.

Disassemble the two-circuit phono plug that will be connected to the microphone cable. So that you do not make a mistake when connecting the cable, remove and discard the screw on the longest contact lug (there will be no connection made to this lug), and connect the conductors from the microphone cable to the two remaining lugs as shown in Fig. 5. This might appear to be an unconventional hookup, considering that the usual "common" contact is not being used. But this connection must be made exactly as described to prevent damaging the IC when power is applied and a microphone is plugged into *J1*.

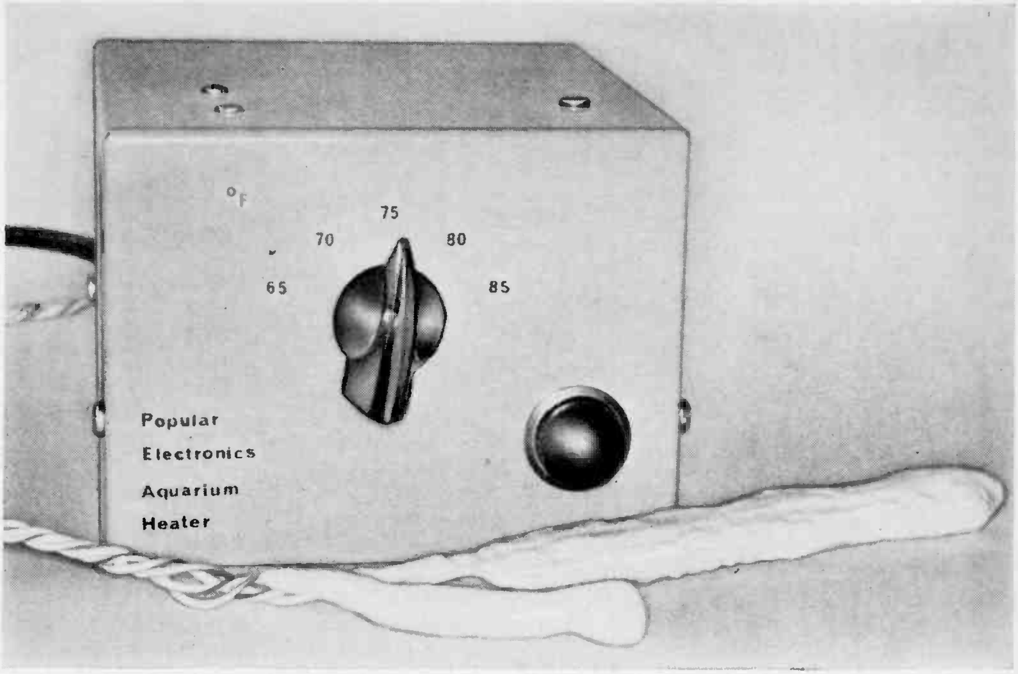
Finally, wire the jumper across the appropriate contacts and the proper impedance speaker to its respective contacts of *P1*. Then slide the circuit assembly into the wrap-around case, and bolt the two pieces together.

How To Use. The input impedance of the CA3020 integrated circuit is 50,000 ohms. Although this is a fairly high impedance, the wiring of *J1* described above precludes any possibility that hum will be introduced into the amplifier when the microphone is unplugged. With the microphone plug withdrawn, the input of the amplifier is short circuited.

Now to use the amplifier, simply plug *P1* into *SO1* and the microphone into *J1*. Being careful to observe the proper polarity, connect the 12-14-volt d.c. source to the power cable. Switch on *S1* and, while talking into the microphone, slowly bring up the volume (rotate *R1* clockwise) until the output sound level is perfect. Make sure, however, that the speaker is facing away from the microphone pickup or you will run into a feedback problem.

Only one precaution remains to be pointed out. The output transistors dissipate considerable heat; so it is necessary that you locate the PA amplifier where air will be allowed free circulation around the rear of the cabinet. If mounting space under the dashboard of your car, for example, is shallow, avoid mounting the PA amplifier there. —30—

What's wrong with just a candle?



Electronic Aquarium Heater

FOR CHILLY FISH FINS

BY STACEY JARVIN

MOST AQUARIUM heaters available on the market today are unsightly, bulky, potentially unsafe, and often not reliable. They operate directly from the a.c. power line, employ an inaccurate bimetallic strip temperature sensor, and are enclosed in a glass test-tube affair, the top of which must be above the surface of the tank water. And, unless you are willing to shell out a lot of money, you cannot buy an aquarium heater that has a calibrated range of temperature settings.

The electronic aquarium heater described here overcomes the major disadvantages of commercial heaters. It is completely safe to operate, is capable of sensing temperature changes on the order of 0.1° F, can be hidden under the gravel or sand in your aquarium, and costs little more than a good commercial heater.

Construction. The heater element, *R7*, is a simple affair made up of twenty-four (24) 300-ohm resistors connected in parallel as shown in Fig. 1. To provide rigidity to the assembly, it is suggested that you "ladder" assemble the resistors between two heavy-duty wire busses.

Although the heater arrangement is rated at only 12 watts in free air, it will safely dissipate 50 watts of "heating" power when submerged in water.

Since the heater element is to be operated completely submerged, it must be water-tight. So, after assembling the element, carefully check the heavy wires you plan to use between it and the control/power circuitry for nicks and holes in the insulation. When you are satisfied the wire is safe to use, solder a 5′-10′ length to each of the heater element busses.

Now, coat the entire assembly and 2″ or 3″ of the wire with epoxy potting compound. (Use only a true epoxy, one that must be prepared from separate resin and hardener compounds immediately prior to use.) Do not make the

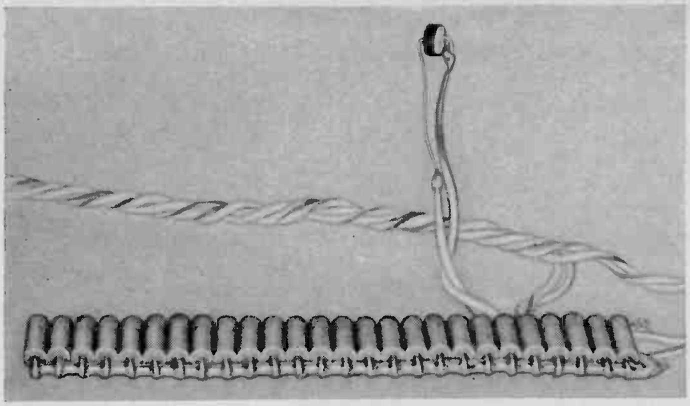


Fig. 1. Heater element (bottom) is assembled ladder fashion between two heavy-duty bus bars. Four-conductor cable is soldered to element and heat sensor. This photo shows 26 resistors since the author did not have proper number of 300-ohm resistors and paralleled several higher values to obtain the necessary 7 ohms resistance. You can do same if necessary.

coating too thick, but make certain that the entire assembly and the attached ends of the wires are completely sealed. A water leak from improper sealing will cause the heater to fail, and copper in solution from the wires will harm your fish.

After the first application of epoxy has set (wait at least 48 hours), put on a second coat and wait for it to set. If the outer coat is not completely set, it will allow volatile solvents to enter the aquarium water—obviously also harmful to your fish.

The temperature sensor, *TDR1*, is also operated while submerged in water. Consequently, the same steps must be taken in selecting interconnecting wires and epoxy potting it as above. When both assemblies are finished, they should appear as shown in Fig. 2.

The layout of the power supply/control circuit (see Fig. 3) components is not critical, permitting any type of chassis wiring you prefer. For your convenience, an actual-size printed circuit board foil pattern and component layout guide are provided in Fig. 4.

When mounting transistors *Q1* and *Q2*, locate them close together, but not touching, to minimize thermal differences in their base-to-emitter junctions. A small heat sink might be needed for *SCR1*; hence, its tab is shown bolted to the angle bracket. (If you substitute another type of SCR for the one specified in the Parts List, check its specifications to make sure that less than 500 microamperes at the gate will drive it into conduction.)

When all components are mounted on the circuit board, mount the board, transformer, fuse holder, potentiometer, and pilot lamp inside the utility box as shown in Fig. 5. The center-tap lead of the transformer can be cut short and the stub taped.

Twist the sensor and heater element wires together and route them and the line cord through rubber-grommet-lined holes in the rear of the utility box. Tie strain relief knots in both cables inside the box, and interconnect all components and assemblies. Assemble the box.

Calibration and Use. Immerse the heat-

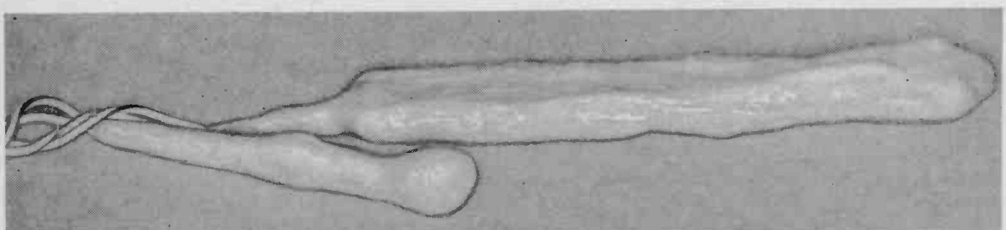


Fig. 2. Entire length of heater element and sensor, plus about 2" of connecting cables, must be thoroughly coated with epoxy potting compound to provide an airtight seal for the immersion elements.

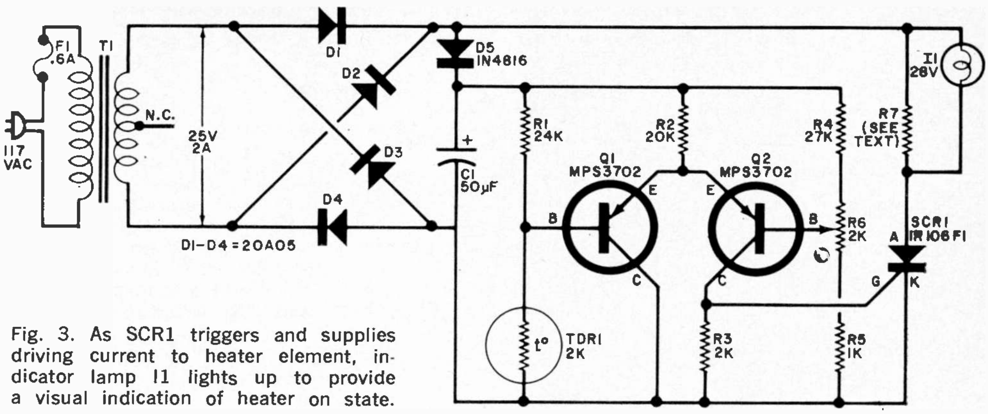


Fig. 3. As SCR1 triggers and supplies driving current to heater element, indicator lamp I1 lights up to provide a visual indication of heater on state.

PARTS LIST

C1—50-µF, 50-volt electrolytic capacitor
D1-D4—2-ampere, 50-volt diode (International Rectifier 20A05 or similar)
D5—1.5-ampere, 50-volt diode (1N4816 or similar)
F1—0.6-ampere fuse
I1—General Electric #GE 1819 28-volt lamp
Q1, Q2—MPS3702 transistor
R1—24,000-ohm
R2—20,000-ohm
R3—2000-ohm
R4—27,000-ohm
R5—1000-ohm
} *All resistors ¼-watt*
R7—24 300-ohm, ½-watt resistors connected in parallel (see text)
R6—2000-ohm linear-taper potentiometer
SCR1—(IR106F1 silicon controlled rectifier
T1—2-ampere, 250-volt filament transformer McGee Radio No. 555P3
TDR1—2000-ohm temperature-dependent resistor (Fenwall No. LP32J2)
1—5" x 4" x 3" metal utility box
Misc.—Control knob; a.c. line cord; rubber grommets; epoxy potting compound; hardware; hookup wire; solder; etc.

er element sensor in a glass of cool water. NEVER operate the system unless the heater is immersed in water, preferably with the sensor in the same water. Plug in the line cord; the pilot lamp should immediately come on, indicating that the system is operating. In a few minutes, when the water heats up, the light should extinguish. Rotating the control knob clockwise should cause the light to come on again, counterclockwise to extinguish it. If the reverse happens, unplug the line cord and reverse the connections to the outer lugs of the potentiometer.

A thermometer of known accuracy is needed to properly calibrate the system. First immerse the sensor and heater in about a pint of cold water. Set the control fully counterclockwise, and plug in the line cord. Now stir the water constantly with the thermometer. As soon as the lamp extinguishes, remove the thermometer from the water and note the temperature indicated. Record your reading on the front of the utility box, in line with the index of the control knob.

Return the thermometer to the water and advance the control until the lamp just comes on again. Stir the water with the thermometer until the light again extinguishes. Record your reading. Continue this process until you have enough calibration marks. Then disconnect power from the system, and use a decal or

ABOUT THE CIRCUIT

The voltage produced by *R1* and temperature-dependent resistor *TDR1* at the base of *Q1* is dependent on the resistance of *TDR1* (see Fig. 3). This voltage is then compared to a reference potential present at the wiper of temperature control *R6*, through the differential amplifier formed by the *Q1/Q2* circuit.

When, due to the cooling of *TDR1*, the voltage at the base of *Q1* changes by about 0.005 volt—corresponding to a temperature displacement of about 0.1° F with the components listed in the Parts List—*SCR1* fires and delivers 50 watts of power to heater element *R7*.

Transformer *T1* isolates the circuit from the a.c. power line and steps down the line voltage to a safe 25-volt level, eliminating the danger of electrical shock. Diodes *D1-D4* form a bridge rectifier circuit that supplies pulsating d.c. to *SCR1*, while *D5* and *C1* form a d.c. power supply for the differential amplifier circuit.

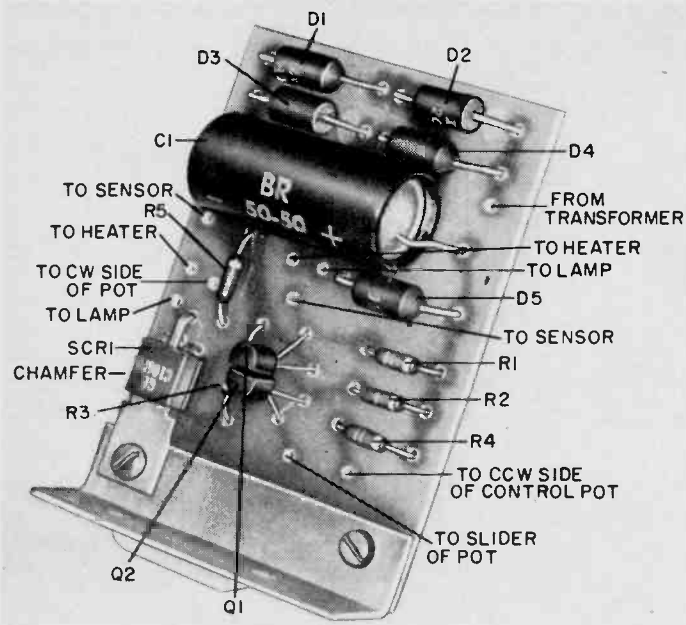
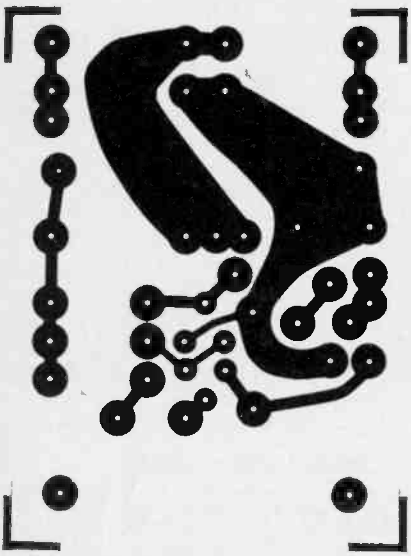


Fig. 4. Actual-size printed circuit board etching guide is given at lower left. Component locations and orientations on circuit board are shown in photo. For proper heat sinking of SCR1, bolt its tab to mounting bracket used for circuit board as shown.



dry-transfer lettering kit to finish the front panel.

In use, the heater element should be buried just under the surface of the gravel and/or sand in the bottom of your aquarium, in a location where the circulator can feed the water over it. Leave the sensor suspended in the water 2" or 3" "upstream" of the heater element. If desired, the sensor element can be camouflaged by the tank plants. Then plug in the line cord and set the temperature control.

The electronic aquarium heater has more than sufficient power for the standard 15-gallon aqarium. It will also serve a much larger aquarium if the water temperature is not to be too much greater than the ambient room temperature. —30—

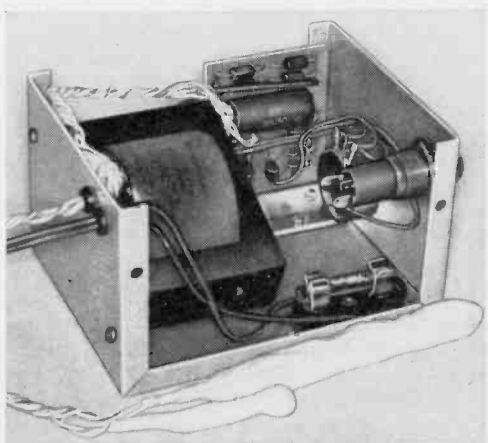
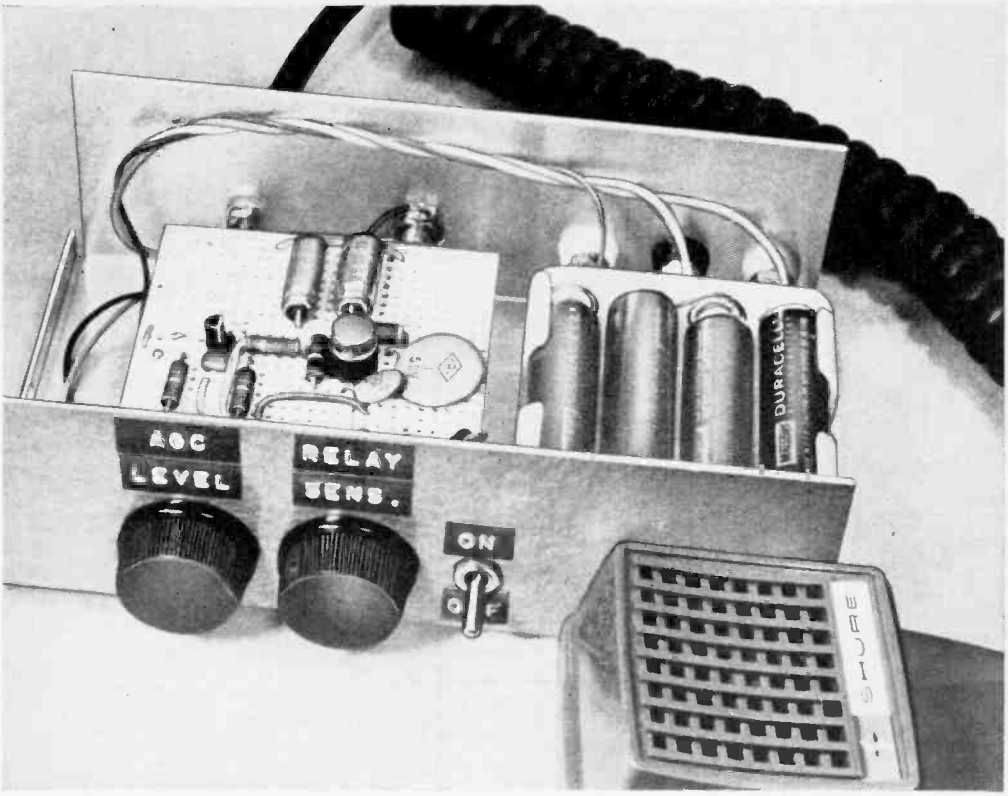


Fig. 5. Route a.c. line cord and heater element/ sensor cable through rubber grommet lined holes.



BUILD THE VOXOR

A VOICE-OPERATED MICROPHONE WITH SPEECH COMPRESSION

BY ROBERT A. HIRSCHFELD

HOW WOULD YOU like a microphone system that operates without a push-to-talk switch and compensates for differences in voice levels automatically? Whether you are using a tape recorder, ham or CB rig, these are real advantages. You can get both of them by building the "Voxor," a unit that has a voice-operated relay (VOX) and speech compression (audio a.g.c.)—features that are normally found only in expensive military and commercial equipment.

The Voxor uses the new Sylvania ECG370 linear integrated circuit and is simply connected between your microphone and recorder or transceiver. All you do is start to talk and the system turns on immediately. When you stop talking, and if you're using a transceiver, it will switch immediately to the receive mode. In the meantime, while you are talking, the Voxor output will be at a nearly constant, high-modulation level.

Construction. The circuit of the Voxor (see Fig. 1) can be built on either perf board or on a printed circuit board. A possible layout is shown in Fig. 2. Components not shown in the figure are below the perf board. To make wiring easier, it is suggested that a 10-pin integrated circuit socket be used for *IC1*. Once the board is complete, it can be mounted on standoffs and connected to the external components.

On the prototype shown in the photos the a.g.c. level potentiometer *R2*, the relay sensitivity potentiometer *R9* and the power on-off switch *S1* are mounted on the front of the chassis. The micro-

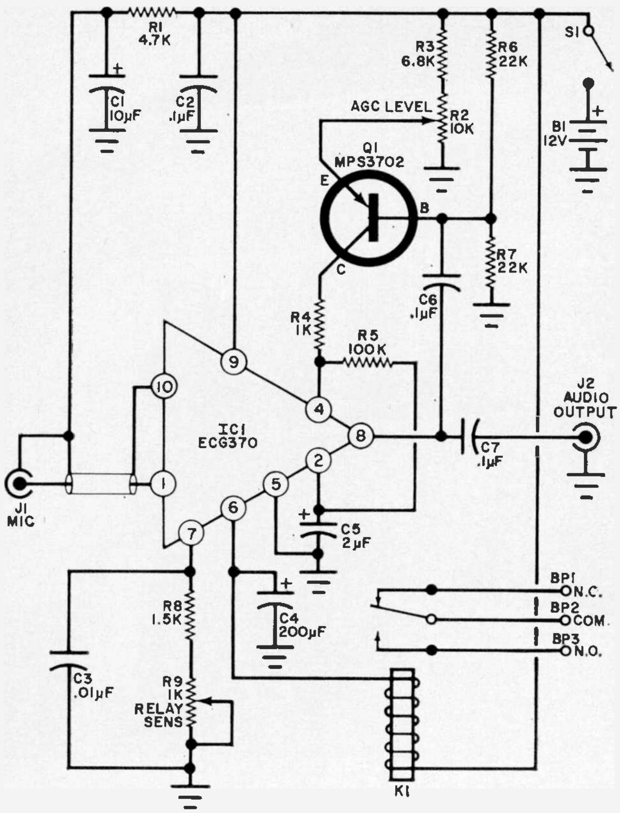
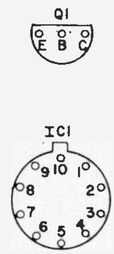


Fig. 1. The circuit is not a speech clipper but a legitimate speech compressor. When connected to a radio telephone transmitter or a tape recorder, the circuit will maintain a high modulation level with the speech clarity of the original input. As a bonus, the circuit will also operate a relay that can be used to switch the transceiver on or start a tape machine when speech does.



PARTS LIST

BP1-BP3—Insulated binding post
B1—12-volt d.c. battery or power source
C1—10µF, 25-volt electrolytic capacitor
C2,C6,C7—0.1-µF capacitor
C3—0.01-µF capacitor
C4—200-µF, 25-volt electrolytic capacitor
C5—2-µF, 10-volt electrolytic capacitor
IC1—Integrated circuit (Sylvania ECG370)
J1,J2—Phono jack
K1—1640-ohm relay, s.p.d.t., 1-ampere contacts (Sigma 65F1A-12DC or similar)
Q1—Npn silicon transistor (Motorola MPS3702 or similar)
R1—4700-ohm
R3—6800-ohm
R4—1000-ohm
R5—100,000-ohm
R6,R7—22,000-ohm
R8—1500-ohm
(*All resistors ½-watt*)
R2—10,000-ohm linear potentiometer
R9—1000-ohm linear potentiometer
S1—S.p.s.t. switch
Misc.—Metal chassis, perf board, standoffs, microphone (Shure 401A), battery holder, knobs, 10-pin IC socket (Cinch-Jones 10-ICS), mounting hardware, etc.

phone input *J1*, audio output *J2*, and the three relay contact binding posts are on the rear. As with any high-gain amplifier, leads should be kept short and direct to prevent feedback and high-frequency oscillations.

While almost any dynamic microphone capable of delivering up to five millivolts can be used, the one specified in the Parts List works especially well with this circuit. Certain microphones, including the one used here, have push-to-talk switches that close the circuit when the microphone is in use and also short out the microphone element itself when it is not in use. Such microphones must be rewired so that the element is never shorted.

To use the Voxor with an input other than the signal from a dynamic microphone, rewire the input circuit as shown in Fig. 3. This can be used as long as the maximum input level does not exceed about 50 millivolts. Larger inputs will

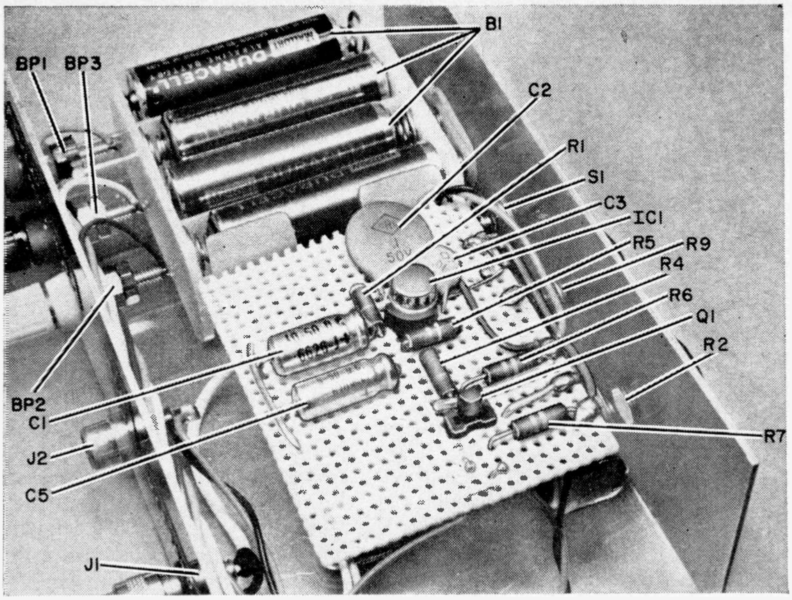


Fig. 2. The author constructed his Voxor on a section of perf board, although any other type of construction may be used. Sockets were used for both IC1 and Q1.

produce distortion. Inputs of less than one millivolt do not give reliable operation of the relay.

While the Voxor can be used with any d.c. supply from 9 to 24 volts, it works best with a 12-volt supply.

The attack and release times of the Voxor are determined by the value of capacitor *C4*. With the value prescribed in the Parts List, the timing is just about right for normal speech. Doubling the capacitance doubles the attack and

HOW IT WORKS

The integrated circuit—containing a complex combination of 34 transistors, diodes, and zeners, plus 20 resistors—performs two separate functions. The first is preamplification, with gain controlled by an external d.c. voltage (applied to pin 4). When this potential is less than 2 volts, the gain of the preamplifier is a maximum (about 100 with a 12-volt supply). With higher voltages, the gain decreases; until, with 2.6 volts or more, there is an attenuation of 100.

The second function is performed by a very high-gain amplifier-detector that receives the same input as the preamplifier but is otherwise independent. A potentiometer, external to the IC, sets the desired "squelch" threshold at pin 7. The output stage of the amplifier-detector is a medium-current *npn* power transistor. This transistor is normally off when only low-level inputs are present: but when the threshold is exceeded, pin 6 provides nearly a short circuit to ground, and the current is sufficient to operate the relay.

The input from the microphone is applied directly to both sections of the IC with d.c. bias derived from *R1* and *C1*. Sensitivity for the VOX section (the second function of the IC) is set by *R9* and the relay is driven directly by the output at pin 6. Normally, *C4* is charged up to the positive supply voltage through the relay coil. When a microphone input occurs, the relay is energized and *C4* discharges. Thus, the relay remains closed even after the input disappears—until *C4* has had time to recharge. This provides a "fast attack" so that early speech won't be lost, and a "slow release" so that the relay won't cut out between normally spaced words in a sentence. Capacitor *C3* makes the VOX less sensitive to high-frequency noise, so that sensitivity to speech frequencies is retained and false triggering made less likely.

Speech compression is performed by detecting the negative audio peaks at the output of the preamplifier (pin 8) through capacitor *C6*. With no audio present, the potential at the base of *Q1* is half of the supply voltage, as determined by the voltage divider made up of *R6* and *R7*. A negative-going audio peak causes *Q1* to turn on momentarily, which quickly brings the control input (pin 4) above the voltage where the preamplifier begins to turn off. This, in turn, charges *C5*, the a.g.c. smoothing capacitor. The net effect is that the first excessive peak seen by the detector causes the gain to be reduced just enough so that succeeding peaks of the same signal strength no longer activate the detector. A nearly constant amplitude of the output voltage is the result. Capacitor *C5* discharges more slowly than it charges so that the a.g.c. action also has a fast attack and slow release. If the speech level drops below the desired level, the amplifier gain increases as *C5* discharges until the preset level is reached.

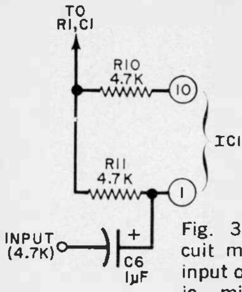


Fig. 3. This optional circuit may be used with an input other than the dynamic microphone specified.

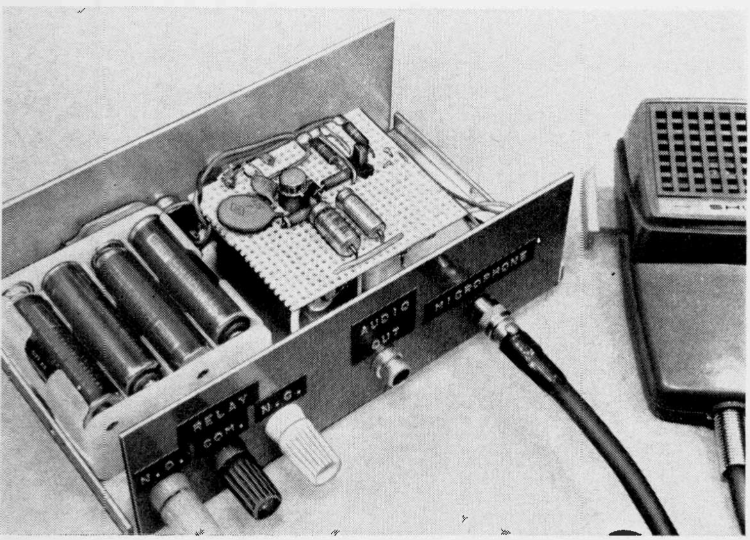
release times; reducing the capacitance, reduces the times.

Operation. After checking the circuit, connect the power supply and microphone and set *S1* to ON. Set the RELAY SENS. control for maximum resistance and note that relay *K1* is de-energized. Decrease the resistance of *R9* until the relay picks up and then back off slowly until it drops out again. Speaking into the microphone should cause the relay to be energized rapidly, with dropout occurring about one second after speech has ended. Setting *R9* closer to the "threshold" point increases relay sensitivity, while increasing *R9* resistance makes the relay less sensitive.

Connect the audio output of the Voxor to the input of the equipment with which it is to be used and set the equipment audio gain to the desired level. Set potentiometer *R2* for minimum resistance (rotor to grounded end). Speaking in a normal voice, the correct distance away from the microphone, adjust *R2* until the audio output of the Voxor decreases to the desired level. Note that changing the voice level or moving closer to or farther from the microphone does not change the audio level. In this way, it is possible to modulate fully a radio transmitter or tape recorder without overloading it.

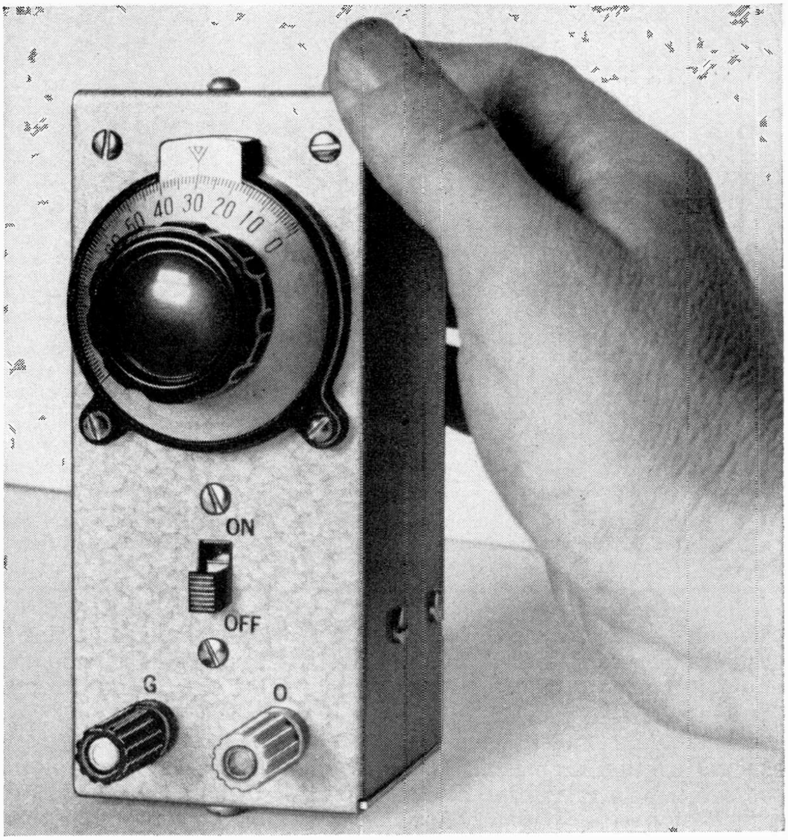
For use with a transceiver, connect the relay common and normally open contacts to the wiring that formerly went to the microphone push-to-talk switch and the audio output of the Voxor to the mike input. Adjust the relay sensitivity so that the Voxor is not activated by the sound from the speaker during the listening interval. To operate the transceiver, just speak into the mike and the switching is done automatically. If the Voxor a.g.c. level and transceiver audio modulation level (if any) controls have been properly set, you will notice an increase in the talk power due to the constant high level of modulation.

The relay in the Voxor can handle most battery or low-voltage tape recorders. Connect the relay common and normally open contacts in series with the recorder motor and associated power supply. Speaking into the Voxor will automatically start the recorder. As with the transceiver, the tape recorder and Voxor controls are set to provide maximum modulation of the tape. —30—



The three relay contacts—normally open, normally closed, and armature are terminated in three binding posts on the rear apron. These are connected as required by the external equipment being controlled, which can be either a tape recorder or transceiver.

BY FRANK H. TOOKER



Beginner's Signal Generator

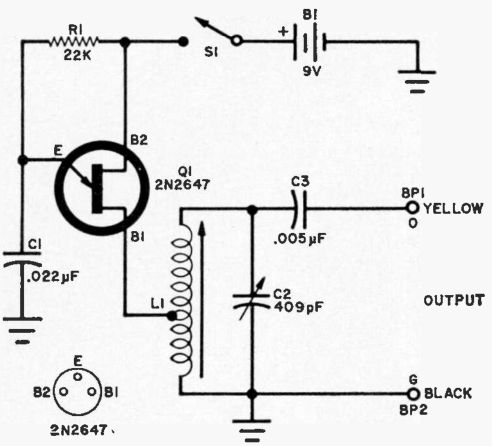
LOW-COST BCB OPERATION FOR A FIRST PROJECT

EVERY RECEIVER, whether simple or complex, requires some r.f. adjustment if it is to operate with maximum sensitivity and selectivity. In fact, the simple superhet receivers that are most often built by beginners usually require more attention than do complex communications receivers.

Unfortunately, most radio beginners lack the necessary test equipment to adjust their receivers properly. The biggest handicap is not having access to a signal generator that provides a signal source with modulation that is unvarying in both frequency and amplitude. There are many excellent signal generators available commercially; but, as the beginner soon learns, the investment required for a generator can be many times the cost of the receiver.

Since most beginners build an AM receiver as their first radio project, the "Beginner's Signal Generator" described here is designed for low cost and BCB operation. While it does not have the elaborate adjustments and advantages of a conventional signal generator, it does provide a modulated signal that can be tuned to any spot in the AM broadcast band. The initial adjustment of the Beginner's Signal Generator is simpler than that of a regenerative receiver.

How It Works. The r.f. signal is generated in the tuned circuit consisting of capacitor *C2* and coil *L1* (see Fig. 1).



PARTS LIST

B1—9-volt transistor battery
BP1, BP2—Banana plug (one yellow, one black)
C1—0.022-µF, 100-volt mylar capacitor
C2—409-pF miniature tuning capacitor (Allied Electronics No. 909-0199, or similar)
C3—0.005-µF disc capacitor
L1—AM loopstick coil (see text)
Q1—2N2647 unijunction transistor
R1—22,000-ohm, ½-watt resistor
S1—S.p.s.t. slide or miniature toggle switch
1—5" x 2¼" x 2¼" aluminum utility box
1—2" vernier dial (Lafayette Radio Electronics No. 99T60303)
Misc.—Battery connector; printed circuit board (or perforated phenolic board and "flea" clips); sheet aluminum for variable capacitor L-bracket and battery holder; 4-40 x ¼" machine screws; ½"-long metal spacers; standard L-brackets for circuit board mounting; hardware; hookup wire; solder; etc.

Fig. 1. Operating frequency is function of L1 and C1. Time constant of R1 and C2 allows Q1 to function as relaxation oscillator. R.f. output is taken off from BP1 and BP2.

The coil chosen for this application is a high-Q "loopstick" which provides maximum efficiency in the generation of tunable BCB signals.

Resistor *R1* and capacitor *C1* allow the unijunction transistor (*Q1*) circuit to operate as a relaxation oscillator with a repetition rate of about 750 pulses per second. The sharp current spike produced at the *B1* terminal of *Q1* each time it fires triggers the *L1-C2* tuned circuit into oscillation. These oscillations gradually decrease in amplitude until *Q1* fires again. This process repeats at a rate of 750 times a second. Thus the r.f. signal generated in the tuned circuit (adjustable in frequency by changing *C2*) and the 750-Hz audio signal both appear at the output. The latter is heard through the speaker or headphones of the receiver being tested.

Construction. The prototype Beginner's Signal Generator was built into a 5" × 2¼" × 2¼" aluminum box. The power switch, tuning dial for *C2*, and output binding posts *BP1* and *BP2* are located on the front of the box. The first step in construction is to cut or drill the component mounting holes in the front of the box as shown in Fig. 2. (Note: if you prefer, you can substitute a miniature toggle switch for *S1*. In this case, drill the appropriate size round hole for the rectangular hole shown and eliminate the small holes at the top and bottom of the rectangular opening.) Mount *S1*, *BP1*, and *BP2* in their respective holes.

Next, referring to Fig. 3, fabricate an L bracket from aluminum stock. Use a #32 drill for the two holes on the crossbar and four holes at the base of the T piece. Then bend the metal along the

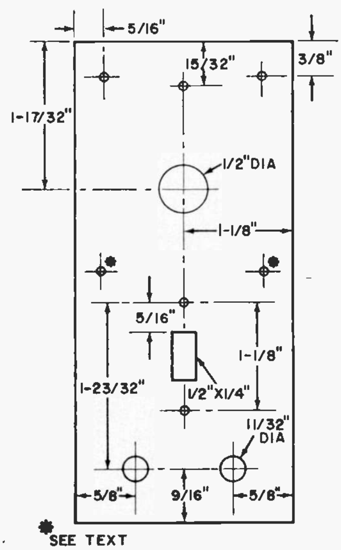


Fig. 2. Dimension details shown in drawing are for machining front of the utility box.

axis shown by the broken line. Use 4-40 hardware to fasten the bracket to the inner surface of the box front and to the frame of *C2*. Now check the mounted parts to make certain that the dial aligns accurately with the shaft of the capacitor and that the vernier dial, when temporarily slipped into place, does not bind against the front of the box. Then mount battery *B1* against the side of the box, using two ½" spacers, #6 hardware, and an aluminum bar (see Fig. 4).

While Fig. 4 shows *C1, L1, Q1,* and *R1* mounted on a printed circuit board, it is simpler and less expensive to mount and wire these parts together on a 1¾" × 1⁵⁄₁₆" perforated phenolic board. To simplify wiring, use "flea" clips.

Layout on the circuit board is not critical. However, make sure that *L1* is located as far as possible from any metal when the board is mounted inside the box. Mount the circuit board to the side of the box with a pair of L brackets and machine hardware.

Referring back to Fig. 1, wire together the components, being particularly careful with the orientation of *Q1*'s leads and the polarity of *B1*. (Note: a tapped coil is best for *L1*, but if only an untapped coil is available, you can close-wind 8-12 turns of #28 enameled wire over the center of the untapped coil windings. Use as few turns as possible to prevent lowering the Q of the coil and producing too broad a signal, but as many turns as needed to provide an adequate signal level in a good-quality receiver. Now, connect one end of the new winding to the *B1* terminal of *Q1* and the other end to case ground.)

Finally, mount the vernier dial on the capacitor shaft. To do this, first completely mesh the capacitor plates. Remove but reserve the screws on the shaft collar of the vernier dial and slip the vernier onto the shaft of *C2*, orienting it as shown in the photo on the first page of this article. Set the vernier dial to its zero index.

With the vernier dial properly oriented, mark the two mounting hole locations on the front of the box. Remove the dial without disturbing its setting. Then drill the two #32 holes in the positions indicated by your markings. Replace the dial and anchor it down with 4-40 hardware. Finally, replace the shaft collar setscrews, driving them through the hole at the bend of the capacitor L bracket. Then assemble the box.

Testing and Use. When the generator is completely assembled, make an output lead by connecting a banana plug to one end of a 24"-long piece of flexible test cable. Do not remove the insulation from the other end of this test cable since it must *never* be physically connected to any point in the receiver.

Plug the output lead into the yellow binding post (*BP1*) on the generator and lay the free end of the cable near the

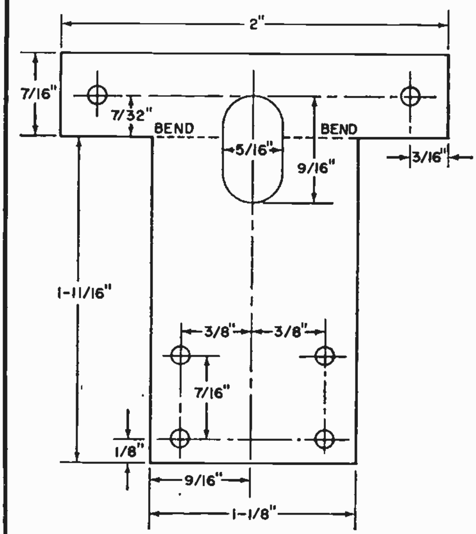


Fig. 3. Bracket for mounting C2 should be fabricated from 22-gauge aluminum stock.

antenna coil of any available AM receiver. Make sure the vernier dial is set to the zero index. Set the receiver dial to the low end of the AM band or 535 kHz.

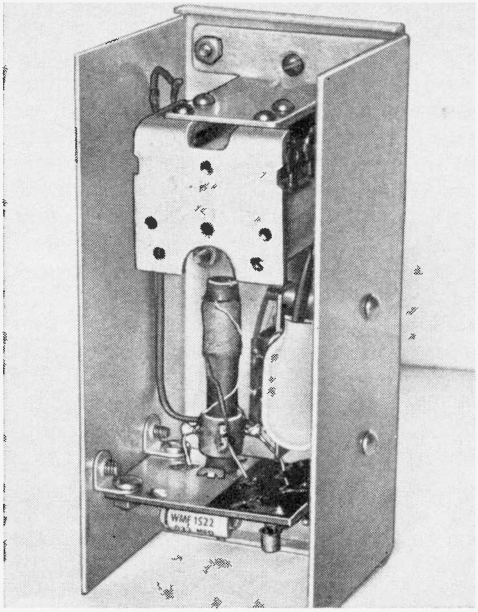
Turn on the power to the receiver, and set the volume control so that you hear a soft rushing sound coming from the receiver speaker. Now switch on the power to the signal generator and use a tuning tool to adjust the slug on *L1* (for this step you will have to temporarily remove the rear of the generator box), until you hear the 750-Hz audio tone in the speaker. If the tone tends to become very loud, do *not* readjust the receiver volume control setting. Instead, put some distance between the generator's output cable and the receiver's antenna.

Continue to adjust the slug of *L1* for maximum signal strength, putting more distance between the receiver and generator as needed. Proper adjustment of *L1* must be made while the tone coming through the speaker is at a low level, since a loud signal tunes too broadly.

In use, regardless of what type of AM broadcast band receiver is under test, always set the volume control of the receiver for maximum and adjust the sound level by changing the distance between the receiver and generator.

In the event you are testing a low-gain receiver and can barely hear the audio tone even when the generator output cable is actually touching the receiver's antenna coil, connect another cable from receiver chassis ground to the black binding post on the generator. This will significantly increase the signal level. However, if the signal level is adequate without this connection, do not use the extra cable. Also, under no circumstances should an a.c./d.c. tube-type receiver be connected in this manner as the chassis of the receiver is likely to be 117 volts a.c. "hot."

Always make tests at low sound levels with minimum coupling between the generator's output cable and receiver's antenna coil. Otherwise, the output of the generator will tend to "swamp" the receiver and you will be unable to tune the R.F. (if any) and I.F. stage(s) on the nose. Result: a badly misaligned receiver and poor selectivity. -30-



Orient C2 mounting bracket as shown at top, and use small L brackets for mounting circuit board.

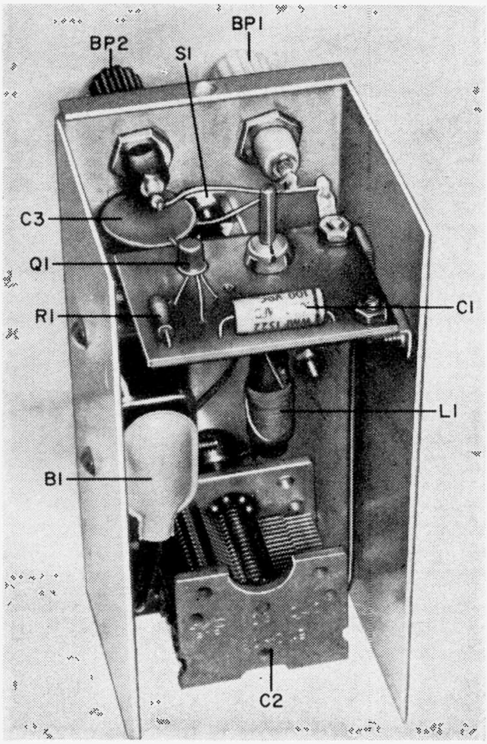
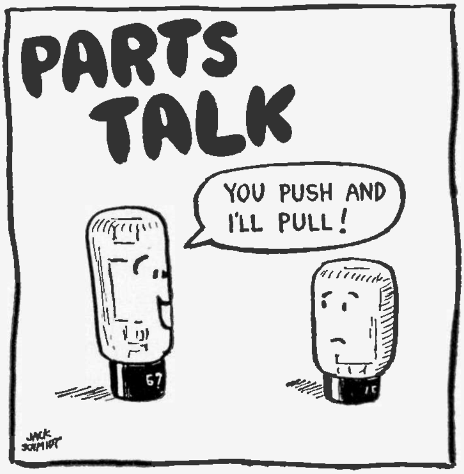
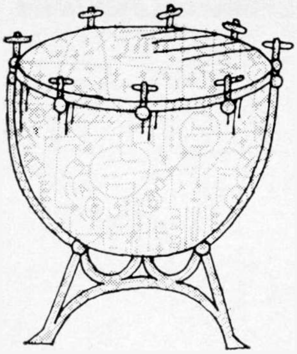


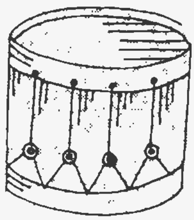
Fig. 4. Mount battery to side of box with length of aluminum stock, ½" spacers, and #6 hardware.



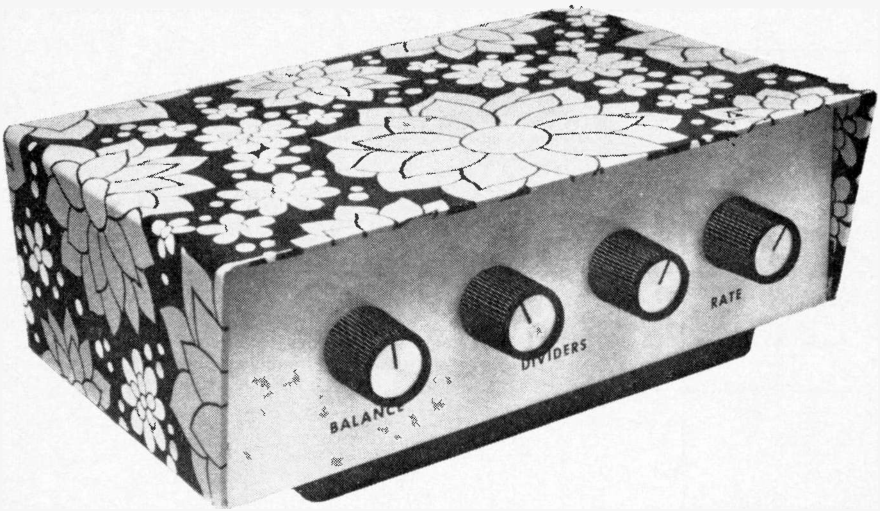
BY JOHN S. SIMONTON, JR.



THE THUMPA-THUMPA BOX



RHYTHM DRUM ACCOMPANIMENT



THE ELECTRIC GUITAR sounds best when accompanied by a tempo-setting, rhythm drum. Unfortunately, few amateur guitarists are lucky enough to find drummers who are willing to accompany them day and night. There are, however, electronic drummers that fill the bill nicely. If the $200-up price tags on commercially made electronic drummers do not appeal to you, try building the "Thumpa-Thumpa Box" for about $17.

The Thumpa-Thumpa Box, or TTB, employs low-cost UJT pulse-generator, divider and simplified "drum" circuits to produce a wide variety of percussion sounds. In fact, the TTB can duplicate most of the tricks of the expensive commercial electronic drummers—and a few that commercial units can't produce.

Just set the TTB's divider and rate controls, and you have automatic bass and wood-block accompaniment. If you are the adventurous type, you can even adjust the circuits so it sounds as if you are being accompanied by anything from a pot lid to J. Arthur Rank's gong!

Construction. Layout of the TTB circuit (see Fig. 1) is not critical; but, while any method of assembly will give acceptable results, a printed circuit board will go a long way toward guaranteeing a successful project. The printed circuit board can be obtained commercially (see Parts List), or you can etch and drill

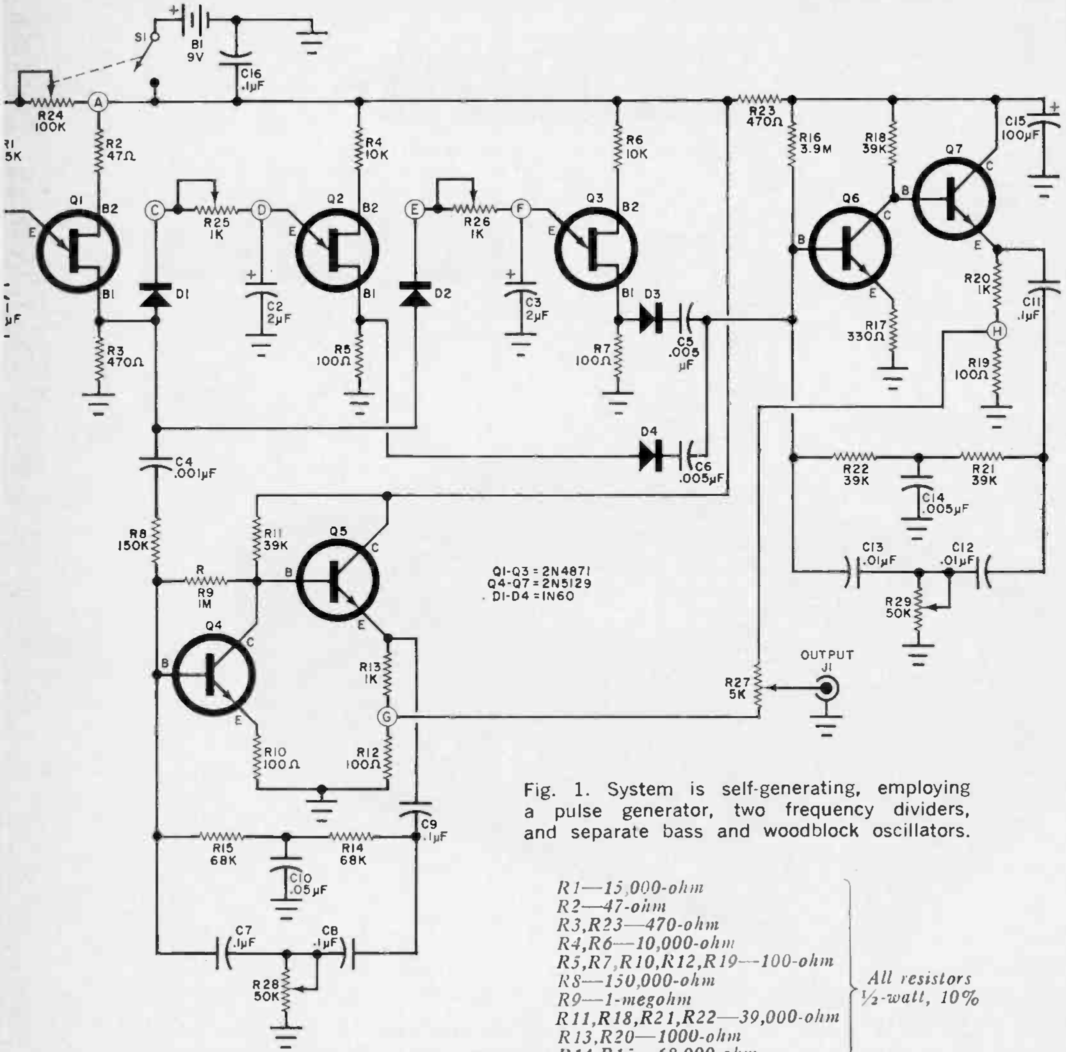


Fig. 1. System is self-generating, employing a pulse generator, two frequency dividers, and separate bass and woodblock oscillators.

PARTS LIST

B1—9-volt transistor battery
C1,C3—2-µF, 6-volt electrolytic capacitor
C4—0.001-µF ceramic disc capacitor
C5,C6,C14—0.005-µF ceramic disc capacitor
C7,C8,C9,C11,C16—0.1-µF ceramic disc capacitor
C10—0.05-µF ceramic disc capacitor
C12, C13—0.01-µF ceramic disc capacitor
C15—100-µF, 10-volt electrolytic capacitor
D1-D4—1N60 diode
J1—Miniature phone or standard phono jack
Q1-Q3—2N4871 unijunction transistor
Q4-Q7—2N5129 bipolar transistor

R1—15,000-ohm
R2—47-ohm
R3,R23—470-ohm
R4,R6—10,000-ohm
R5,R7,R10,R12,R19—100-ohm
R8—150,000-ohm
R9—1-megohm
R11,R18,R21,R22—39,000-ohm
R13,R20—1000-ohm
R14,R15—68,000-ohm
R16—3.9-megohm
R17—330-ohm
(*All resistors ½-watt, 10%*)
R24—100,000-ohm, linear-taper potentiometer
R25, R26—1000-ohm, linear-taper potentiometer
R27—5000-ohm, linear-taper potentiometer
R28, R29—50,000-ohm, linear-taper "trim-pot"
S1—S.p.s.t. switch (part of R24)
Misc.—Metal chassis case; printed circuit board; battery holder; battery connector; control knobs (4); rubber feet; #6 machine hardware; hookup wire; solder; etc.
Note—The following items are available from PAIA Electronics, Inc., P.O. Box 14359, Oklahoma City, OK 73114: etched and drilled printed circuit board for $3.50 postpaid (specify #8690); complete kit of parts, including pre-punched, unpainted case, but less battery, hookup wire, and solder for $16.75 plus postage for 2 lb. Oklahoma residents add 3% sales tax.

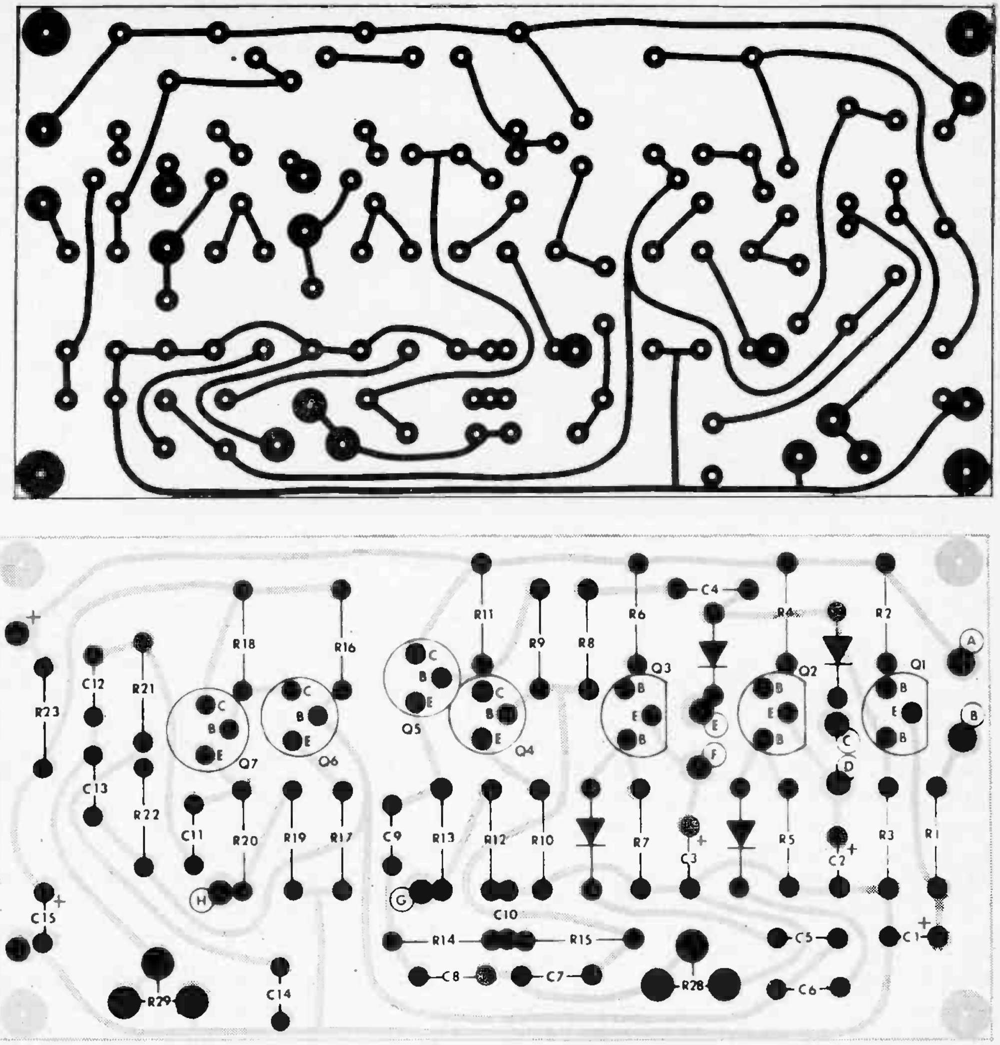


Fig. 2. Actual-size printed circuit board etching guide is shown at top. Directly above are component placement and orientation on circuit board after etching and drilling.

Battery can be conveniently mounted inside chassis with dual AA cell holder; use a conventional snap-on connector. Holes drilled directly in line with R28 and R29 (see top center of photo) provide access for tuning bass and woodblock oscillators. Mount output jack on rear.

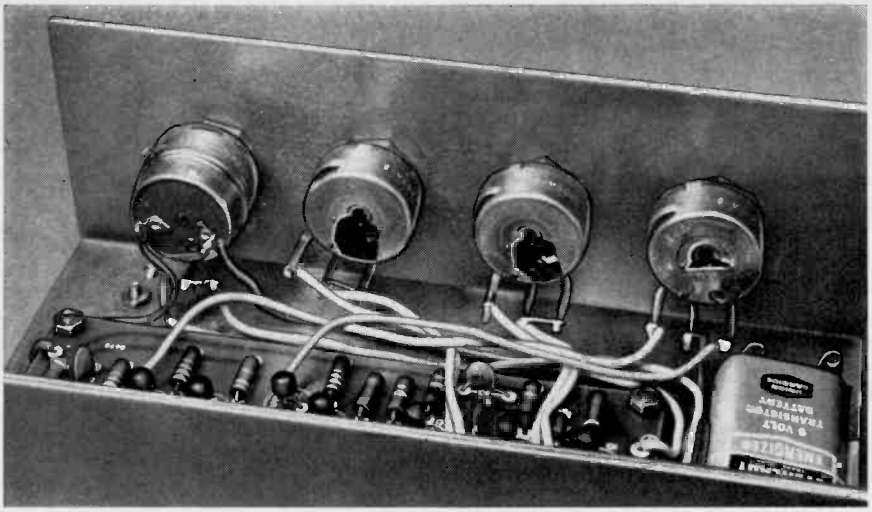


Fig. 3. All controls, except pots R28 and R29, are mounted on front panel. Battery holder and printed circuit board are mounted inside the chassis; use rubber feet on under side.

your own board by following the actual size etching guide shown in Fig. 2. In either case, mount the components on the board as shown, paying particular attention to the polarities of the electrolytic capacitors and lead orientation of the diodes and transistors. Also, when soldering the transistor and diode leads to the foil pattern, use a heat sink and a soldering iron rated at 35 watts or less.

The project can be assembled inside any metal enclosure that will accommodate the circuit board, battery, and controls. It is a good idea to decide on the locations of the components and drill the mounting holes first. Deburr the holes; then spray paint the cover or cover it with self-sticking vinyl, and just spray paint the front and back of the box.

Now mount the dual-AA-cell holder, jack, and potentiometers in their respective locations (see Fig. 3). Then mount four rubber feet to the bottom of the case.

Solder an 8″ length of wire to the circuit board at locations A through H and the hole marked with a + sign. The completed circuit board should be the last item mounted inside the case. Use 4-40 machine hardware and ⅜″-long insulated spacers and make sure the holes in the rear of the case line up with *R28* and *R29*.

Connect and solder the free ends of the circuit board wires to the controls and *S1* as shown in Fig. 4, removing and discarding any excess wire as you go. Then finish wiring together the circuit, referring back to Fig. 1 as needed. Finally, slip the battery into its holder, use a dry-transfer lettering kit to letter the functions of the controls on the front panel, and assemble the case.

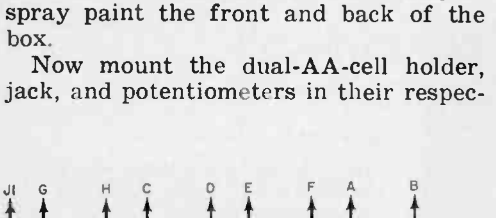


Fig. 4. Diagram shows the connections between pots and S1 lugs to lettered holes on circuit board.

How to Use. Connect a cable from the output jack of the TTB to the input of a hi-fi or instrument amplifier. Rotate the BALANCE control fully counter-clockwise, turn on the amplifier and TTB, and adjust the RATE control for a slow-tempo beat. Then rotate both DIVIDER controls fully clockwise.

Adjust the setting of *R28* for the most pleasing sound. Rotate the BALANCE control fully clockwise, and adjust the setting

HOW IT WORKS

The Thumpa-Thumpa Box consists of five basic sections: a pulse generator, two frequency dividers, and two ringing oscillators. As shown in Fig. 1, unijunction transistor *Q1* and its associated components make up a simple relaxation oscillator that serves as the "clock" generator for the system.

With *S1* closed, *C1* charges up through *R1* and *R24*. When the potential across the capacitor exceeds the threshold of *Q1*, the UJT fires and allows *C1* to discharge rapidly and produce a voltage spike across *R3*. The rate of charge and discharge, or frequency, of the clock generator can be varied by changing the setting of *R24*.

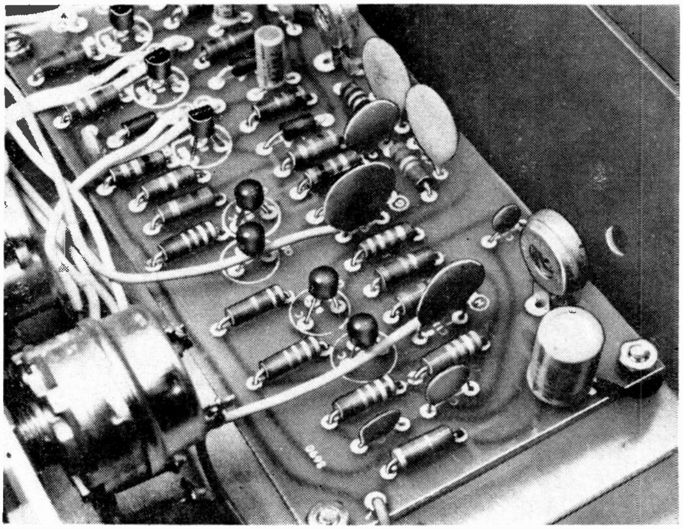
Each clock pulse does several things simultaneously. First, it triggers the ringing oscillator formed by *Q4* and *Q5* to produce a tone similar to that of a bass drum. Second, it is coupled through potentiometers *R25* and *R26* to deposit charges on *C2* and *C3*, respectively. Diodes *D1* and *D2*, normally reverse biased, prevent the charges from leaking off.

The amplitudes of the charges across *C2* and *C3* increase with each successive pulse from the clock generator. At some point during the voltage build-up, *Q2* and *Q3* fire, either simultaneously or independently, and rapidly discharge *C2* and *C3*, respectively. The resulting pulses that appear across *R5* and *R7* are then coupled to the base of transistor *Q6* in the "wood-block" oscillator. (Potentiometers *R25* and *R26* can be varied independently so that frequency dividers *Q2* and *Q3* fire at different rates to produce a wide variety of syncopated rhythms.)

The wood-block (*Q6* and *Q7*) and bass (*Q4* and *Q5*) oscillators are almost identical, each being composed of common-emitter gain and emitter-follower buffer stages. Feedback for the individual oscillators through the parallel-T filters (shown below each pair of transistors) is such that the amplifier is held just below the point of oscillation.

When a pulse is coupled to the input of either of these two oscillators, the circuit immediately breaks into a rapidly decaying oscillation. So, by properly selecting the gain of the amplifier and time constants of the parallel-T networks, the period and decay of the oscillating signals can be made to simulate the sound of practically any percussion instrument.

The output of the Thumpa-Thumpa Box is fed to an external amplifier. And potentiometer *R27* serves as a balance control to provide the desired mixture of bass and wood-block beats.



Bolt assembled circuit board to chassis via short spacers and #6 hardware. Note proper method of neatly dressing hookup wires.

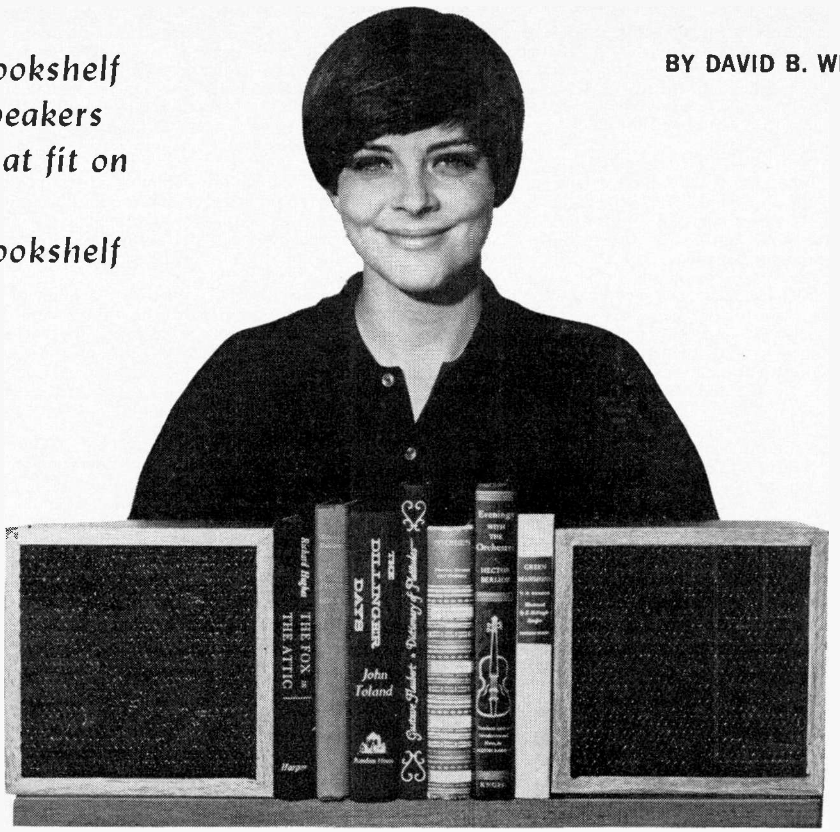
of *R29* for the most pleasing sound. Now rotate the BALANCE control back and forth to make sure the mixing, or balancing, action takes place.

In operation, the DIVIDER controls are used to produce the rhythm pattern desired. Tempo can be set by adjusting the RATE control. The BALANCE control is used to accentuate your choice of either bass or wood-block sounds. (Once *R28* and *R29* are set, they do not need to be touched again.)

A final note: the cover of the TTB case is held in place by the pressure of the sides against the front and rear of the box. However, if the TTB is to be subjected to rough handling, it is a good idea to bolt the halves of the case together with the aid of four L brackets. The mounting screws for the rubber feet can be used to anchor the brackets to the bottom of the case, and self-tapping sheet metal screws can be used to bolt the top to the brackets. —30—

Bookshelf speakers that fit on a bookshelf

BY DAVID B. WEEMS



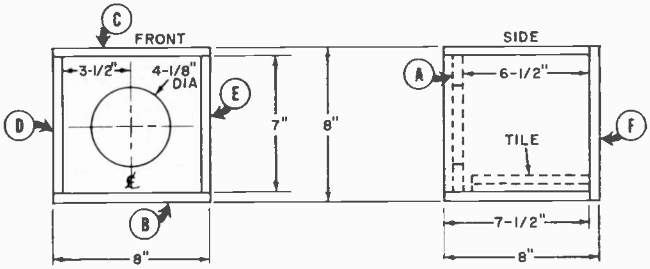
A PAIR OF LOADED DICE

It is an established fact that many so-called bookshelf speaker systems are just too large to fit on a bookshelf. The "loaded Dice," a true stereo bookshelf speaker pair, not only have the right dimensions, they are also inexpensive and easy to build. And if you prefer not to put them on a shelf, you can always use them as bookends on a tabletop or desk. (To double as bookends, each enclosure is loaded with almost three pounds of ceramic tile.)

Although the cubic shape used for the Dice is not recommended for large speaker systems, in the case of a subminiature system, it works admirably. The difference is due to the ability of the acoustical damping material to better absorb the frequencies that would normally be accentuated by the small cube. For best results, the entire enclosure must be filled with acoustical fiberglass.

The speakers used in the Dice are low-cost versions of the currently popular high-compliance type. The small cones are suspended by a rolled edge, the design of which, when coupled with a large magnet, can produce good sound in a small sealed enclosure.

Construction. The enclosures can be built at little or no cost, depending on whether you have to buy new lumber or have scraps from a previous job that you can use. Just about the only tools you need for assembly are a hammer and a



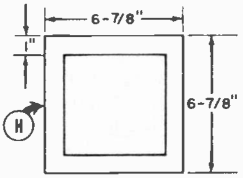


Fig. 1. Small cabinet size allows walls to be butt-jointed; sides are then finished with adhesive-backed vinyl covering. Grille frame fits directly into well in front of speaker.

BILL OF MATERIALS

1—Full-range speaker (No. XS-510 available from McGee Radio Co., 1901 McGee St., Kansas City, Mo. 64108. $3.49)
1—Two-lug screw-type terminal strip
1—8" x 8" piece of ½" plywood for rear panel
1—7" x 7" piece of ½" plywood for speaker mounting board
2—7½" x 8" pieces of ½" plywood for top and bottom panels
2—7½" x 7" pieces of ½" plywood for side panels
1—6⅞" x 6⅞" piece of ⅜" plywood for grille frame
2—6" x 6" x ½" patio tiles
1 yd. "Contact" plastic veneer
Misc.—#8 x ½" panhead sheet metal screws (4); #10 x 1½" wood screws (4); ¼" flat washers (4); ½ lb. #4 finishing nails; 12" zip cord; fiberglass wool; ⅛"-thick polyfoam; wood glue; water putty; silicone rubber caulking compound; sandpapers; etc.

saw since small boxes do not require the same degree of bracing and careful joining of parts that are musts with large enclosures.

You can begin construction by cutting the five enclosure panels, speaker mounting board, and grille frame for each system you plan to build to the dimensions given in Fig. 1. Then, after making the speaker cutout, apply two coats of flat black paint to the sides of the cutout and front surface of the speaker mounting board.

Strike a line ½" in from and parallel

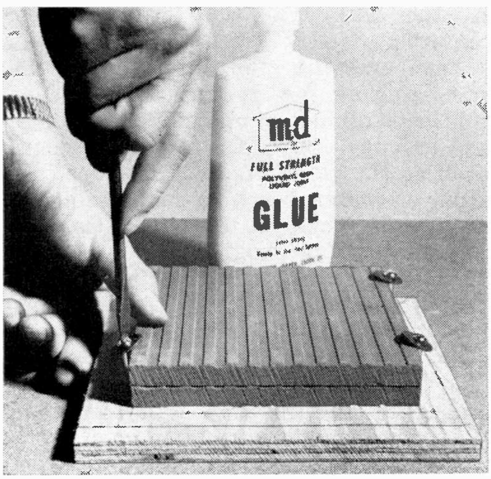


Fig. 2. Bolted down with woodscrews and washers, patio tiles load bottom of enclosure to prevent skidding when the speaker is employed as bookend.

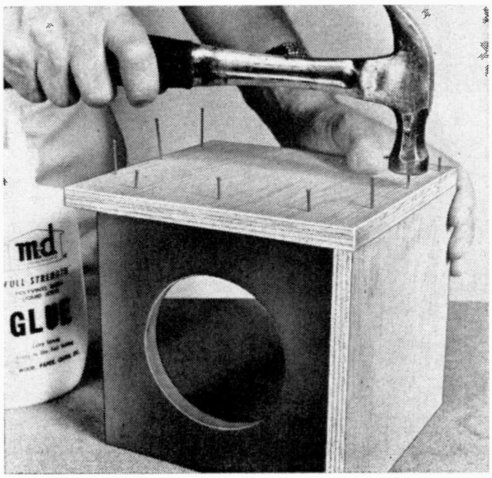


Fig. 3. Before assembly, start finishing nails into top, bottom, and rear walls of cabinet. Then apply beads of glue and hammer home nails as shown here.

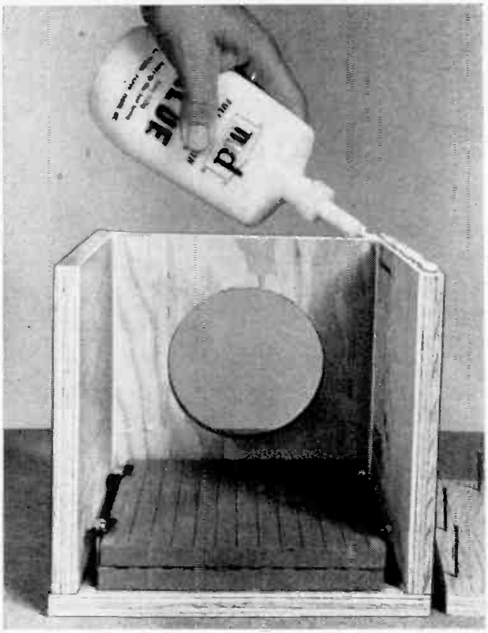


Fig. 4. Top should be last wall mounted to speaker mounting board. Note, at far right, nails partially driven into top wall to facilitate assembly.

to the front edges of the side and bottom panels to locate the position of the outer edges of the speaker mounting board. Set the speaker board onto the bottom plate, and strike another line on the bottom board along the rear edge of the speaker board. Then strike one more line 1″ in and parallel to each side edge of

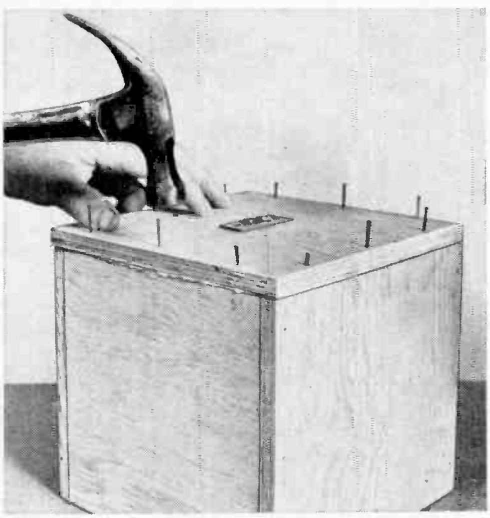


Fig. 5. Mount screw-type terminal strip to rear of cabinet; then glue and nail rear wall to cabinet shell, trueing up sides, top, and bottom as you go.

the bottom panel for the patio tiles.

Now set the patio tiles on the bottom panel, locating them within the lines previously drawn. Use glue and four #10 × 1½″ woodscrews with ¼″ flat washers to secure the tiles in place as shown in Fig. 2.

Next, glue and nail the bottom and one side panel to the speaker board as seen in Fig. 3. Then glue and nail the remaining side in place. Apply a liberal bead of glue to the top edges of the speaker board and enclosure sides; also start nails into the top panel (see Fig. 4). Lower the top panel onto the enclosure assembly, square it with the sides, and hammer home the nails.

Prepare the rear panel as follows. First determine the center-to-center distance between the two screws of a two-lug, screw-type terminal strip. This distance tells you how far apart the holes must be for the terminal strip to mount on the rear panel. Now, use a ¼″ drill to bore holes through the center of the rear panel. Try the terminal strip for fit; if the holes are too small to accept both the screw ends and solder lugs, enlarge the holes with a hand reamer.

Separate the conductors for a distance of 2″ at one end of a 12″ length of zip cord. Remove ¼″ of insulation from each conductor. Then pass one conductor through each hole, and solder them to the lugs on the terminal strip. Gently pull on the zip cord until the terminal strip is flat against the outside surface of the rear panel. Use small tacks or wood screws to anchor the terminal strip in place. Then drive the screws all the way into the terminal strip contacts.

Turn over the rear panel and fill the holes passing the zip cord with silicone rubber caulking compound. Then, glue and nail the rear panel to the enclosure shell as shown in Fig. 5. This done, use a pin or center punch to countersink all nail heads. Then fill the nail holes with "water putty" or plastic wood.

After allowing sufficient time for the putty to harden, sand all surfaces (sides, top, and bottom) as in Fig. 6. Brush away all sawdust. Cut a piece of "Contact" self-sticking vinyl veneer to 9″ by 33″. (This material is available in many patterns, textures, and colors. The richest among them is the wood "veneer"

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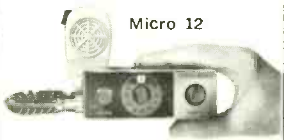

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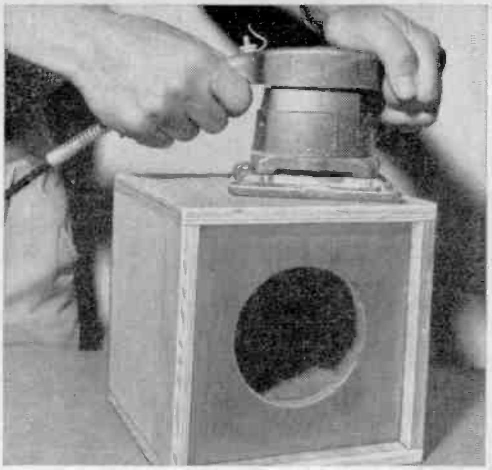


Fig. 6. Power sander is fast way of smoothing surfaces, but you can use wood block and sandpaper.

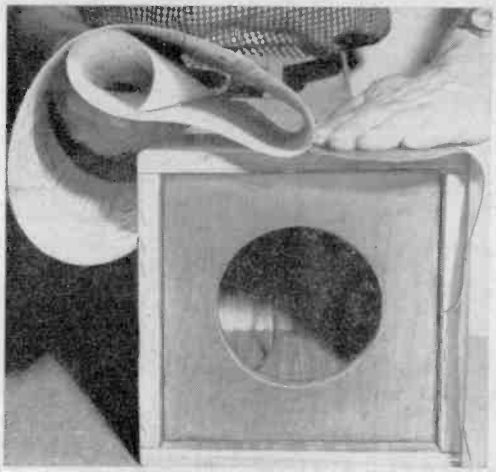


Fig. 7. Thoroughly clean off wood dust before you carefully apply adhesive-backed vinyl to cabinet.

pattern, of which there are several shades and wood grains.) Carefully following the instructions printed on the peel-away paper, stick the veneer to the enclosure sides, starting at a bottom corner so that the seam will not be visible. Apply the veneer so that it is flush with the rear edges of the enclosure and overlaps the front edges (see Fig. 7).

After pressing the Contact into place and removing all wrinkles and air bubbles, make a 90° slit at all four corners. Fold the side strips over the front edge of each side. Then cut the top and bottom strips at 45° angles so that when you fold them over, the effect will be a miter cut.

Cut a piece of acoustical fiberglass to 6″ × 24″. Roll it up and insert it through the speaker cutout into the enclosure. Now carefully unroll it, and press it into place around the interior walls. Then press into place against the rear wall another piece of fiberglass.

Route the zip cord out of the enclosure through the speaker cutout. Then fill the interior of the enclosure with small pieces of the fiberglass, and cement a ⅛″-thick ring of polyfoam around the speaker cutout to form a gasket for the speaker.

Connect and solder the free ends of the zip cord to the speaker lugs (see Fig. 8). Set the speaker into its cutout

Fig. 8. Fill cabinet with cut-up pieces of fiberglass wool, cement on gasket, and wire up speaker.

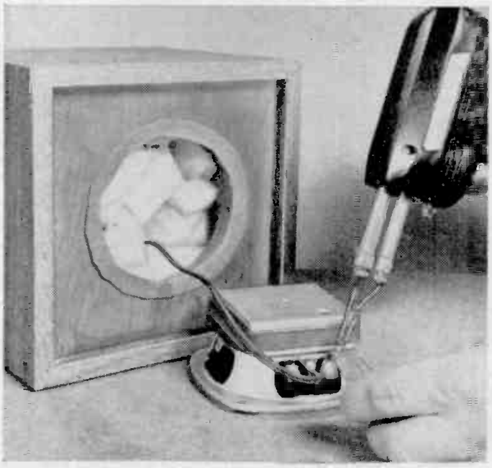
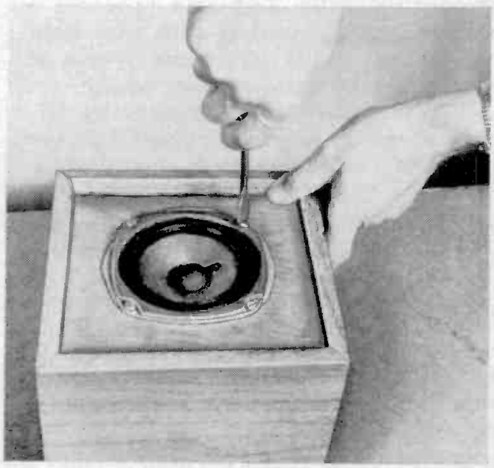


Fig. 9. Speaker front mounts to speaker board. Be careful to avoid cone damage in mounting speaker.



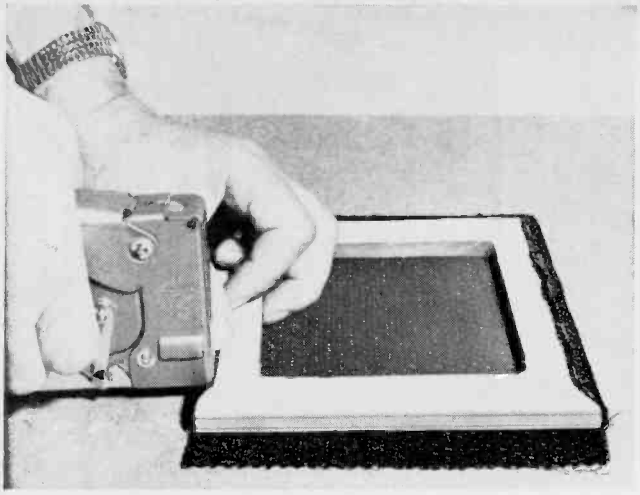


Fig. 10. To provide proper fit, the corners of the grille cloth must be notched to remove excess material before cloth is stapled to frame.

and use #8 × ½" panhead sheet metal screws to fasten it down as shown in Fig. 9.

Now determine the polarity of the speaker by momentarily touching a 1.5-volt battery to the screw contacts on the terminal strip and observing cone movement. Place a red dot or other identifying mark on or near the screw contact that is the positive end of the battery when the cone moves outward.

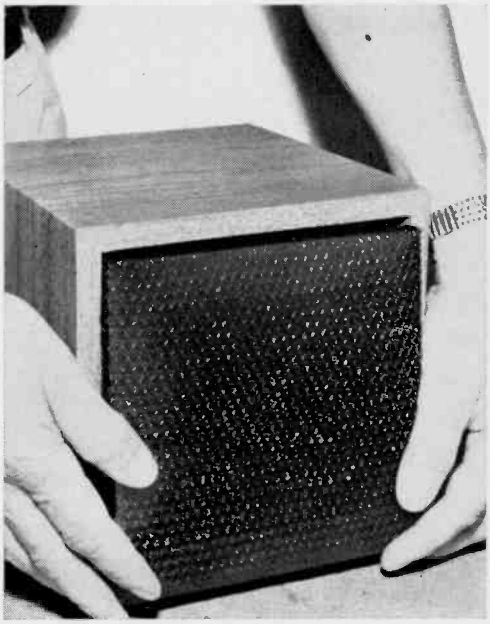
Center the grille frame over the 9" × 9" grille cloth, and cut a square notch at each corner of the grille cloth to obviate a thick overlapping at the corners. Tack or staple the grille cloth to the frame as in Fig. 10. The grille assembly can now be press-fitted into the front of the enclosure (Fig. 11). If you selected a very thin grille cloth that produces a loose fit, simply drive a thin wire brad through the grille cloth and frame at each corner into the speaker board.

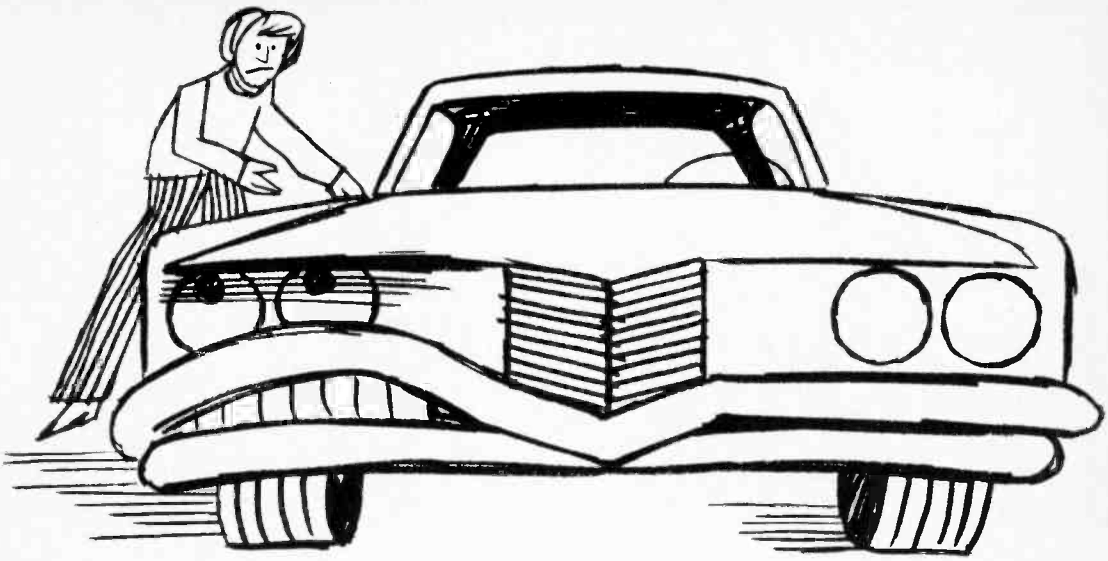
Finally, cement a 7½"-square by ⅛"-thick sheet of polyfoam plastic to the bottom of the enclosure to provide protection to the furniture on which the speaker is placed and to increase surface friction between the enclosure and a shelf or table.

Connect your speaker or stereo pair to an amplifier or receiver, taking care to connect the identified screw terminal to the "hot" 8-ohm output. Better yet, try switching the leads to one speaker (if you use a stereo pair) to check for proper phasing. When properly connected, the bass response of the system will be markedly better.

Whether you use the Dice speakers as main speakers or as extensions in remote locations, you will be delighted by their appearance and clean sound reproduction. In fact, these easy-to-build boxes might prove so appealing that you will make several pairs to provide stereo listening throughout your home. —30—

Fig. 11. Grille assembly wedge fits into front of cabinet. If fit is too loose, drive thin finishing nails through cabinet corners and into frame.





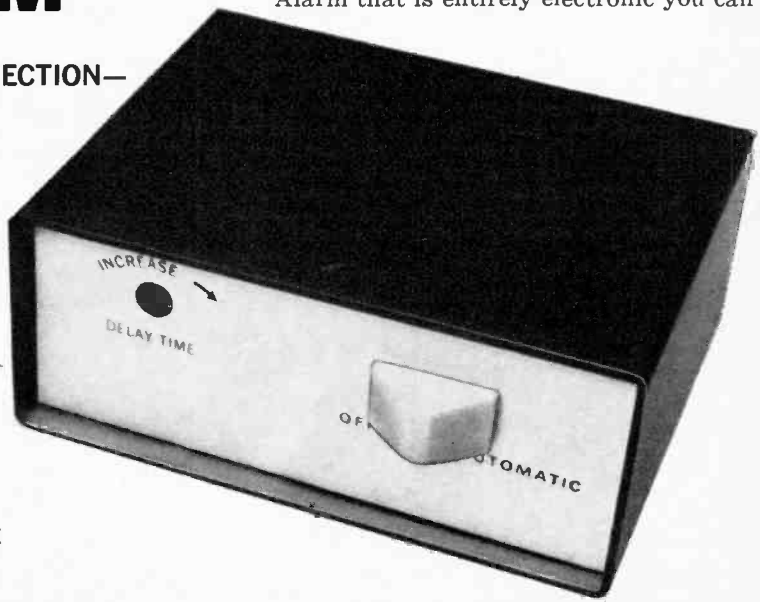
Automatic VEHICLE BURGLAR ALARM

OVERALL PROTECTION— WITHOUT AN EXTERNAL KEY SWITCH

BY GEORGE MEYERLE

IF YOUR CAR is stolen, there are automobile rental agencies which will give you special rates until the insurance pays off. That's some comfort; but these days most people should prefer a burglar alarm system to prevent theft in the first place. Most of these alarm systems require an external lock in a hole drilled somewhere in the car frame—and that leads to trouble due to dirt and ice in the lock or the fact that you lose or forget the key.

With an automatic Vehicle Burglar Alarm that is entirely electronic you can



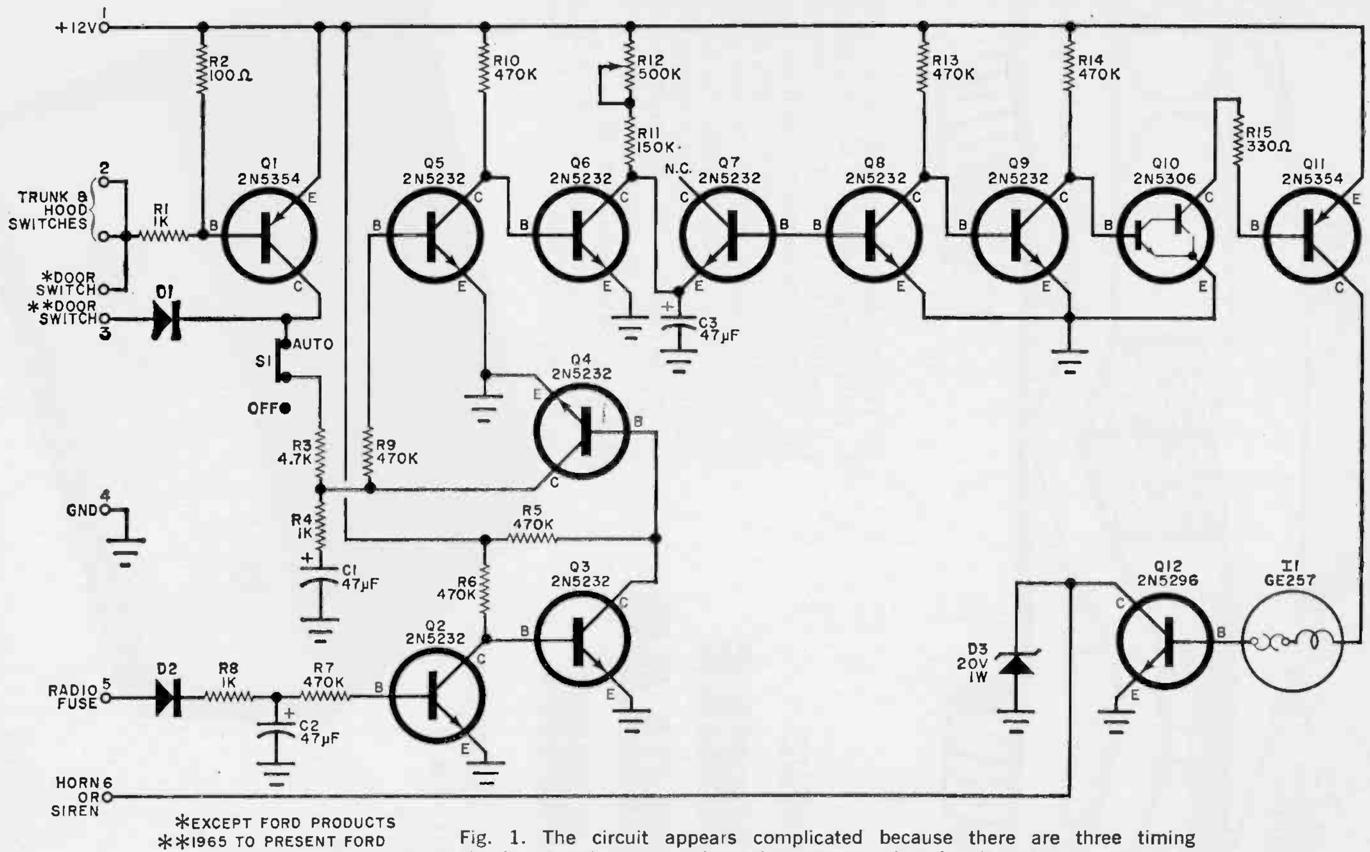


Fig. 1. The circuit appears complicated because there are three timing circuits as well as a multi-transistor power driver for the vehicle horn. If you desire siren operation, substitute a 220-ohm, 1-watt resistor for I1 and use the output line to operate a suitable relay, that in turn operates the siren.

protect your car easily and completely without the use of an extra key. Once it is installed, you can forget about it and rest assured that the car, plus the contents of the hood and trunk, are protected by a loud, persistent alarm system.

Hidden in the glove compartment, the alarm arms itself two minutes after the ignition key is turned off. This gives you sufficient time to get out of the car and close all the doors. When you return and open the doors, you have 10 to 45 seconds (depending on how you set the controls) to put the key in the ignition switch and turn it either to the ignition or accessories position before the alarm circuit is activated. Wired directly to the courtesy light circuit, the system operates when the car doors are opened. Other, optional switches are mounted under the hood and trunk covers to protect those areas.

If the alarm should sound before you get the key in the ignition, it will shut off as soon as the key is inserted. For the alarm, you can use either the vehicle horn or an optional siren. With the horn the alarm does not operate continuously, but "beeps" about once per second.

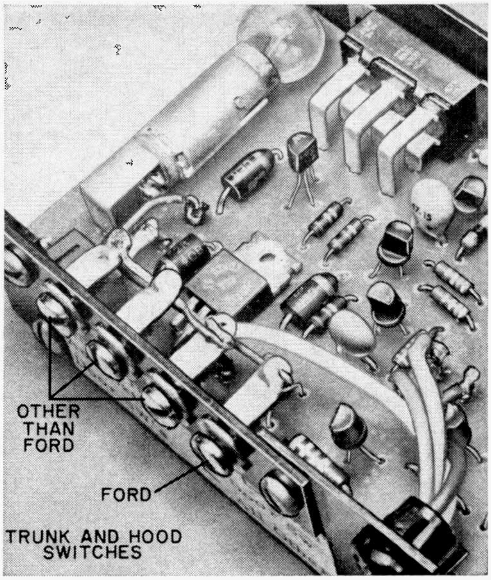


Fig. 2. The prototype was arranged for both Ford and non-Ford products. If you build your own, use only the terminals required and leave the others off. Three other-than-Ford lugs are in parallel.

The alarm sounds for about two minutes and then automatically stops. If the trouble has not been corrected—door, trunk or hood closed—the alarm starts again. If the condition has been corrected, the alarm remains off and rearms itself for further protection. This feature prevents needless public annoyance and battery drain and may also prevent a passerby from cutting a wire to make it stop. All he has to do is close the open door, hood, or trunk.

The circuit is designed so that, if you don't use the hood protection switch and a thief uses a jumper on the ignition circuit, the alarm will sound when he opens the door and tries to drive the car. The alarm will also sound, after the slight delay, even if a protected area is opened for a fraction of a second and then closed immediately.

A switch on the alarm chassis can be used to disable the system but it will not shut off the alarm once it has been set off by an intruder. The alarm system is designed to operate with any 12-volt negative-ground system. It is not temperature sensitive and standby current is only 250 microamperes.

PARTS LIST

C1-C3—47-µF, 15-volt tantalum electrolytic capacitor (Sprague 150D or similar)
D1,D2—50-volt, 1-ampere silicon diode
D3—20-volt, 1-watt zener diode
I1—Thermal flash lamp (GE257 or similar)
Q1,Q11—2N5354 (GE)
Q2-Q9—2N5232 (GE)
Q10—2N5306 (GE)
Q12—2N5296 (RCA)
R1,R4,R8—1000-ohm
R2—100-ohm
R3—4700-ohm
R5-R7,R9,R10,R13 R14—470,000-ohm
R11—150,000-ohm
(All resistors ¼-watt)
R12—500,000-ohm, printed circuit potentiometer
R15—330-ohm, ½-watt resistor
S1—S.p.s.t. slide or toggle switch
Misc.—Metal cabinet, insulated color-coded leads, barrier strip (three lug), solderless splice connectors (2), fuse connectors (2), normally closed spring-loaded switch (2, optional), horn relay for Ford products, siren (optional), mounting hardware.
Note—The following are available from Metrotec Industries, 1405 Northern Blvd., Roslyn, N.Y. 11576: printed circuit board, $1.75; complete kit including all hardware, fuse connectors, solderless splices, decal, two remote switches, and metal cabinet, $17.50; wired and tested unit with 2-year guarantee, $29.95; extra trunk and hood switches, 50¢ each; horn relay for Ford products after 1965, $1.50; heavy duty siren, $17.95. New York state residents, add 5% sales tax.

Construction. The circuit of the automatic burglar alarm is shown in Fig. 1.

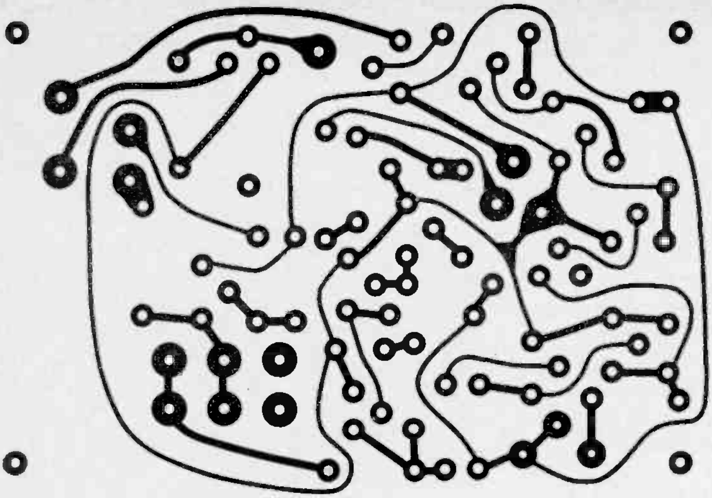


Fig. 2. Actual size foil pattern for the alarm. It can be easily duplicated with some reasonable care.

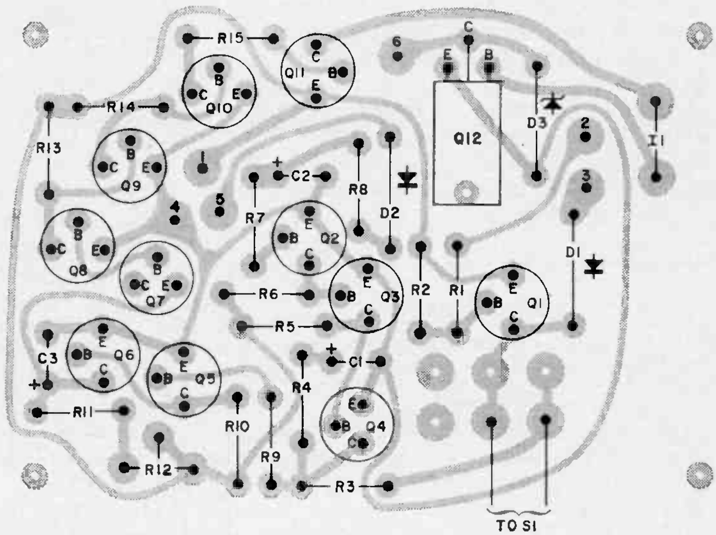


Fig. 3. Install the components as shown here. Be sure the semiconductors and the electrolytics are correctly installed and watch for solder bridges.

A printed circuit board (Fig. 2) should be used in the construction. (See Parts List if you want to buy one already etched and punched.) Mount the components on the board as shown in Fig. 3.

Install the board in a suitable metal enclosure with switch *S1* on the front panel. Drill a hole for screwdriver adjustment of potentiometer *R12*. Also drill a hole and put a grommet in it for the wires to the car's electrical system. These wires should be color-coded and about 5 feet long. Wires are connected to terminals 1, 4, 5, and 6 on the board. Also connect a wire to terminal 3 if your car is a Ford product. If it is not, mount a three-lug barrier strip on the back of the alarm chassis and connect the three lugs in parallel to terminal 2 on the circuit board. (See Fig. 4, A and B)

Installation. The alarm may be placed in the glove compartment with a small hole in the bottom or rear of the compartment for the leads. Connect the lead from terminal 1 to any point that is always at 12 volts, whether or not the ignition is on. This can be on the clock, cigarette lighter, turn indicator, dome light, battery, etc. The lead from terminal 4 is secured to any point that is in electrical contact with the vehicle chassis

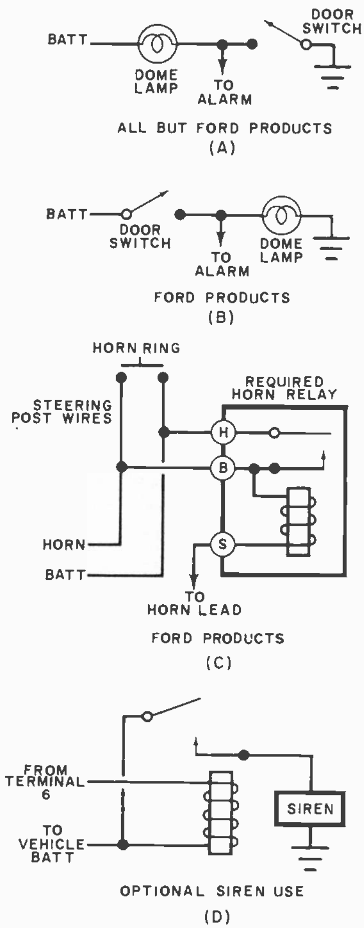


Fig. 4. Top three drawings illustrate differences between Ford and non-Ford products. Bottom illustration shows how optional siren can be driven by a relay.

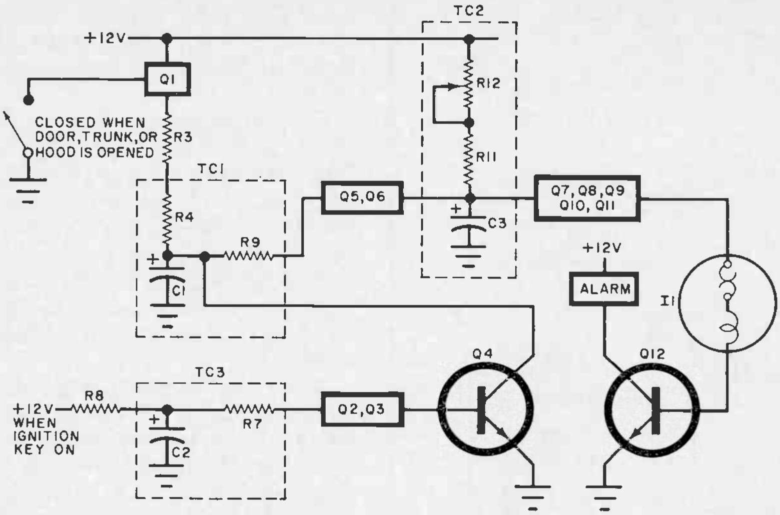
(ground). Connect the lead from terminal 5 to either side of the fuse that supplies the radio (or any other accessory that is powered only when the ignition key is in either the ignition or accessory position).

Connect terminal 6 to the horn. If the car is not a Ford product, the horn sounds only when this wire is grounded. You can use a length of test lead with one end connected to the chassis and the other end terminated in a pin or needle to find the wire that will make the horn sound. If you have a Ford product, an additional horn relay must be used, wired as shown in Fig. 4C.

If the car is not a Ford product, connect one lug of the barrier strip (terminal 2 of the board) to the lead coming from the dome or courtesy lights. The other two lugs on the barrier strip are used to make connections to the switches on the hood and trunk. These switches should be installed so that they close when the hood or trunk lid is opened. To install the switches, locate a spot where the lid comes close to the metal chassis when the lid is closed. Use good-quality insulated wire to connect these switches to the barrier strip on the alarm. Secure the wires so that they do not interfere with other vehicle wiring and operation. Do not hook up the dome light or remote switches to the barrier strip at this time.

In Ford products, the door switches are not grounded on one side. Therefore connect these switches to terminal 3 on the board and ignore the barrier strip. If you want hood and trunk protection in Ford

Although designed for automobiles, the burglar alarm can be fitted to a boat by installing hood or trunk switches on various access doors. Anyone entering such a protected area causes the boat's horn to blast an alarm signal.



HOW IT WORKS

All of the protected-area switches are open when the doors, trunk and hood are closed. When any one of these areas is opened, the associated switch closes. The base of transistor *Q1* is automatically grounded and the transistor is turned on. The time constant of timing circuit *TC1* is about 2 minutes. While *TC1* is discharging, *Q5* and *Q6* are turned on and timing circuit *TC2* is energized. Its time constant is made variable from about 10 to 45 seconds. As soon as this shorter time constant is reached, alarm drivers *Q7* through *Q11* supply base current to power transistor *Q12* through thermal flash lamp *I1*.

As long as base current is flowing in *Q12*, the alarm sounds. The flash lamp has a built-in thermal circuit breaker that opens the filament circuit after the filament has reached a predetermined temperature. When the breaker opens, the current to the lamp and *Q12* is interrupted and the alarm stops. After a very short time—about one second—the filament cools off and the breaker closes to remake the circuit. This cycle repeats producing a "beeping" of the horn or alarm.

After about 2 minutes when the time constant of *TC1* has been reached, if the protected area has not been closed and all switches returned to open, the alarm system continues to operate. If the protected area has been closed in the meantime, *TC1* stops charging and the system is reset, ready to operate again if any switch is closed.

When the operator gets into the vehicle, he has the time determined by the setting of *R12* (10 to 45 seconds) to insert the ignition key. When this is done, timing circuit *TC3* charges up and transistors *Q2*, *Q3* and *Q4* are turned on. This drains the charge off of *TC1*. When the ignition key is removed, *TC3* starts its discharge of about two minutes. After that, *TC1* is ready to be charged up again.

products, wire these switches to the barrier strip (terminal 2) connectors.

When all wiring is complete, recheck everything to make sure it is correct. Close the trunk and hood lids and use an ohmmeter to make sure that the normally open switches are open when the lids are closed and closed when the lids are open.

With all doors closed, connect the door, hood, and trunk switches to the alarm. Insert the key in the ignition and momentarily turn on the accessories. Turn the ignition off and wait at least two minutes. The alarm is now armed as it would be in normal use. If any protected area is opened now, even for a fraction of a second, the alarm should sound after 10 to 45 seconds. To stop the alarm, turn the ignition on momentarily. Using a small screwdriver, adjust potentiometer *R12* to get the desired off time between triggering and sounding of the alarm.

If you require an unlimited amount of time with the doors, trunk or hood open, place the key in the ignition and turn it

(*Continued on page* 150)

Strange Power of AIR IONS

THE NEGATIVE IONS ARE THE GOOD GUYS— POSITIVE IONS THE BAD

BY HOWARD F. BURGESS

IN THE 1700's the naive and superstitious believed that "air electricity" could influence both mind and body. A crime committed when a strong dry wind was blowing was believed to be caused by the wind, and some judges in Europe were more lenient during these windy seasons.

Yesterday's fantasy is today's scientific fact. The most exciting research programs develop when an old superstition is found to have some scientific truth. Many, such as the riddle of "air electricity," are being put together one bit at a time. Like a jig-saw picture puzzle some pieces fall into place. Others which can be recognized as part of the picture must wait on a piece that is still missing.

Although there are still some important bits to find, the picture of "air electricity" is becoming clear. We now know beyond a doubt that it can do much to control the mind and body of man. It may be the secret of controlling disease.

In 1921 Frederick Dessauer, of Germany, recognized enough pieces of the puzzle to make a start and by 1931 a picture was beginning to take shape from the data he had been able to collect. He was convinced that "air electricity" was charged air particles which surround us at all times. He had also found that if the negative particles exceed the positive particles, a condition was created which was beneficial to both mind and body. Harmful effects were found when the positive particles exceeded the negative.

Since the early work of Dessauer, many men and many laboratories have added bits to the picture. Researchers have found that air electricity is really air ionization and the results depend upon whether the majority of the ions are positive or negative in polarity. The negative ions are the good guys and the positive ions seem to be the bad guys.

What is an Ion? "Ion" is a short name for a very small piece of matter. Ions are usually measured in millimicrons which are one thousandth of one millionth of a meter. Although small, the physics involved is quite complicated. However, for present purposes the explanation can be quite simple.

An ion is a molecule or group of molecules that has become electrically charged as a result of gaining or losing an electron. A "negative ion" is one which has gained an electron. A "positive ion" is one which has lost an electron. Ions are created in many ways. Any force which can dislodge an electron from an uncharged molecule will create two ions. The molecule which loses the electron becomes a positive ion and the molecule which picks up the wandering electron becomes a negative ion. When ions of opposite polarity collide, another exchange takes place and they are neutralized.

Nature is an endless source of ions. Energy from outer space such as X-rays, ultraviolet, and cosmic rays create ions. Radioactive material in the soil also contributes to the supply. Other natural events such as thunder storms, rain and snow add their effect. Even the wind and the moon have their part in the story.

Air is composed of several gases including oxygen, nitrogen, carbon dioxide and others in lesser amounts. Air also carries varying amounts of pollution in the form of microscopic particles of anything that man can dump into the atmosphere. Water vapor also has a major part in air ionization.

Air ions seldom consist of just one gas molecule. An ion generally consists of a cluster of gas molecules which are sometimes grouped around a water particle or air pollution material. These clusters are classified according to size. Small ions may consist of 3 to 8 molecules and are capable of rapid movement. They are somewhat important for their effect on man. The intermediate sized ions may have several hundred molecules. They move slower than the small ions, and have the greatest effect on living things. Ions classed as large may contain several thousand molecules. They move very slowly and are generally related to air pollution.

For research work ions of the small and intermediate size are desired. These can be generated artificially in several ways. Radioactive sources are very good ion generators but are difficult for the ordinary experimenter to obtain. Ions can also be generated by use of a high voltage applied between special electrodes. Another source is a simple electric heating element at higher than normal temperature. Generators usually require some type of electric filter to remove ions of the unwanted polarity.

Ions are disappointingly short-lived. After generation they will travel only a short distance before being neutralized by another particle.

Ion Effects. Many events generally accepted without an explanation are the results of natural ions. The oppressive feeling before a thunder storm that is felt by both men and animals is due to the predominance of positive ions ahead of a storm. The oppression may take the form of headaches, rheumatism or respiratory attacks. The fresh, wonderful feeling that follows a storm comes from the high level of negative ions that follows a storm front. A misty rain of small droplets usually raises the positive level while a shower of large drops brings up the negative count.

The strong dry winds which occur in some areas will bring up the positive count and may have a marked effect on the temperment of both man and beast. Tests have shown that in areas that have long been noted as health resorts, the ion count many times runs predominantely negative.

In a recent news broadcast from *Radio Moscow,* Doctor G. Tsitsishvili of the Sanitary and Hygenic Institute stated that it has been determined that the higher you live (above sea level), the longer you live. Although no mention was made of ions, the findings of the doctor are interesting. American researchers have found that the number of negative ions increases with altitude.

As in other things, man alters the level and polarity of ions. Ions produced by nature are generally of the small or intermediate size and are found in clean air. But, air pollution is a factor in generating large ions. Large ions are found in urban areas or where there is air contamination. They are slow in movement. Because they are large and slow, they absorb the smaller but faster ions that collide with them and so reduce any possibility of negative ionization.

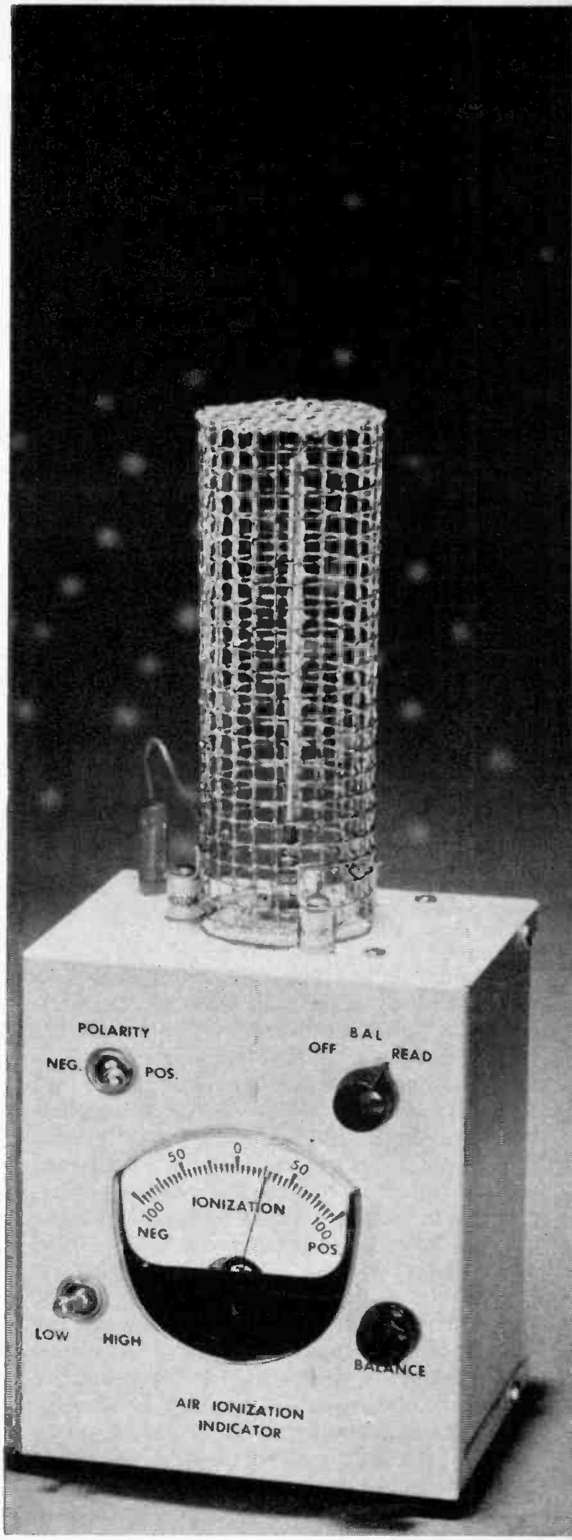
Research in air conditioning has shown that ions in an unoccupied room with open windows will be very similar to that outside. If the windows are closed, ion level of both polarities will decrease somewhat. As people begin to occupy the room the number of large ions increases and small and intermediate ions will continue to decrease. The comfort factor will decrease as the number of large ions increase. Forced ventilation through duct work will decrease the ion density but will increase the unbalance in favor of the positive ions. It has been shown that air in close quarters can be kept at the correct temperature and humidity but the occupants will still be quite uncomfortable and distressed if the number of

(*Continued on page* 151)

MAKE YOUR OWN ION CHAMBER

Detect and Measure Air Ionization Polarity

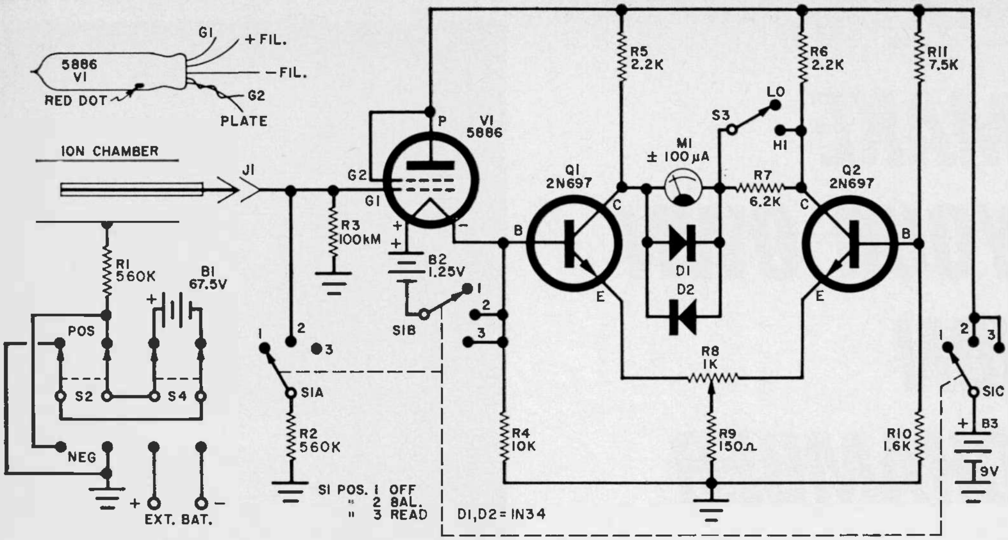
BY HOWARD F. BURGESS



USEFUL and interesting information can be gained about the effects of air ionization by making measurements under various conditions. A commercial instrument capable of doing this is expensive and delicate but a simple unit can be built which will indicate the polarity and relative amount of ionization present where larger changes are involved.

A home-built ion chamber is used to detect the ions of the polarity which we wish to count. The collected charges are then routed to the grid of an electrometer tube. This tube is a vacuum tube capable of sensing currents far smaller than those which can be detected by an ordinary tube. Currents in this type of instrument can be less than one millionth of a microampere.

The tube was chosen in preference to a field effect transistor because it can take more abuse from the high voltages which may be encountered in this type of work. Luckily the electrometer tube requires only a modest plate voltage. The output of the tube is quite low and requires amplification (transistors *Q1* and *Q2*) to operate the meter, *M1*.



Ions detected by the ion chamber develop a small voltage drop across the very high resistance of R3. This voltage is amplified and operates a transistorized bridge. Sensitivity depends on the value of R3 which must be extremely high to make the circuit effective.

PARTS LIST

B1—67½-volt B battery
B2—1.25-volt mercury cell (Mallory RM12R)
B3—9-volt transistor battery
D1,D2—1N34 diode
M1—100-0-100-microampere meter
Q1,Q2—2N697 transistor
R1,R2—560,000-ohm
R4—10,000-ohm
R5,R6—2200-ohm
R7—6200-ohm
R9—150-ohm
R10—1600-ohm
R11—7500-ohm
(*all resistors ½-watt*)
R3—100,000-megohm resistor (see text)*
R8—1000-ohm, wirewound potentiometer
S1—3-pole, 3-position ceramic switch
S3—S.p.s.t. toggle switch
S2,S4—D.p.d.t. toggle switch
V1—5886 electrometer tube (Allied CK5886)
Misc.—Phone tip packs (4), standoff insulator (3), 1"x3" terminal strip, battery holders, 4"x5"x6" utility box, knobs, hardware, etc.
**Victoreen Instrument Div., 10101 Woodland Ave., Cleveland, Ohio 44104.*

Construction. The unit is housed in a 4" x 5" x 6" aluminum box and construction is quite simple. The small parts are mounted on a 1" x 3" terminal board as in the photo. Switch *S1* must be of high quality ceramic. The variable resistor *R8* can be a standard wirewound potentiometer; however a vernier or 10-turn potentiometer makes for easier adjustment if you are lucky enough to have one. The only unusual items are the 5886 electrometer tube (*V1*) and its grid resistor (*R3*) which has a value of 100,000 megohms. Both items are made by the Victoreen Company and are available from sources shown in the Parts List.

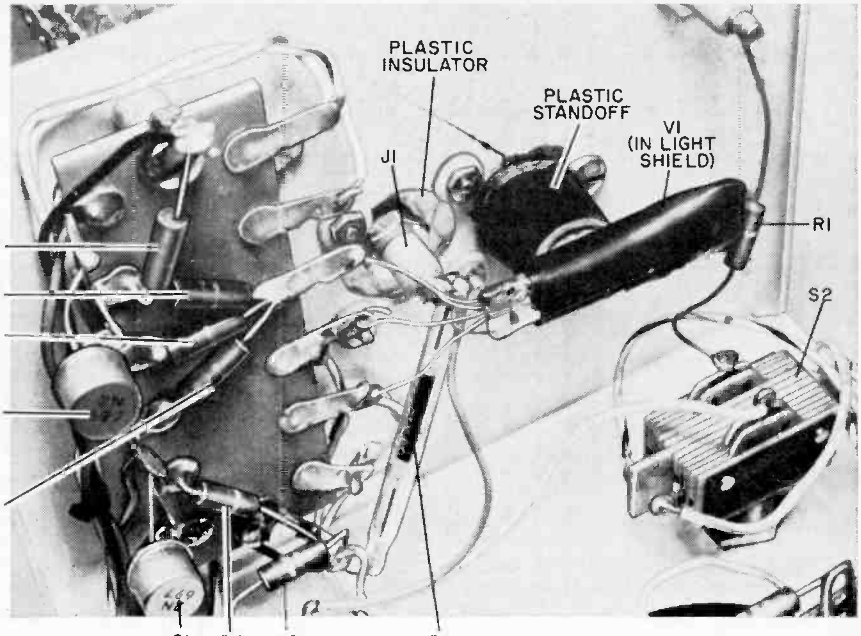
The tube must be covered to protect it from light while it is in operation or the photoelectric effect of light falling on the elements can upset the operation of the sensitive circuit. Only the best of in-

HOW IT WORKS

The ion chamber consists of an outer electrode which is in the form of a screen cage through which air can flow. The inner electrode is a rod in the center of the cage. If a polarizing voltage is connected with the negative to the cage and the positive to the rod, negative ions are attracted to the rod. This produces a voltage across resistor *R3*. The value of the voltage depends on the number of ions present. This voltage is sensed by the electrometer tube *V1* which activates the meter drive circuit. The meter is driven by transistors *Q1* and *Q2* in a balanced bridge circuit. The zero-center meter will read to right or left depending on whether the charge is positive or negative.

If the polarizing voltage is reversed to the screen cage the center rod will collect positive ions and the meter will read to the right to indicate the level of positive ionization.

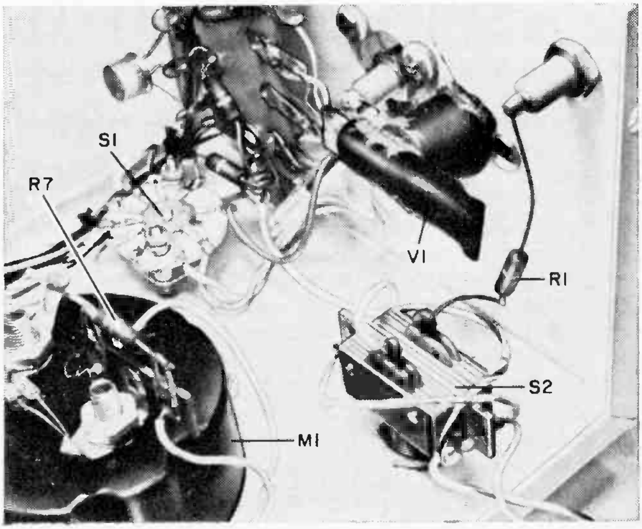
The sensitivity of the meter can be reduced by *S3* when high field strengths are encountered. The number of ions collected depends somewhat upon the value of polarizing voltage applied to the chamber. For personnel safety reasons the voltage should be kept below 250 volts.



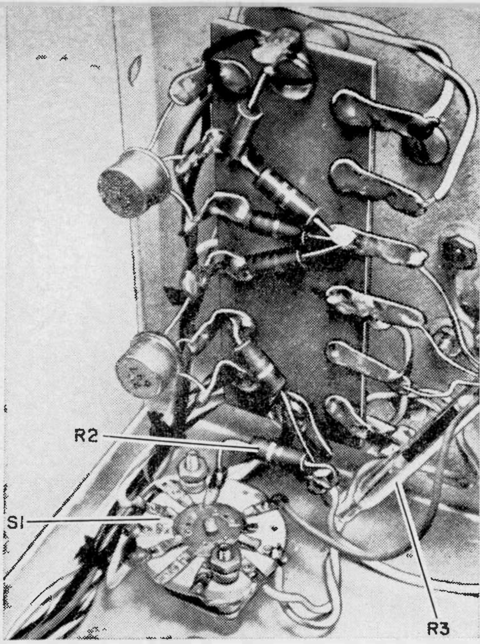
Component installation. Because the presence of light greatly reduces the electrometer tube sensitivity, it must be enclosed in an opaque tape housing. It mounts on a standoff.

sulation should be used in the grid circuit of the 5886 if full sensitivity is to be obtained. After assembly, all insulation in the grid circuit should be cleaned with alcohol to remove any oils or moisture left by the fingers.

The ion chamber, which is mounted on top of the case, consists of an outer electrode which resembles a small cage 6″ high and 2″ in diameter. It is constructed of ¼″ wire netting as shown in the photos. The bottom is open and is insulated from the metal case by three ceramic insulators. The polarizing voltage of 67½ volts supplied by the battery mounted in the case will be sufficient for most work. For experimental work where higher voltage is required, provision has



Switch S2 reverses the polarity of the ion chamber voltage. Resistor R1 is a safety resistor to reduce current flow in case of accidental short between cage and case.



Function switch S1 is located near the electronics board. Use a high-quality ceramic switch to prevent leakage around the very high value of resistor R3.

been made to switch to an outside source which can be connected to terminals on the rear of the case.

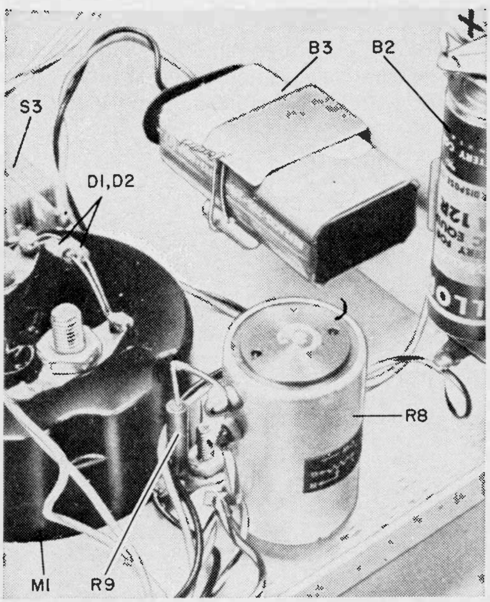
The cage is electrically above ground by the amount of the polarizing voltage. Resistor R1 has been placed in the circuit to prevent serious shock in case the cage is touched. Voltage to the cage can be removed by the switch in the rear.

The inner conductor of the chamber is a rod or wire 1/16″ in diameter and five inches long. A phone tip is mounted on one end of the rod and plugs into a tip jack. This makes for easy removal for experiments with other types of chambers. The tip jack should be mounted on insulating material of the best quality with a long leakage path. Do not depend on the insulation supplied on the tip jack; cut out a square of quality plastic as shown.

The 10,000-megohm resistor R3 is expensive. To make a substitute, use a ceramic-body r.f. choke, about 1½″ to 2″ long, with a pigtail at each end. Remove the coil and clean the form thoroughly. Draw a line of Higgins india ink about 3/64″ wide between the pigtails. Allow the ink to dry completely and never handle the form so as to touch the ink line or otherwise introduce body oils that might reduce the resistance. You may also use a narrow piece of PC board by drilling a small hole close to each end. Then wrap copper wires through each hole, leaving short lengths to make connections. Solder the wire wraps and draw an india ink line between the two solder joints.

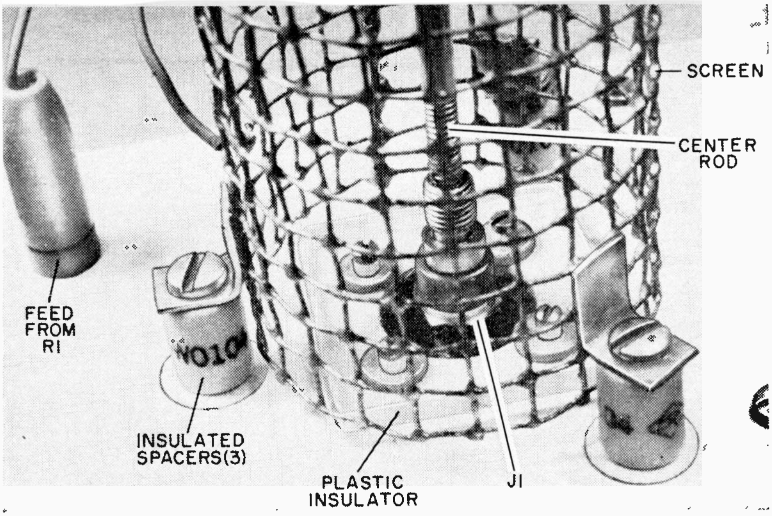
Adjustment and Operation. When the construction is finished and checked, place *S1* in the OFF position and *S3* in the LOW position and install the batteries. When *S1* is moved to the BAL position, the unit becomes operational but with greatly reduced sensitivity. The meter should now be adjusted to center zero. If the meter does not adjust to zero with *R8* near the center of its range, the value of *R10* should be changed to balance the currents of the two transistors. The value of *R10* can be raised or lowered a small amount as required.

When the meter zeroes near the midrange of *R8* and all appears well, put *S1* in the READ position and close *S3* by placing it on HIGH. Several seconds may be required for the meter to stabilize. If *S2* is in the POS position, the meter will read to the right for any positive charge. Now place *S1* in BAL and reverse *S2*. Return *S1* to READ and read the negative charge. Under normal conditions the readings will be small and nearly equal.



Standard potentiometer may be used for R8 instead of 10-turn unit. Diodes mount on meter terminals.

The cage is mounted on three ceramic spacers around the perimeter and is connected via an insulated lead to resistor R1.



Never change S2 *except when* S1 *is in the* BAL *position.*

If a lighted match is brought close to the chamber the results of ionization will be seen. Tobacco smoke blown into the chamber will also indicate ionized particles. If an ultraviolet lamp is available, turn it on the chamber and observe the results.

A small slow-moving fan is useful to force air through the chamber. A fan which stirs the air too violently or which has arcing brushes can generate ions of its own which can make measurements meaningless.

An interesting test can be made on electric heaters. Many heaters generate positive ions and the side effects that go with them. One electric hair dryer tested was capable of pushing the meter off scale from as far away as six feet. The use of such heaters will probably not cause any violent side effects but they have been known to cause drowsiness, fatigue and headaches. Long periods of continued use could be damaging to the general health. Heaters which are rich in ions usually have heating elements which glow brightly.

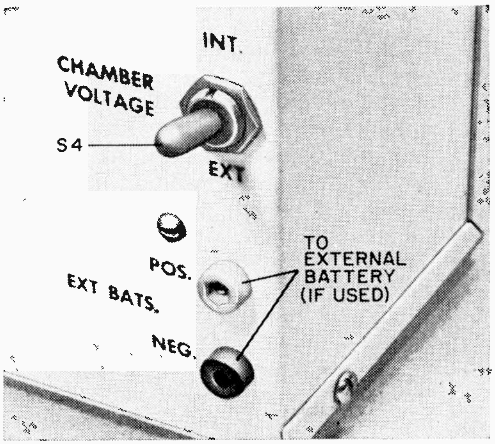
It has been found that metal duct work in some air conditioning systems creates a positive ion condition by attracting negative ions to the duct walls and leaving an excess of positive ions. The result can be minor respiratory troubles.

If the meter is placed near an automobile exhaust in a position which will allow the gases to reach the ion chamber large values can be read. In this case both positive and negative ions will be indicated. These will re-combine in a short time under normal conditions.

Radioactive material will also register on the meter. As an auxiliary use the meter can be used to measure or monitor radioactive conditions or fallout. Other types of chambers may be constructed for use in this field.

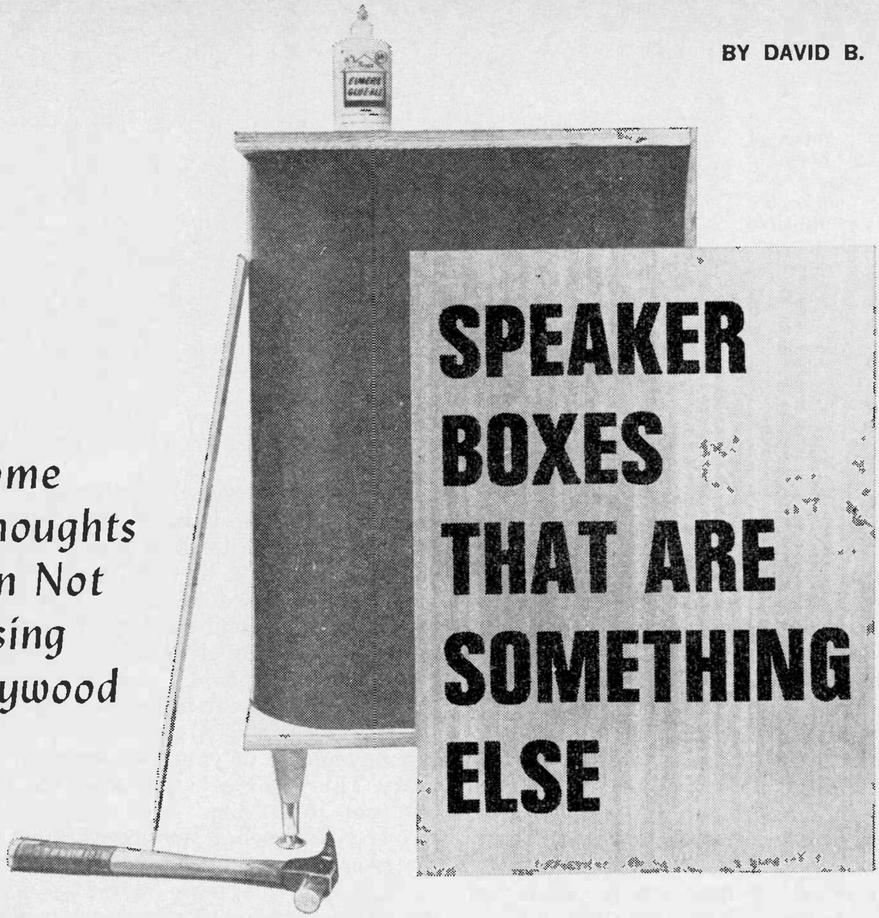
If the instrument is operating properly it will be sensitive enough to register movements of your body several feet away. This is a static charge on the body and not ionization. This effect can be reduced somewhat by connecting the meter case to a good ground.

Although this little meter is not as versatile as the sophisticated laboratory models, it will make many interesting measurements and it will introduce you to the fundamentals of what may prove to be one of the secrets of life itself. —30—



Switch S4 is used if it is desired to use a higher voltage for the ion chamber for more sensitivity.

BY DAVID B. WEEMS



SPEAKER BOXES THAT ARE SOMETHING ELSE

Some Thoughts On Not Using Plywood

WHETHER by design, accident, or habit, plywood has become the common working material of hi-fi enthusiasts who build their own speaker enclosures. Considering that plywood is stronger than solid lumber of equal thickness and that it is available in large, flat sheets, it is not a bad choice.

Unfortunately, the cost of plywood has skyrocketed over the years—so much so that many hi-fi'ers are beginning to have second thoughts about building their own enclosures. Plywood, however, is not necessarily the only, nor maybe even the best, material for constructing speaker enclosures. There are many other materials that, while not as strong as plywood, have better acoustical damping and resonance characteristics.

If this comes as a surprise, considering that most factory-made enclosures are made of plywood, rest assured that it is an acknowledged truth. Manufacturers use plywood for two basic reasons. First, labor—not materials—is the greatest expense involved in building an enclosure. Second, some of the substitute materials would not look good in advertising copy. The buying public has come to accept and expect plywood; so plywood enclosures are what they get.

In this article, your attention will be called to some of the better plywood substitutes. Equipped with this information and other pertinent data, you should be able to choose a material that will allow you to cut drastically the cost of your next speaker enclosure project.

Enclosure Basics. The purpose of any speaker enclosure is to isolate the speaker from the room so that sound produced at the rear of the speaker does not interfere with the sound coming from the front. Any material which interrupts the transmission of sound from rear to front will serve the purpose. Only one qualification is necessary to the rule: the material must not vibrate. Vibration of the enclosure walls uses up energy that should go into the production of sound. Worse, it has resonances of its own, resulting in a rough system response curve.

There are actually two resonant characteristics in every enclosure; that of the enclosed air, called "Helmholtz" resonance, and wall resonance. Fortunately, you can avoid the worst effects of each by careful planning of the shape of the enclosure.

On all counts, a cube-shaped box is bad. The path length of sound reflected by opposing walls in such a symmetrical enclosure is the same in all three directions, and five of the six walls have essentially the same resonant frequency. The speaker changes the resonance of the wall on which it is mounted. Five nearly identical walls can add up to some nasty "booming" effects, especially if they are thin and undamped. Consequently, the first rule in enclosure design is to have a minimum of three different-size walls.

The rectangular box, with its three pairs of different-size walls, is the traditional choice of enclosure builders. Even here, the ideal is to have no two walls with the same resonant frequency. The speaker mounting and its opposing walls present no problems in this area; they naturally have different resonances, although they are identical in outline. All you do is brace *one* wall of each of the remaining two wall pairs to obtain the desired six different resonances.

Another design goal is to make the resonant frequency of the walls as high as possible. In light of the fact that many speaker manufacturers strive to lower the resonance of their speakers, this might at first appear to be a strange approach. There are, however, several good reasons for raising the resonant frequencies of the walls. First, the higher the resonance, the easier it is for the walls to absorb objectionable sound. If the frequency can be raised enough, ordinary acoustical damping material

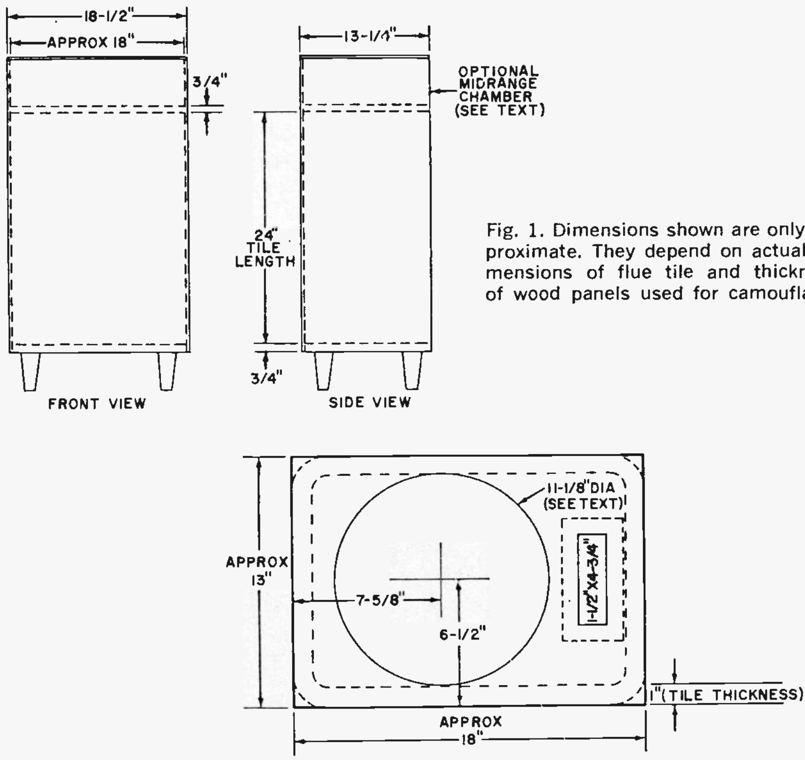


Fig. 1. Dimensions shown are only approximate. They depend on actual dimensions of flue tile and thickness of wood panels used for camouflage.

(such as fiberglass, cotton batting, etc.) in the enclosure will help to cancel resonance effects. Also, there is the bonus that the same methods used to raise the resonance of the walls will increase wall damping.

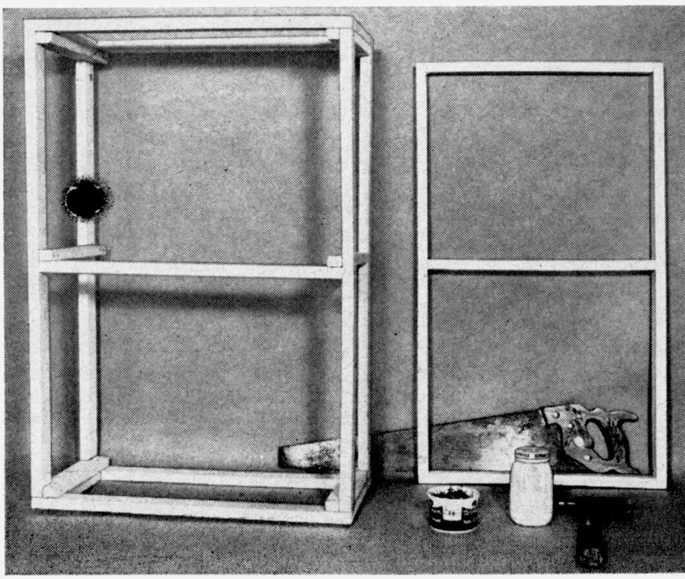
The resonant frequency of a wall panel is dependent on its size, thickness, stiffness, shape, and (if used) damping material. Consequently, if other factors are equal, a panel of small area has a higher natural resonance than a large panel. This explains why relatively thin materials that are unsuitable for large enclosures can be satisfactory for small enclosures. Thick, stiff walls of unequal length and width tend to have high resonant frequencies, but don't overdo the unequal length and width trick or you will end up with a "pipe" effect, and air column resonance within the enclosure will become a problem. For all practical purposes, the longest internal dimension should be less than three times the shortest dimension.

Substitute Materials. When choosing substitutes for plywood, the denser the better. You have probably seen or heard of excellent speaker enclosures made of concrete, brick, and ceramics. (Aluminum and steel meet the density requirement, but both tend to "ring" and should be avoided.) For example paper is denser than wood. So, you might start with a sheath of paper, a quart of glue, and a lot of patience and end up with a pretty good enclosure. But there must be a more practical approach.

A common material that has greater density than plywood and which is already being used as a plywood substitute goes under such names as particle board, chip board, etc., implying that it is made of wood chips and sawdust bound into board form with a resin glue binder. The boards are available in different sizes and thicknesses, the most common being 8′ × 4′ with thicknesses of ½″, ¾″, and 1″. Size for size and thickness for thickness, these boards are considerably less expensive than plywood. Lacking a grain, they are less resonant but less strong than plywood.

Chip board is essentially a semi-finished material. It is cut to size and glued and screwed or nailed together in the same manner as plywood. The only extra step is that it must be finished (painted or covered with a wood-grain plastic veneer or contact material).

The remaining plywood substitutes, with one exception, are laminated materials. If you like the unusual, there are several materials that are more convenient than gluing together sheets of paper. One of these is the corrugated paperboard shipping carton. Of particular value here are the heavy cartons rated as two- and three-ply paperboard that are used to ship large or extra heavy items. A check with your local hardware,



Laminated enclosure walls require wood frame made from pine for support and bracing.

plumbing, or appliance dealer might turn up paperboard of sufficient size that can be laminated to make enclosure walls.

As a point of fact, enclosure walls made of laminated paperboard are roughly comparable in performance to plywood walls of equal thickness. The only problem is that they are more difficult to join at the corners. One method of construction, as shown in the photo on page 122 is to nail and glue the laminated walls to a pine frame. Finishing can be with wallpaper.

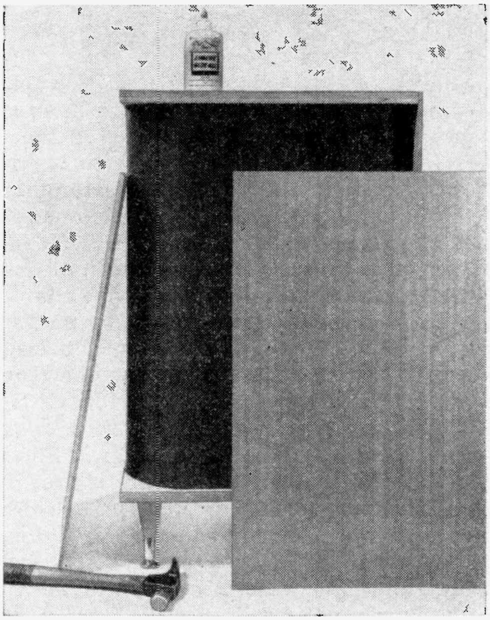
Almost any plywood enclosure can be improved by cementing another material, such as celotex or asphalt roofing felt, to the interior walls.

The use of a combination of materials, such as celotex, gypsum wallboard, and thin plywood was discussed in the "Club Sandwich Reflex" speaker system in the 1964 ELECTRONIC EXPERIMENTER'S HANDBOOK. Materials for "sandwich" enclosures need not have great density, particularly if the ratio of stiffness-to-mass is high. One such material is styrofoam. However, it is almost transparent to low frequencies, which defeats the purpose of the enclosure. This also rules out the use of a styrofoam-only enclosure.

G. A. Briggs, the well-known speaker authority with the Wharfedale Wireless Works Ltd., mentions in his "Cabinet Handbook" that he has used a material like styrofoam as a core between 1/8"-thick layers of hardboard on one side and plywood on the other side to obtain a very lightweight enclosure that is virtually resonance-free.

Select laminated materials and you can probably duplicate an enclosure at a fraction of the cost of using plywood. Simply follow the published design you want to copy, substituting the laminated material for plywood. Just be sure to plan it so that the interior volume of the enclosure remains the same. This means that if you use a frame for mounting the wall panels, you must compute the cubic displacement of the frame and make suitable adjustments in the sizes of the walls to maintain the design volume.

One remaining plywood substitute worthy of mention is ceramic tile. And in calling out its relative merits, a construction project was devised, the details for which follow.



Once plywood end plates are secured to flue tile, glue and nail front and sides to the end plates.

A Flue Tile Speaker System. Several years ago, experimenters in England started putting speakers into lengths of sewer pipe. (An example of such a speaker system was published under the title "Drain Pipe 8" in 1963 EXPERIMENTER'S HANDBOOK). Although purists criticized these systems because the low frequency radiation was so distinctly separated from the highs and referred to them as "resonant columns," they actually sounded better than they looked.

Another perhaps more practical tile enclosure form is the ceramic flue tile. These tiles are available in various sizes and they are easily adapted to speaker enclosures of usable dimensions, even if the weight of the completed system is a bit unwieldy. Plywood is used in such enclosures very sparingly at the top and bottom open ends of the tile. Further stiffening of the plywood ends can also be obtained by running a threaded rod through the enclosure ends and tightening it down with nuts.

In their freedom from wall vibration, flue tile enclosures are a purist's dream, but they are a decorator's nightmare. One such system, called "Another Ceramic Tile Enclosure (EXPERIMENTER'S HANDBOOK, Spring 1965), produced very good sound but certainly won no awards for appearance.

With a little imagination, you can camouflage the flue tile. The method employed in the project illustrated in Fig. 1 is to extend the plywood plates at the open ends of the tile to a rectangular shape just large enough to accommodate the outer perimeter of the tile. Thin finished wood panels can then be nailed to the plywood ends to hide the flue tile.

You can start construction by cutting two pieces of ¾″ plywood to the sizes needed for the end plates. Set one plate aside temporarily, and referring to the bottom drawing in Fig. 1, cut the openings for the port and speaker. (For a 12″ woofer, cut an 11⅛″ opening; for an 8″ speaker, cut a 7″ opening.) Then prepare two 1½″-long and two 6¼″-long sides from 1¾″ × ¾″ pine for the port. Glue and nail these pieces to the bottom plate over the port opening.

The enclosure is easily assembled with the liberal use of silicone rubber caulking compound. Aside from mechanically joining the two dissimilar materials—wood and ceramic—the caulking compound provides an excellent air seal.

Assembly is best accomplished as follows. First, apply a liberal bead of caulking compound to the lip of the flue tile. Invert the tile onto the blank plywood top plate, and carefully square the two pieces in relation to each other. Allow the compound to set solid as the weight of the tile bears into the silicone rubber.

When the caulking compound has completely set, invert the assembly. Cut a piece of acoustical fiberglass wool to size and cement it to the inner surface of the top plate. Then cement a fiberglass wool liner around the inner surfaces of the tile. This damping material is necessary to reduce the reflections that would otherwise be caused by the hard, relatively smooth interior surfaces of the tile.

Next, repeating the instructions given above for the top plate, caulk the bottom plate to the open end of the flue tile. After allowing sufficient time for the caulking compound to set, use a sharp knife to pare away any bleed-over silicone rubber that might interfere when the thin wood sides are attached later.

Again invert the assembly, and front-mount the woofer in its cutout as shown in Fig. 2. Bring the speaker cable out through a hole drilled in the bottom plate, and fill the hole with caulking compound.

Now, connect the speaker cable to your amplifier and feed in some music that is heavy on the bass. If the sound is not just right for your taste, drop cut-up pieces of fiberglass wool into the enclosure (through the port) until you are satisfied. Then turn off the music and disconnect the speaker cable.

All that is left to do at this time is to add a good midrange speaker and/or tweeter, if desired. If you plan to incorporate the midrange speaker and/or tweeter, determine how much longer to make the side and front wood panels. Then cut the sides and front to size (the rear of the system does not need a panel, nor should there be a panel at the rear of the midrange speaker/tweeter chamber). Nail and glue the panels to the end pieces of the woofer chamber. Then cut to size and nail and glue a top plate in place.

Finally, wire the midrange speaker and/or tweeter together, and connect a suitable crossover network between the two chambers to make a "system" that can be connected to your amplifier. That's it! —30—

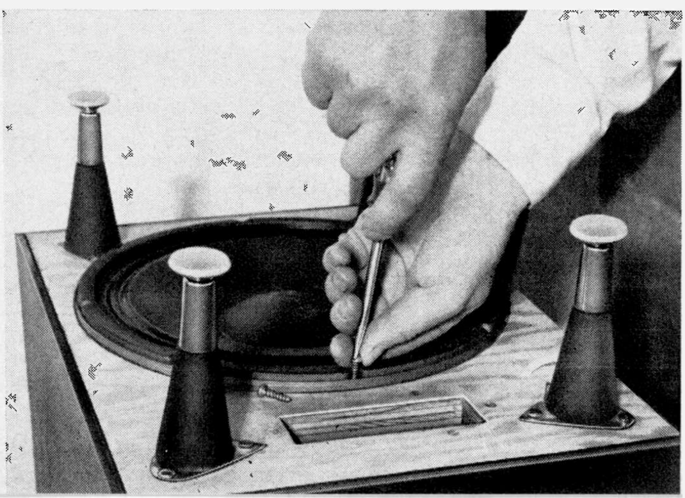


Fig. 2. Because speaker board is fixed by caulking compound, it is necessary to front-mount woofer. Staple or tack grille cloth over speaker cone to protect it against dust and pets.

A REAL BOSS SOUND

THE WAA-WAA

Be first with a new vibration

BY JOHN S. SIMONTON, JR.

IF YOU'RE an avid admirer, and a participant in, the rock music scene, you may have noticed that really "new" sounds are coming out of few recording studios and even fewer groups. Fuzz, reverb, tremolo, and vibrato are being overworked.

The groups that have something new have been keeping it under wraps; but now the secret is out—it's the "Waa-Waa" sound.

You don't need fancy gear to create your own Waa-Waa sound. This story tells how to build a foot-operated self-contained Waa-Waa unit that is simply plugged into the circuit (using ordinary shielded phone cables) between your guitar and amplifier.

Unless you press the Waa-Waa pedal, the sound from your guitar remains unchanged. Pressing the pedal (and releasing it according to the effect you want to create) introduces a totally new sound experience. It's pretty difficult to describe in print. Some groups think it sounds like a "wow" or "whoop"; others use the Waa-Waa to create an effect as if the music were being modulated by the gentle spring breeze. You can do all sorts of tricks with the Waa-Waa and the difference is that this is practically a musical instrument itself. It's not just an idiot box that you turn on and forget. You actually play the Waa-Waa to add a new dimension to any sound signal that is rich in harmonics.

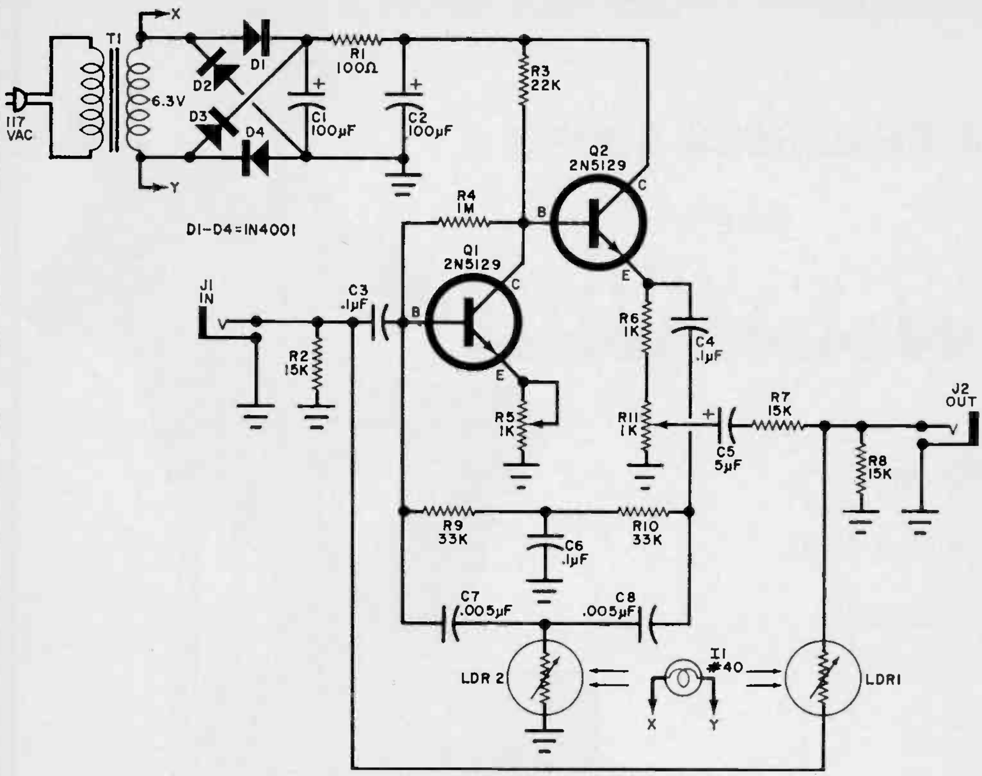


Fig. 1. The circuit is a variable-frequency, narrow-band amplifier whose gain and center frequency are determined by the amount of light on the LDR's.

PARTS LIST

C1,C2—100-µF, 10-volt electrolytic capacitor
C3,C4,C6—0.1-µF disc capacitor
C5—5-µF, 6-volt electrolytic capacitor
C7,C8—0.005-µF disc capacitor
D1-D4—1N4001 diode
I1—#40 pilot lamp
J1, J2—Open-circuit phone jack
LDR1—Light dependent resistor (Clairex 703L)
LDR2—Light dependent resistor (Clairex 703)
Q1,Q2—2N5129 transistor
R1—100-ohm
R2,R7,R8—15,000-ohm
R3—22,000-ohm
R4—1-megohm
R6—1000-ohm
R9,R10—33,000-ohm
All resistors ½-watt
R5,R11—1000-ohm, printed circuit type trimmer potentiometer
T1—Transformer, secondary: 6.3 volts at 300 mA
Misc.—Chassis, wooden foot pedal, mounting bracket for light dependent resistors and light, light mask, spring, dust cover, terminal strips, rubber feet (4), line cord, strain relief, flat black paint, shielded, cable, wire, etc.
Note—The following are available from PAIA Electronics, P.O. Box 14359, Oklahoma City, Oklahoma, 73114: etched and drilled PC board #7690, $3.00, postpaid in continental U.S.; prepunched case including all brackets, spring, etc., unpainted, #7690C, $5.10, plus postage for 2 pounds; complete kit including case, circuit board, and all parts, #7690K, $18.75, plus postage for 3 pounds. Oklahoma residents, add 3% sales tax.

Construction. The electronic portion of the Waa-Waa is straightforward and follows the schematic shown in Fig. 1. Component layout is not critical and any method of assembly may be used. Use of a printed circuit board lends a professional touch and guarantees correct wiring. You can make your own board using the foil pattern shown in Fig. 2 or you can buy one as described in the Parts List. Install the components as shown in Fig. 3.

Mechanical construction of the Waa-Waa can be done in one of a number of ways. Basically, what is needed is a U-shaped, sloping top chassis, large enough and strong enough to support the user's foot. A wooden pedal forms the

HOW IT WORKS

The circuit is basically a bandpass amplifier composed of a common-emitter gain stage *(Q1)* and an emitter-follower stage *(Q2)*, with feedback through a parallel-T filter *(C6, R9, R10* and *C7, C8, LDR2)*. The width and center frequency of the pass band are controlled by the resistance of LDR2, a value proportional to the amount of light falling on the photoresistor's surface.

When the foot pedal is up, *LDR1* is exposed to the light from *I1*. The light striking *LDR1* causes its resistance to be so low that it provides a direct, low-resistance path from the input jack to the output, bypassing the amplifier. As the foot pedal is depressed, it first blocks the light falling on *LDR1*, thereby raising its resistance so that the signal goes through the amplifier. As the pedal is depressed further, the section of the mask which is in front of *LDR2* gradually begins to expose the surface of this photocell. Its resistance is thus decreased, raising the center frequency of the amplifier's pass band.

Potentiometer *R5* is used to adjust the gain around the feedback loop and is set so that the circuit is held just below the point of oscillation. Potentiometer *R11* is used to adjust the gain at the output and is set so that there is no noticeable change in the volume of the instrument as the Waa-Waa is switched in and out.

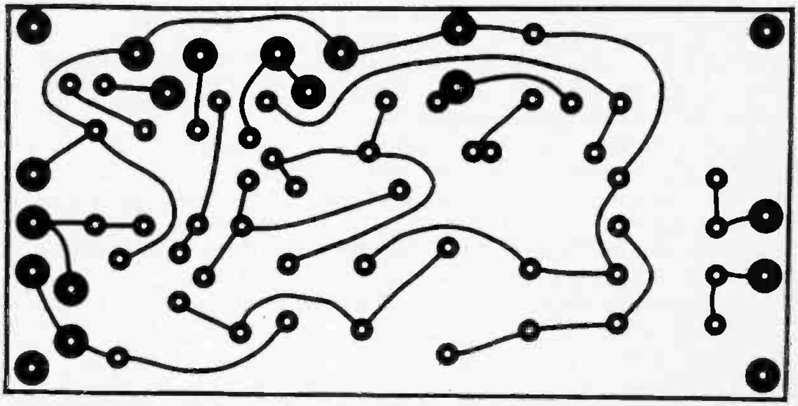


Fig. 2. Actual-size foil pattern can be used to make your own circuit board.

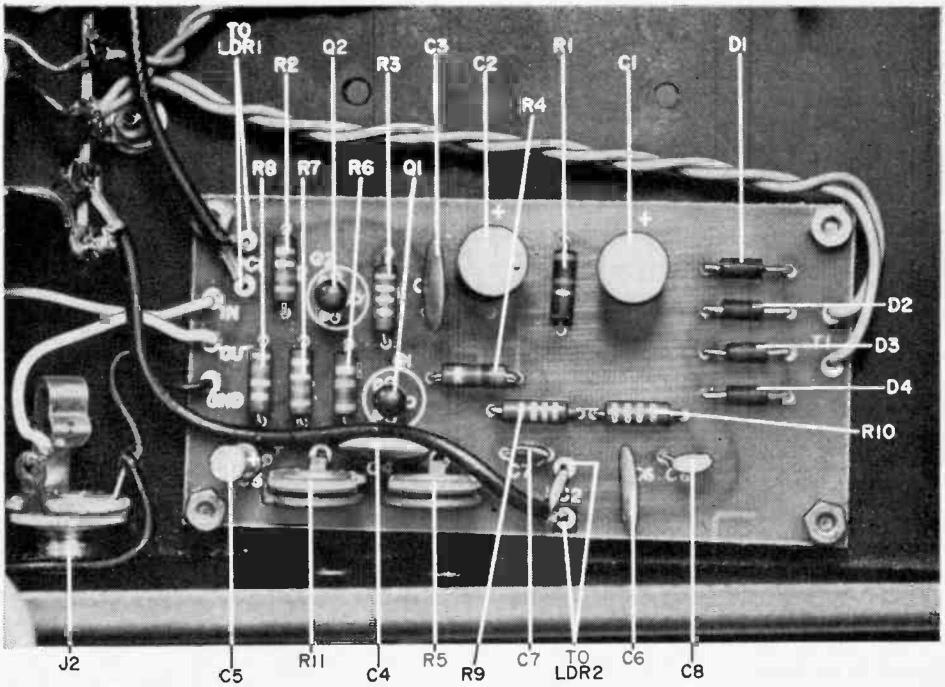


Fig. 3. After installing all components on board, make sure both trimmer potentiometers are accessible through holes drilled in side of chassis. This view also shows connections to other elements.

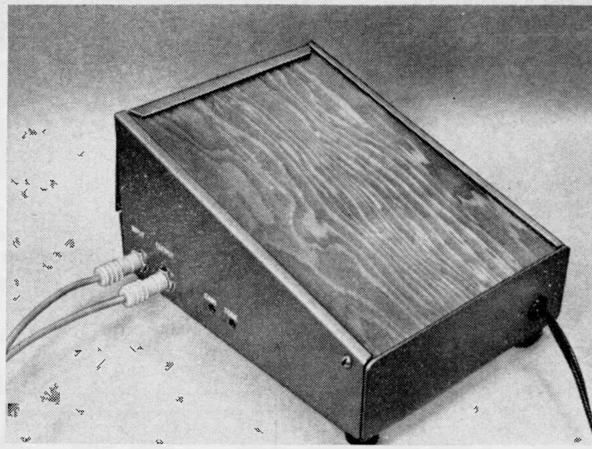
top of the assembly. The pedal is hinged at the heel (lower) end by a pair of long wood screws. A mild-spring steel spring supports the pedal and returns it to the top position when the foot is relaxed or removed.

On the underside of the wooden pedal, is a specially shaped light mask which, as the pedal goes up and down, passes between a light source and a pair of photoresistors or light dependent resistors.

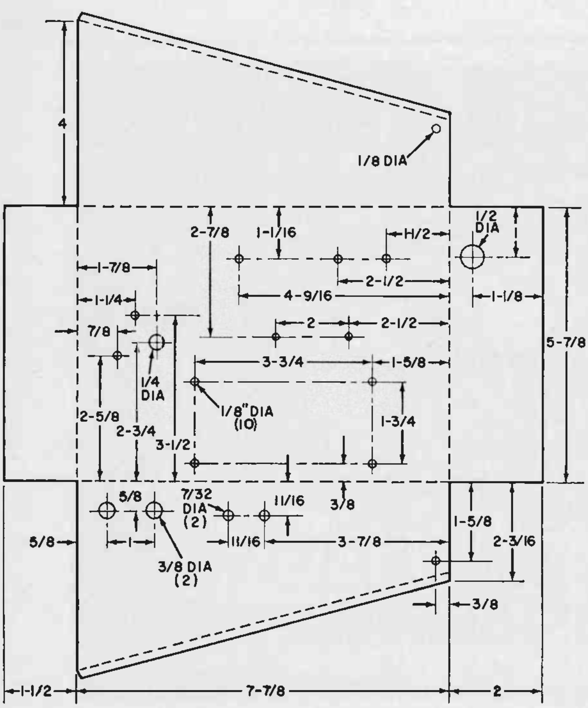
If you have the metalworking facilities, you can duplicate the prototype chassis, using 16-gauge steel or aluminum and following the layout shown in Fig. 4. Once the chassis is made, fabricate the wooden pedal out of ¾" plywood with the dimensions given in Fig. 5. This illustration also shows the spring that is fabricated from 16-gauge mild-spring steel. The dimensions of the support bracket for the photoresistors and the light mask are shown in Fig. 6.

The entire interior of the Waa-Waa, including the mask and photoresistor bracket, must be finished in flat black to minimize internal reflections from the light. After the photoresistor bracket has dried, mount it on the chassis as shown in the photos. The two photoresistors are glued in place as shown in Fig. 6.

Attach the PC board, temporarily, to



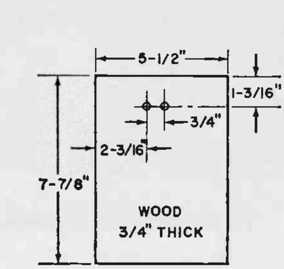
The completed Waa-Waa. Two audio leads, one input and one output, plug into the appropriate jacks. Two holes alongside are for trimmer adjustments.



ALL MEASUREMENTS ARE IN INCHES

Fig. 4. If you want to fabricate chassis similar to the one shown in the photos, follow construction details shown here.

Fig. 5. Fabrication details for the wooden pedal and spring. Two holes in the pedal support the shadow mask. Spring serves to return the pedal to the top of its travel when the foot is removed from the top.



PEDAL SIZE AND MASK PLACEMENT

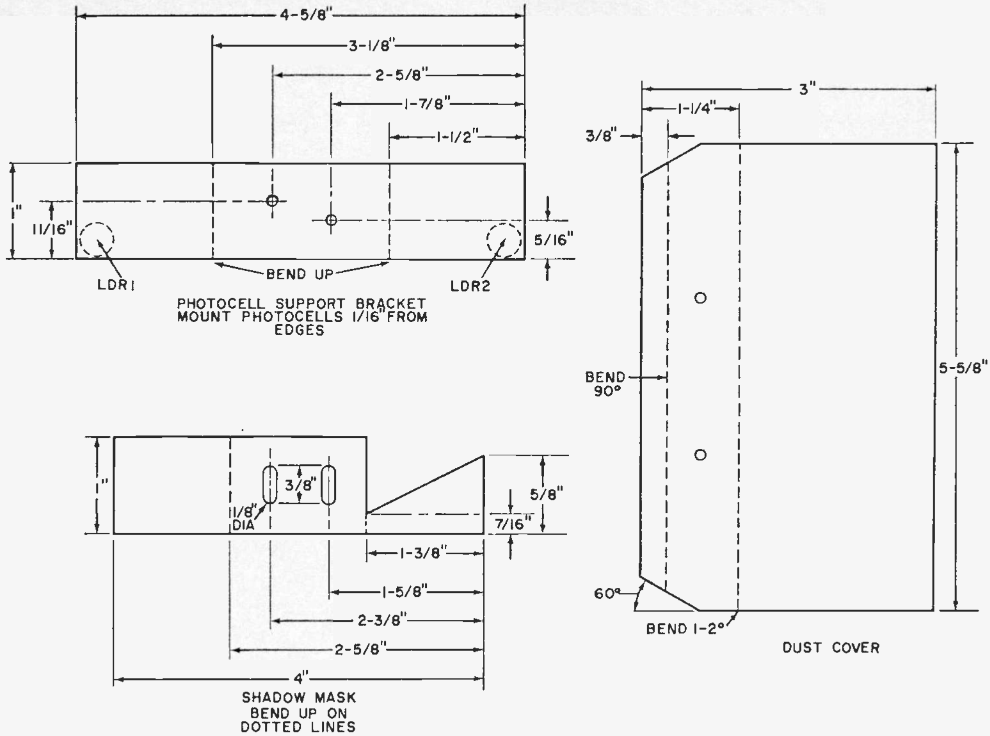


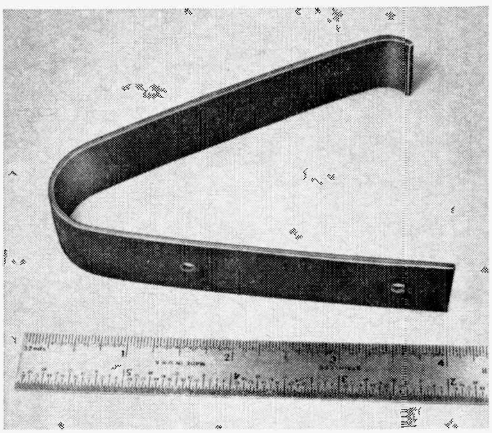
Fig. 6. Construction details for the photocell support bracket, the shadow mask, and the dust cover. These can be made from thin sheet metal and painted flat black to remove reflections.

the chassis, using four small standoffs. Note and mark the chassis for both trimmer potentiometers. Remove the PC board and drill holes in the chassis so that the trimmers can be adjusted from outside with a screwdriver.

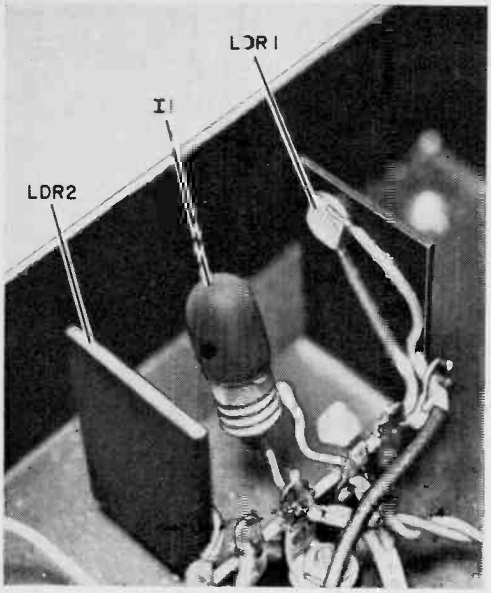
Using suitable hardware, mount the transformer on the bottom of the chassis. Mount the input and output phone jacks. After soldering appropriately long leads on the PC board terminals, attach the board (on its spacers) to the chassis. Make sure that the two trimmers face the holes for adjustment. Mount a six-lug terminal strip (one lug grounded) close to the photoresistor support as shown in the photos. Lamp *L1* can be installed in a socket or it can be attached to heavy leads soldered to its base connectors. Connect both sides of the lamp to ungrounded lugs on the terminal strip.

Now position the lamp midway between the two photoresistors. Coat the lamp with flat black paint. After the paint dries, scratch a small clear spot on each side of the lamp so that, when it is lit, a small beam of light falls on the sensitive face of each photoresistor.

Insulate the leads on the photoresistors and connect them to the outside terminals on the terminal strip. Using shielded cable to minimize hum, connect



The spring has a small curve at the top to slide along the wooden foot pedal as it is depressed.

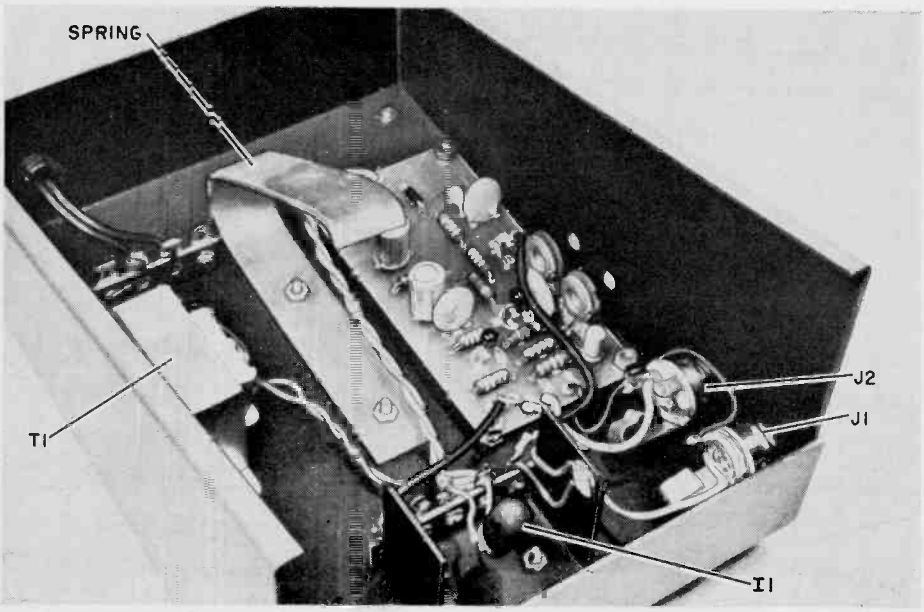


Lamp I1 is painted flat black and small dots of paint are removed on each side to shine on LDR's. Dot where paint was removed appears black here.

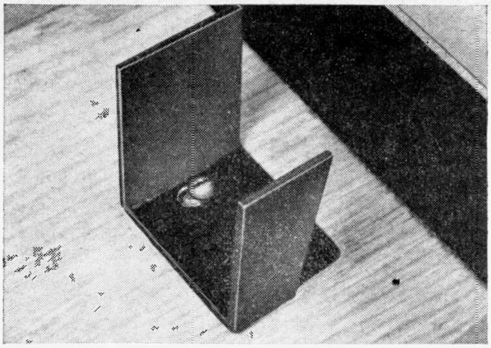
these terminals to the appropriate terminals on the PC board. Use a two-lug (non-grounded) terminal strip to connect the primary leads of the transformer to the line cord. Pass the cord through a hole with a grommet in it in the lower end of the chassis.

Wire the system according to Fig. 1, making sure that the photoresistors are properly installed. Install the wooden foot pedal temporarily, using the hinge screws to hold it. Hold the light mask against the bottom surface of the pedal with the angled portion covering *LDR2*. When the pedal is depressed, the mask must slide cleanly between the lamp and the photoresistors. Put screws through the slotted holes in the light mask to position it laterally but leave it able to move up and down on the pedal.

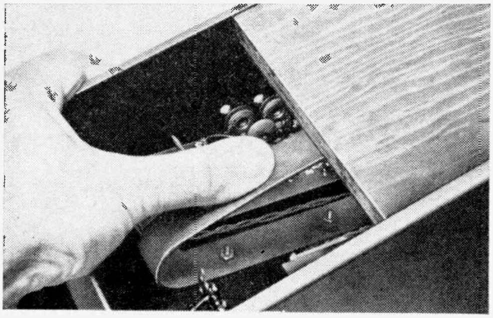
Remove the wood pedal. Attach the spring, using suitable hardware, so that the top of the spring is slightly higher than the chassis walls. Re-install the pedal and secure it with the hinge screws. Check that, as the pedal is depressed, the light mask slides clean. With the pedal all the way up, the uppermost surface of *LDR1* may be in shadow but the majority of its surface must be fully lit by the beam from *I1*. Adjust the final position of the mask so that both photoresistors are completely in shadow when the foot pedal is lightly depressed and *LDR2* is fully lit when the pedal is pressed all the way down. Provide some form of mechanical stop to arrest the pedal at the bottom of its travel. (In the prototype, this stop is provided by the



Interior view of the Waa-Waa showing the location of all parts. Note the two holes for the trimmer potentiometers. The lips on the chassis top limit the wooden foot pedal at the top of its travel.



Shadow mask is secured to underside of foot pedal. The flat black paint removes all reflections.



The spring must be slightly depressed to allow foot pedal to slide under the chassis upper lips.

hitting of the mask against the frame that holds the photoresistors).

Fabricate the light and dust cover as shown in Fig. 6 and mount it on the top end of the foot pedal. The inside of this cover must be painted flat black.

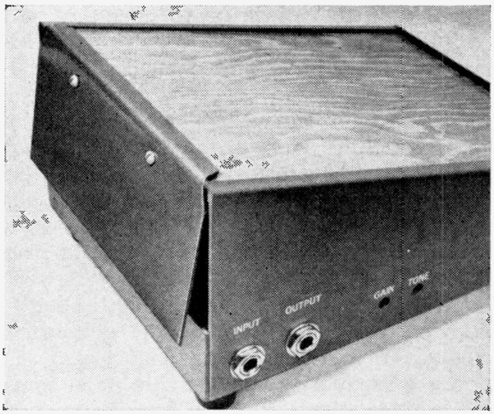
Operation and Use. Plug the output from the instrument you are going to use into the input jack, *J1*, of the Waa-Waa and run an audio cable from the output jack, *J2*, to the amplifier. Supply power to the Waa-Waa, set the amplifier volume to a reasonable level, and use a small screwdriver to turn the potentiometers, *R5* and *R11*, fully clockwise. At this point, a squeal may be heard from the amplifier as the Waa-Waa breaks into oscillation. Adjust *R5* until there is no oscillation at any setting of the foot pedal.

Now strike a chord on the instrument and press the pedal. The effect of the Waa-Waa should be obvious; however, there will also be a noticeable increase in volume as the pedal is depressed. Adjust *R11* so that the volume change is minimized.

As you learn to use the Waa-Waa, you may feel that only a slight motion of the pedal produces too great a change in the tone of the instrument. This can be changed by reducing the size of the hole in the paint on the side of *I1* which illuminates *LDR2*. You may eventually find that just a pinhole produces the proper results.

There may be an annoying squeak as the pedal rubs against the sides of the case and the spring. This can be eliminated by coating the offending areas with one of the silicone lubricants.

For maximum effect, the Waa-Waa should be used with instruments producing a tone rich in harmonics, such as a guitar or harmonica. The effect on a guitar is most noticeable when the strings are plucked next to the bridge but this is really a gimmick on top of a gimmick. In general the effect of the Waa-Waa is less noticeable on bass instruments (unless they generate good harmonics as does a bass harmonica). The pedal may be pressed and released rapidly to get a distinctive "wow" or it may be moved slowly to produce a weird "wind in the willows" effect.



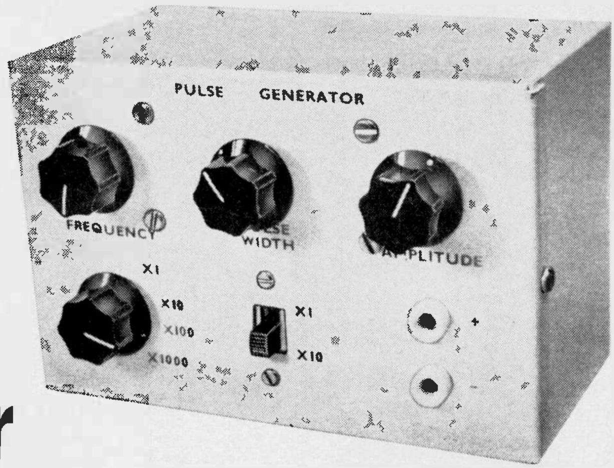
Dust cover keeps the ambient room light from affecting LDR's. A pair of long wood screws form a hinge at the heel (lower) end of wood foot pedal.

The thing to do is experiment. The effect is so unusual that a beginner is as expert as anyone else so no one can say you're doing it wrong.

One word, however! A little Waa-Waa goes a long way. The listener should get the impression of having heard something new, but he shouldn't be able to say exactly what it was. —30—

BY PHILIP HARMS

Portable Pulse Generator



PERFECT TRIGGER SOURCE FOR THOSE DIGITAL PROJECTS

IT'S ELEMENTARY! If you have built or are planning to build one of those digital instruments (timers, voltmeters, counters, etc.) that have become so popular since integrated circuits for digital applications were introduced, you'll need a pulse generator to check it out.

Pulse generators of many varieties are available—to be purchased or built—but most of them are too fancy and/or expensive for the needs of the ordinary experimenter. Here's one you can build for about $12 (less, if your junk box is well stocked) and it meets all the usual requirements. It is compatible with both IC and discrete transistor circuits and it is adjustable in the three major parameters: pulse width, amplitude, and frequency. Specifications for the generator are given in the Table.

As a frequency source, this pulse generator uses a unijunction transistor, which operates over wide voltage ranges and oscillates from very low audio frequencies up to several hundred kilohertz. Its output trigger is easily adapted to conventional pulse design, and frequency is controlled by varying the applicable timing resistor or capacitor.

The pulse generator is portable, using a 9-volt transistor battery with a current drain of 9 milliamperes, no load.

Construction. The pulse generator, whose schematic is shown in Fig. 1, can be built in an aluminum box about 6″ × 4″ × 3″. The battery is secured to the rear panel by a metal clip or elastic band.

Assemble the electronic components on a 3″ × 1½″ piece of perf board as shown in Fig. 2. (The transistor sockets are optional.) The controls and the output jacks are mounted on the front panel as shown in Figs. 2 and 3 and the front-panel photo. The perf board is mounted on stand-off spacers directly over the controls. The capacitors associated with *S1* and *S2* are mounted directly on the switches. Although component placement is not critical, lead lengths should be kept to a minimum.

The front panel can be lettered using any type of dry-transfer process, following the nomenclature shown in the photograph.

Operation. Although the Table of Specifications for the generator lists a maximum pulse width of 100 microseconds, the generator has a maximum duty cycle of about 75%. This means that, above a pulse width of 75 microseconds, the instrument "cheats" slightly and makes the width of every other pulse slightly narrower than it should be according to the setting of the controls. You will notice this discrepancy if you apply the generator output to an oscilloscope. It does not mean that the generator is not operating properly. If an attempt is made

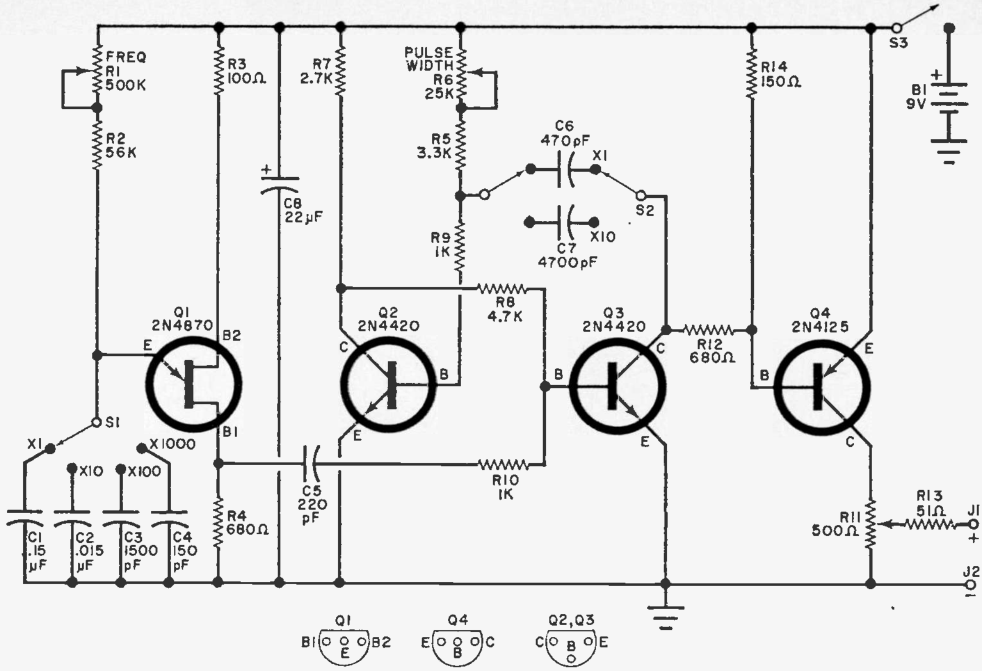


Fig. 1. The circuit consists of a variable-speed UJT oscillator driving a time-adjustable one-shot multivibrator. In this way, the narrow spikes from the UJT are converted into one of two selected output pulse widths.

PARTS LIST

B1—9-volt battery
C1—0.15-μF capacitor
C2—0.015-μF capacitor
C3—1500-pF capacitor
C4—150-pF capacitor
C5—220-pF capacitor
C6—470-pF capacitor
C7—4700-pF capacitor
C8—22-μF, 15-volt electrolytic capacitor
J1,J2—Banana tip jack
Q1—2N4870 unijunction transistor
Q2,Q3—2N4420 transistor
Q4—2N4125 transistor
R1—500,000-ohm potentiometer
R2—56,000-ohm
R3—100-ohm
R4,R12—680-ohm
R5—3300-ohm
R7—2700-ohm
R8—4700-ohm
R9,R10—1000-ohm
R13—51-ohm
R14—150-ohm
All resistors ½-watt
R6—25,000-ohm linear taper potentiometer
R11—500-ohm potentiometer
S1—Single-pole, 4-position rotary switch
S2—D.p.d.t. slide switch
S3—S.p.s.t. switch on R1
Misc.—4" x 6" x 3" chassis, knobs (4), battery support, dry-transfer lettering, spaces (4), perf board, transistor sockets (4, optional), wire, solder, etc.

to increase the pulse width to more than 100 microseconds, the generator may start to divide the frequency. To insure stable operation, it is good practice to start with a narrow pulse width and then increase it as necessary.

Some times it is necessary to terminate the output in a low impedance. In this case, current drain will increase in proportion to the duty cycle, so it is a good idea to keep the pulse width as low as possible.

A 9-volt battery should give about 48

PULSE GENERATOR TECHNICAL SPECIFICATIONS

Frequency range: 10 Hz to 100 kHz
Pulse width: 1 to 100 microseconds
Amplitude: 0 to 8 volts
Rise time: 10 nanoseconds at output terminals
20 nanoseconds with 3" coax lead
Fall time: 35 nanoseconds at output terminals
60 nanoseconds with 3' coax lead
Output series resistance: 51 ohms
Power supply: 9 V at 9 mA, no load
Maximum pulse duty cycle: approximately 75%

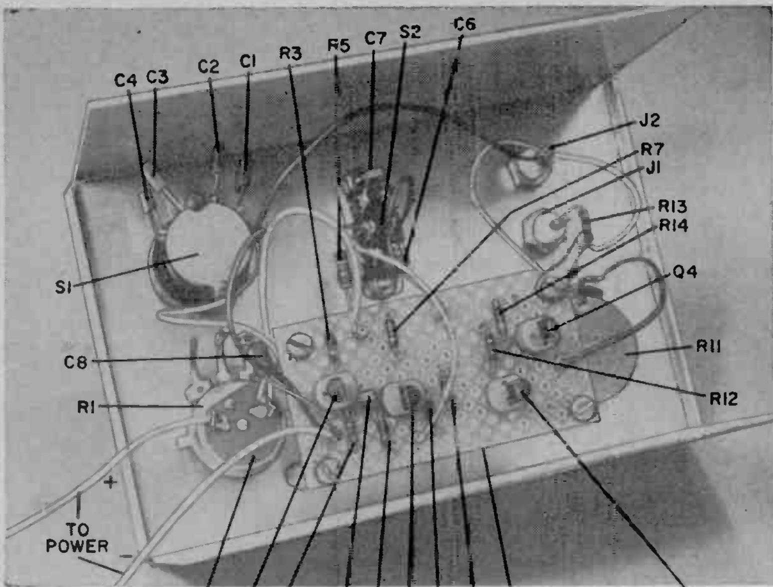


Fig. 2. Underside of chassis shows placement of board components and front-panel mounted controls and terminals.

hours continuous operation in this pulse generator before performance is impaired. If you need more life, use six D cells. Needless to say, the generator should be turned off when not in use.

In checking the rise time of your pulse generator, remember that the rise time you measure can be no better than the rise time of the oscilloscope you are using. Also remember that, if too long a coaxial lead is used on the output, some degradation of the rise time may result due to capacitance in the cable.

If you want a negative going pulse, simply reverse the output lead. To obtain a negative going pulse which is

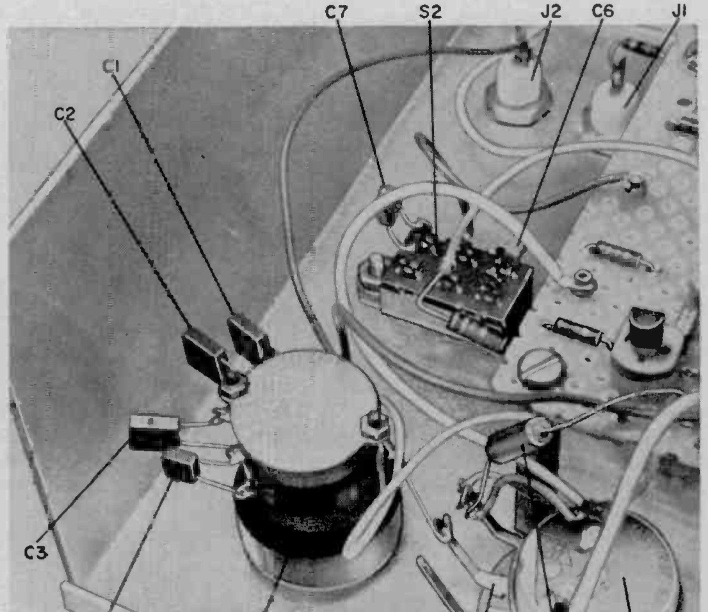
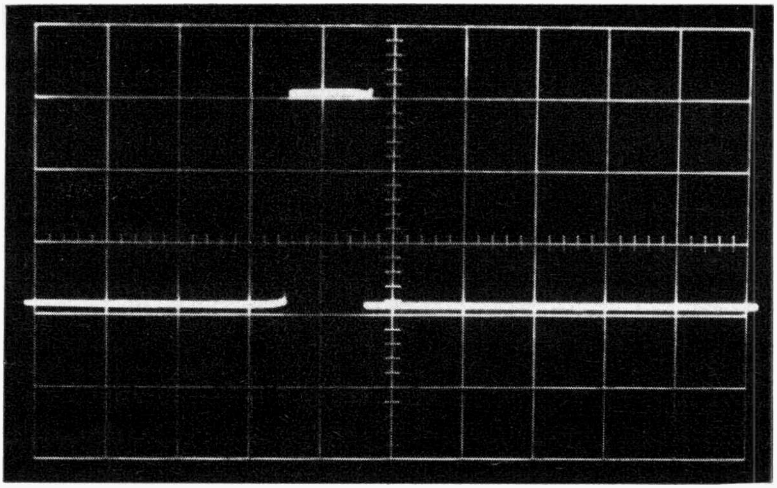


Fig. 3. Close-up view shows oscillator timing capacitors mounted on S1 and multivibrator capacitors mounted on S2. Perf board mounts on spacers.



Typical output pulse shows the extremely rapid rise and fall times on this pulse generator. The width of the pulse can be adjusted by the setting of switch S2.

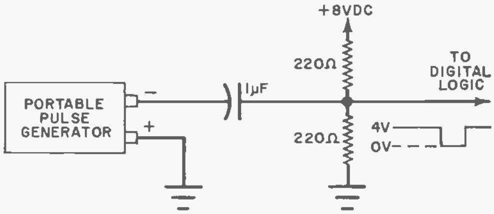


Fig. 4. If you want to drive 4- or 5-volt IC's with pulse generator, this external circuit is needed.

HOW IT WORKS

The basic pulse frequency is generated in the relaxation oscillator circuit containing unijunction transistor *Q1*. Potentiometer *R1* provides the fine frequency adjustment while selector switch *S1* chooses the applicable multiplier capacitor (*C1* through *C4*). The selected capacitor charges up at a rate determined by *R1* and *R2*. When the capacitor charges up to about two-thirds of the supply voltage, the emitter of *Q1* is forward biased and the capacitor discharges rapidly through the base-1 junction and *R4*. The resulting pulse is differentiated (narrowed) by *C5* and applied to the base of *Q3* through *R10*.

Transistors *Q2* and *Q3* form a monostable (one-shot) multivibrator. This circuit is in a stable state with *Q2* saturated (collector voltage near ground) and *Q3* cut off (collector voltage at supply voltage) until triggered by a pulse at the base of *Q3*. This causes *Q3* to turn on, which forces the base of *Q2* negative and turns it off. The selected timing capacitor (*C6* or *C7*) then charges up at a rate depending on the total resistance of *R5* and *R6*. Once the capacitor is charged up, the circuit reverts to its original condition, until the next pulse arrives from *Q1*. The result is a pulse at the collector of *Q3* whose width is independent of the width of the trigger from *Q1* but with a maximum width that must be slightly less than the time between input pulses. Also, the width cannot be reduced to less than that of the input trigger.

The negative (with respect to the supply voltage) pulse at the collector of *Q3* saturates *Q4* and its collector voltage rises, generating an output pulse across *R11*. The latter can be adjusted to give any desired amplitude. Resistor *R13* minimizes overshoot of the output pulse and prevents damage to *Q4* if the output is shorted.

referenced to 4 volts, reverse the leads and use the setup shown in Fig. 4. Since most integrated circuits operate on a 5-volt pulse and can be damaged if too high a pulse is applied to them, it is a good idea to mark the generator's dial at the 5-volt point.

The pulse generator is designed to drive all types of integrated circuits; however some forms require current-drive capability while others supply current back to the generator. The generator will drive several RTL circuits because they draw current *from* the generator. On the other hand DTL and TTL types use the generator as a current sink and supply current *to* it. This means that the output resistance to ground must be kept low. Thus if several DTL or TTL circuits are to be driven and long coax cables are used, a buffer IC should be tied into the input of the IC circuit. —30—

ONE-STEP Motion Detector

*Ne plus ultra*sonic intruder alarm

BY DANIEL MEYER

IT WOULD TAKE all ten fingers—and maybe a couple of toes—to count the various types of intruder alarm systems that can be leased, purchased, or home-built. None, however, is better than an ultrasonic system of the type used in areas of tight military security. The "One-Step Motion Detector" described here is such a system. When you have the One-Step for protection, it is not necessary for the intruder to break a wire or tape or even touch anything to set off the alarm—and there are no visible or invisible light beams to be broken. All the intruder has to do is take one step into the protected area and his very presence disturbs the ultrasonic field to actuate the alarm circuit.

Built around integrated circuits to reduce cost and construction complexity, the One-Step generates a signal with a frequency of 40 kHz (far above the limit of human hearing) and aims it at the area to be protected. (The area covered is in the shape of a 50° cone fanning out from the detector to a distance of about 15 feet.) The receiver portion of the detector uses the 40-kHz output as a reference and compares it with the frequency reflected from the protected area. If there is no movement in the area, there is no difference between the radiated frequency and the reflected frequency, and no alarm is given. If the two do not agree, the receiver actuates the alarm circuit.

Besides detecting intruders, the One-Step can be used for other alarm purposes. Since the air turbulence caused by flames is sufficient to create a Doppler shift, you can use One-Step as a fire detector. A wild-life photographer can use the device and let the alarm signal trip a camera shutter and photoflash. One-Step can also be used to activate a counter to indicate the passage of objects or to open a door as a person or object approaches. You can even use it to detect rodents or other small animals.

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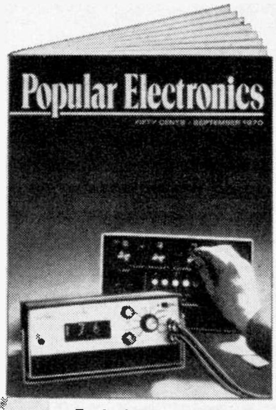

Each month, PE's editors choose from a wide range of electronic components, equipment, devices, test gear and experimental projects. From lasers and computer components to audio-visual devices, stereo and hi-fi, electronic music, unusual electronic games and practical items for your home use and entertainment. Once selected, each project is laboratory-tested by one or more of the editors to make sure it performs as it is supposed to. You get 8, 10, or more valuable projects each issue—more than 100 per year... All with "how-to-build-it," "how-it-works" instructions, most with actual size PC foil patterns and all geared to increase your electronics know-how and add to your knowledge of the dynamic field of electronics...and besides, they're just plain fun.

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For recording more than one tape

Build the X10/X100 Instrument Sensitivity Booster
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Automatic Lightning Protection
Ground your antenna

Build Security 1
Speech scrambler for your telephone

One-Step Motion Detector
Ultrasonic intruder alarm

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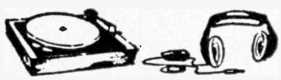

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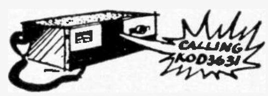

COMMUNICATIONS

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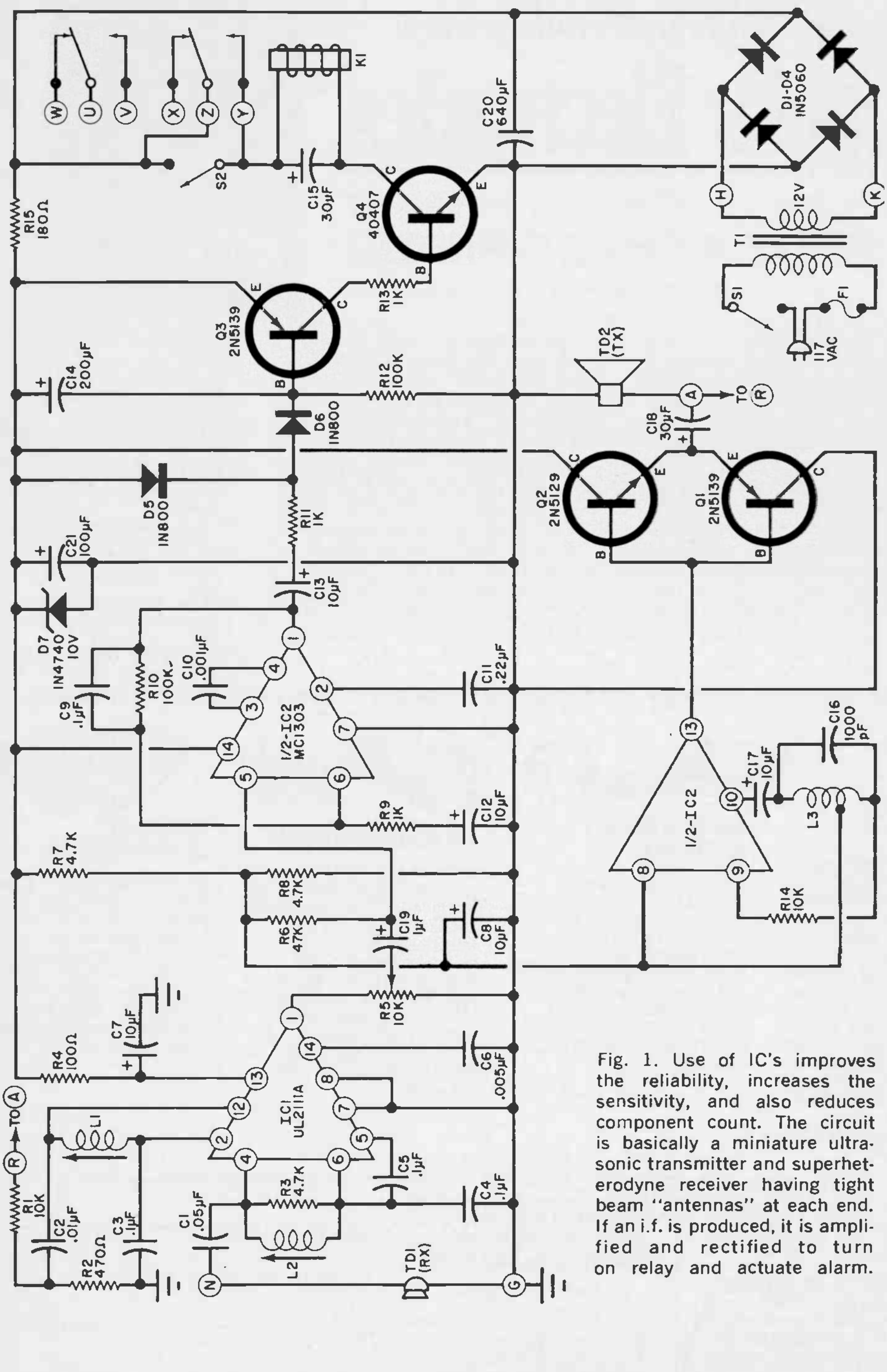


Fig. 1. Use of IC's improves the reliability, increases the sensitivity, and also reduces component count. The circuit is basically a miniature ultrasonic transmitter and superheterodyne receiver having tight beam "antennas" at each end. If an i.f. is produced, it is amplified and rectified to turn on relay and actuate alarm.

circuit can be used with One-Step. The external circuit is controlled by normally open or normally closed 1-ampere contacts on the relay in the detector.

Construction. Most of the circuitry of the One-Step (see Fig. 1) is contained in two integrated circuits so construction of the device is much simpler than if discrete components were used throughout. To further simplify construction, make or buy the printed circuit board whose foil pattern is shown in Fig. 2. Mount the components on the board as shown in Fig. 3. Use a 35-to-50-watt soldering iron, 60/40 alloy resin-flux solder, and take care in soldering.

The detector shown in the photos was built in a U-shaped metal enclosure 13" × 2½" × 2½", though any type of enclosure will do. Drill holes at each end of the channel for *TD1* and *TD2*. With the transducers in place, mount transformer *T1*, fuseholder for *F1* and an outlet for the connection to the external alarm circuit at one end of the chassis. Drill another hole for the power cord. Put a grommet in the hole before installing the cord.

Mount the printed circuit board on four insulated standoffs. Make a pair of transducer connectors by using twisted pairs with conventional phono plugs at the ends. Connect the board to the external components.

If you want to have a remote reset, connect a s.p.s.t. switch (*S2*) to terminals Y and Z. For automatic reset, connect a jumper between these two

ANIMALS AND ULTRASONICS

In most commercial installations of ultrasonic alarm systems, the ultrasonic generator is left on all the time and only the alarm circuit is de-activated when detection is not desired. This may not be such a good idea around the home or anywhere pets are considered. While humans cannot hear the 40-kHz signal, animals can; and, although it affects different animals in different ways, it's best to keep it turned off when not in use to avoid discomfort to them. Remember also that, when you are using the detector, it can be activated by animals, causing false alarms. In fact, they may be attracted to it.

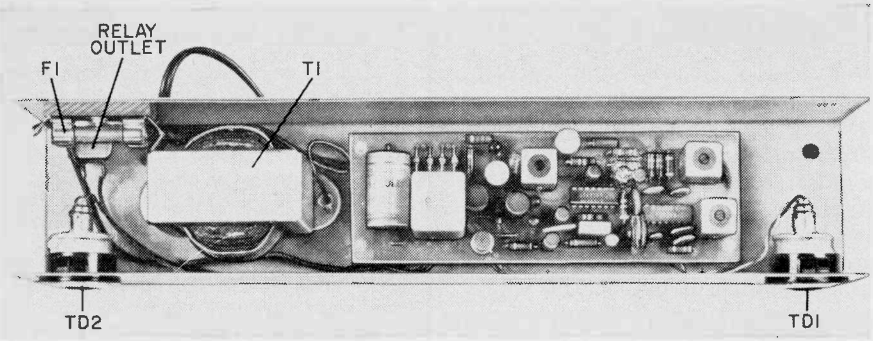
PARTS LIST

C1—0.05-μF capacitor
C2—0.01-μF capacitor
C3,C4,C5,C9—0.1-μF capacitor
C6—0.005-μF capacitor
C7,C8,C12,C13,C17—10-μF, 15-volt electrolytic capacitor
C10—0.001-μF capacitor
C11—0.22-μF capacitor
C14—200-μF, 6-volt electrolytic capacitor
C15,C18—30-μF, 15-volt electrolytic capacitor
C16—1000-pF polystyrene capacitor
C19—1-μF, 50-volt electrolytic capacitor
C20—640-μF, 25-volt electrolytic capacitor
C21—100-μF, 15-volt electrolytic capacitor
D1-D4—1N5060, 1-ampere diode
*D5,D6—1N800, silicon diode (General Electric)**
D7—1N4740, 10-volt, 1-watt zener diode
F1—1-ampere fuse and holder
*IC1—Integrated circuit (Sprague ULN2111A)**
*IC2—Integrated circuit (Motorola MC1303)**
K1—D.p.d.t. relay, 12-volt, 300-ohm coil, 1-ampere contact rating (Price Electric 22E121-FF or similar)
*L1-L3—15-20-mH coil (Wee Coil Inc. 387-2000 or similar)**
Q1,Q3—Transistor (National Semiconductor 2N5139)
Q2—Transistor (National Semiconductor 2N-5129)
Q4—Transistor (RCA 40407)
R1,R14—10,000-ohm
R2—470-ohm
R3,R7,R8—4700-ohm
R4—100-ohm
R6—47,000-ohm
R9,R11,R13—1000-ohm
R10,R12—100,000-ohm
R15—180-ohm
(All resistors ½-watt)
R5—10,000-ohm printed-circuit potentiometer
S1,S2—S.p.s.t. switch (S2 optional)
T1—Filament transformer, secondary 12 volts 2 amperes (Stancor P-8130 or similar)
TD1,TD2—40-kHz transducer (Massa MK-109 or similar)
Misc.—Spacers (4), transducer connectors (2), line cord, mounting hardware, etc.
Note—An etched and drilled printed circuit board for $3.50 and a complete kit of parts including punched chassis for $37.25 are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, TX 78216.
**Also available from Southwest Technical Products are: DHD-800 diode (20¢); 15-20-mH coil ($2); ULN2111A integrated circuit ($2); MC1303 integrated circuit ($5.25); 40-kHz transducer ($4). These prices are for single units.*

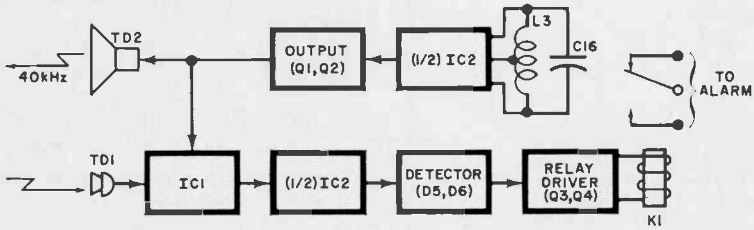
WHAT IS DOPPLER SHIFT?

Doppler shift is a change in the observed frequency of a train of waves (acoustical or electromagnetic) caused by the relative motion of either the source, the medium through which the wavetrain passes, or the observer. The most common example of Doppler shift occurs when the sound of a train's whistle is higher in frequency as the train approaches and lower as it passes.

Doppler shift is the principle used in police radar systems to measure the speed of vehicles. It is also used to measure the relative velocity of stars and the rotational speed of planets or satellites. Certain types of military radar systems also operate on the Doppler principle.



The prototype One-Step was constructed within a long slim metal cabinet. The transducers should be a foot or so apart and arranged so that the beams overlap to cover protected area.



HOW IT WORKS

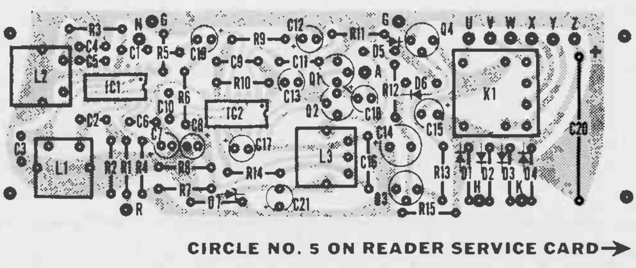
The transmitter portion (at the top of the diagram) consists of a 40-kHz ultrasonic oscillator, formed by half of *IC2* and tuned circuit *L3-C16*, and a complementary emitter follower, *Q1* and *Q2*. The output drives ultrasonic transducer *TD2*. The beam from *TD2* is cone-shaped, about 50 degrees wide.

The receiver portion of the One-Step has two inputs: one is the 40-kHz signal generated in the transmitter and the other is the observed frequency (Doppler shifted or not) existing in the area covered, and picked up by *TD1* (which also has a 50-degree pattern of coverage). In integrated circuit *IC1*, the detected (observed frequency) signal is amplified and mixed with the 40-kHz reference from the transmitter. As long as the two frequencies are identical, there is no output from *IC1*. However, if there is any motion within the protected area, the signal picked up by *TD1* is Doppler shifted from the reference. The difference produces a beat frequency which is a function of the rate of change of the target motion. The output of *IC1* is a low-frequency audio signal, usually between 10 and 50 Hz.

The output of *IC1* is applied to level control potentiometer *R5* and then to the second half of *IC2*, where it is amplified. The gain of this amplifier is determined by the ratio between resistors *R9* and *R10* and its frequency response is determined by *C9*, *C10*, and *C12*.

The amplified low-frequency signal, present only when there is motion in the protected area, is rectified by *D5* and *D6*. Capacitor *C14* then integrates the signal, thus making it necessary for the motion to continue for a second or so before the signal is high enough to operate the relay driver circuit (*Q3* and *Q4*). This helps to suppress false signals due to line-voltage variations, or random air motion within the protected area. The relay is normally energized so that any attempt to disable the system by cutting the power will cause the alarm to sound. The second pole of the relay may be used to activate an external alarm. The load is restricted only by the current-carrying capacity of the relay contacts. The built-in power supply can handle one ampere at 12 volts d.c. to an external load. The power supply is a conventional full-wave bridge rectifier with capacitor-input filtering. Zener diode *D7* stabilizes the amplifier circuit and prevents supply loading and line-voltage variations from affecting circuit operation.

Fig. 3. When installing components, be sure that the diodes, IC's, and electrolytic capacitors are installed correctly.



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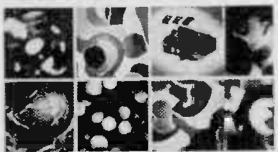

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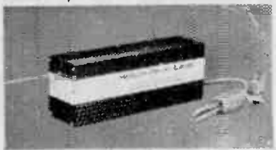

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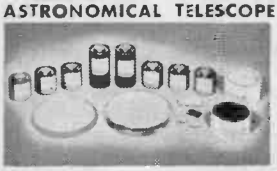

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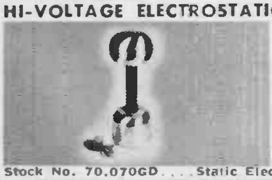

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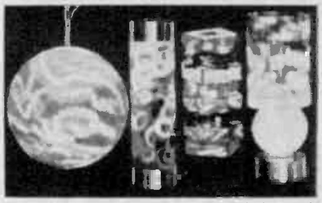

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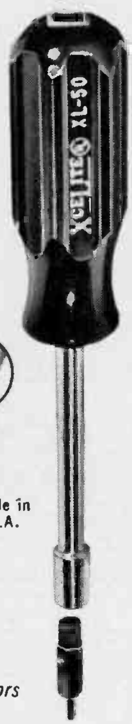

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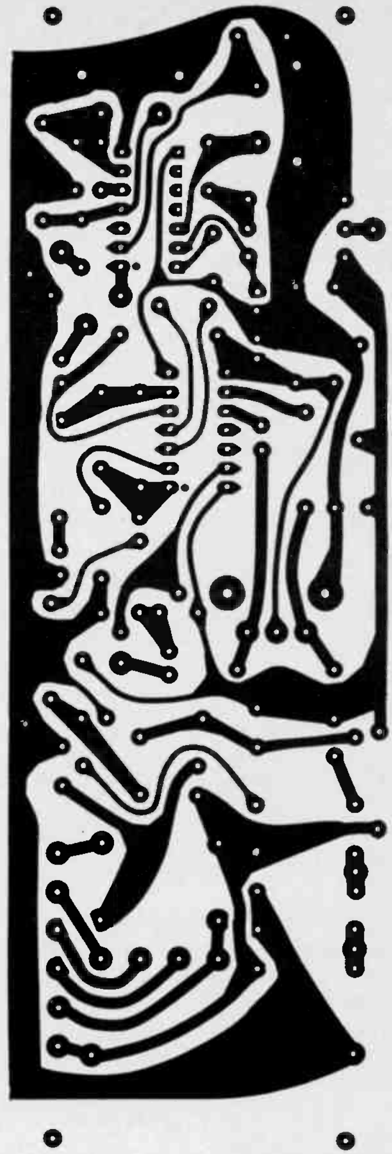

Fig. 2. Actual size printed circuit foil pattern for ultrasonic alarm. Due to circuit complexity, the use of a foil pattern prevents wiring errors.

terminals. The isolated relay contacts (at board terminals U, V, and W) are connected to the external outlet. Make sure that a jumper is connected between terminals A and R to provide the receiver with the reference signal.

Place a metal cover, suitably painted or covered with contact material, over the completed chassis.

(*Continued on page* 150)

BUILD THE

"No Fooling" Fence Alarm

Electronic system can't be surreptitiously deactivated

BY LYMAN GREENLEE

A FENCE ALARM system is a good idea providing it can't be bypassed or deactivated by a clever intruder. It should actually fool him into thinking it's something it isn't and sound the alarm if tampered with in any way. This system does the job easily. A combination of open and closed loops in the fence circuit (see Fig. 1) is employed to control the gate of silicon controlled rectifier *SCR1* which, in turn, controls the signaling device—either a horn or a lamp. The SCR is in series with a 12-volt horn relay and is gated off when the system is armed but not tripped. Resistors *R1-R4* are in parallel with each other when the SCR is not conducting current.

A closed loop consisting of the upper and lower wires in the fence connects *R4* across *R3*. If this loop is cut at any point, the voltage at the gate of *SCR1* doubles, causing the SCR to conduct and power the horn or lamp. In like manner, if *R2* is shorted out, by connecting the center wire to either the upper or lower wire in the fence, the potential at the gate of *SCR1* again doubles and trips the system.

An SCR conducts current in only one direction. So with a dc supply, once it is triggered into conduction, it will continue to pass current until the circuit is interrupted. Switch *S1* is used to reset (interrupt) the circuit once the system has been activated. Momentarily closing *S1*, then releasing it, restores the system to its normal armed condition—provided the fence is returned to its normal condition. If the short or open circuit that caused the alarm to trip is allowed to remain, *SCR1* will continue to conduct current until the battery runs down or is removed from the circuit altogether even if the reset switch is repeatedly operated.

Construction. Before proceeding to assemble the alarm, decide where the electronics package is to be located. If indoors, a small utility box will do. For

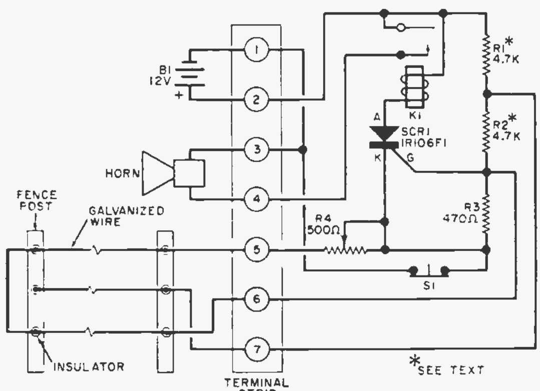

Fig. 1. Fence wires form closed loops and are resistively balanced with system. Imbalance due to short or open circuit will trigger alarm system.

PARTS LIST

B1—12 volt battery (see text)
K1—12-volt horn relay (not to exceed 1.5 amperes coil current drain)
R1,R2—4700-ohm, ½-watt resistor (see text)
R3—470-ohm, ½-watt resistor
R4—500-ohm linear taper potentiometer
S1—Spst normally closed pushbutton switch (see text)
SCR1—IR106F1 silicon controlled rectifier
Misc.—4⅛" x 2¾" x 1" chassis; 5" x 4" x 3" metal utility box (see text); 12-volt dc horn or siren (or 12-volt buzzer or lamp for silent alarm—see text); 7-lug screw-type terminal strip; 4-lug standard terminal strip; fence posts; fence wire; insulators; screen door spring; #6 machine hardware; hookup wire; solder; etc.
Note: The following items are available from Lyman E. Greenlee, P.O. Box 1036, Anderson, IN 46015: silicon controlled rectifier mounted on heat sink for $3.00; electronics package kit, not including horn or battery, for $18.00.

outdoor installations, however, it is advisable to use a box large enough to accommodate both the electronics package and the battery supply. This box should be equipped with a lock and the pushbutton switch specified for *S1* should be replaced by a key-operated normally closed switch.

Referring to Fig. 1, mount all of the components shown to the right of the screw-type terminal strip (except *R1* and *R2*) and the terminal strip on a small chassis (for indoor installations, mount the terminal strip on the utility box cover). The photos show the alarm system built for indoor installations.

Wiring is very simple. When soldering *SCR1* into the circuit, of course, it is advisable to use a heat sink to guard against heat damage. One very important point to keep in mind: do *not* allow any part of the circuit to contact the chassis electrically. This is necessary to insure adequate gate protection for the SCR.

When the electronics package is assembled, the values of *R1* and *R2* must be determined as follows. Temporarily connect a jumper wire between terminals 5 and 6 on the terminal strip. Tack solder a 1000-ohm resistor in series with a 25,000-ohm potentiometer; then connect this assembly between the gate of *SCR1* and the positive side of the battery. Do *not* omit the resistor under any circumstances. The gate circuit must have a minimum of 1000 ohms in it or *SCR1* will be destroyed.

Slowly rotate the shaft of the potentiometer until you find the pull-in and dropout points of *K1*, leaving it at the setting where the relay pulls in. Without disturbing the setting of the pot, remove it from the circuit and use an ohmmeter to measure the final series resistance. Replace the network and remove the jumper from terminals 5 and 6. Adjust the setting of the pot to the point where *K1* again pulls in. Measure the network resistance. Your reading should be between 2000 and 5000 ohms in the first test, and about double this value when the short is removed from across lugs 5 and 6 of the terminal strip.

The resistance values obtained in your tests must be derated by about 25 percent to insure positive and reliable triggering of *SCR1*. Assume that they were 6000 and 12,000 ohms. After derating, these values will be 4500 and 9000 ohms, respectively. Hence *R1* should be 4500 ohms, and since the second test yielded a resistance for *R1* + *R2*, *R2* should also have a value of 4500 ohms. In this case, you would use 4700-ohm resistors for both *R1* and *R2* since 4500 ohms are not standard values for resistors. Simply connect and solder these resistors into the circuit and set aside the electronics package.

Now you can proceed to erect your fence. Locate the fence posts, either wood or metal, no more that 15 ft. apart, after deciding where to position the gate. Porcelain insulators must be used wherever the fence wires are to be supported by the posts. (Alternatively, if you want to economize, you can use lengths of rubber or vinyl hose in place of the more expensive porcelain insulators.)

Only new, clean wire should be used for stringing the fence to assure good soldering. You can use barbed wire in localities where it is not illegal or galvanized steel wire. Do not use aluminum wire since it is difficult to solder. All connections and splices must be thoroughly soldered. If

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a splice is left unsoldered, corrosion can cause contact resistance to increase and trip the alarm system.

A three-wire fence scheme is shown in Fig. 1. This system will be adequate for most installations where the top wire of the fence is no more than 40 in. from the ground. For higher fences, or where greater security is desired, use the five-wire scheme illustrated in Fig. 2.

Treat both the fence and gate as a continuous system, using heavy-duty flexible wire to interconnect the two at the hinged end of the gate. And to provide gate surveillance, rig a conductive latch system as part of one or more fence loops.

Starting 12 in. from the ground, string the lowest wire onto the fence insulators. At the end of the fence, bend this wire over and string the top of the fence 28-30 in. from the bottom wire. Then, midway between the top and bottom wires, string the third wire. (The same or lesser wire spacing can be used for the five-wire fence scheme.)

When you finish stringing the wire, go over the fence carefully and check your soldering. Be particularly careful to make certain that no part of the loop system touches earth ground. If necessary, raise the lowest wire in locations where the wire comes within 3 in. of the ground.

Now, count the number of fence posts in the system and prepare one less fence "jiggle," referring to the upper illustration in Fig. 2 for details. The ring should be made from heavy copper wire, or a slotted copper ring, two quadrants of which must be insulated by vinyl tape or heat-shrinkable tubing. Use a length of screen-door spring at the top to provide tension. The insulator can be fabricated from plastic, unclad epoxy-fiber glass or phenolic circuit board, or any other insulating material that will not disintegrate when exposed to the elements. When hanging the jiggle, orient the ring so that the insulating tape normally contacts the fence wire.

Now, if a trespasser, unaware that the fence is part of an alarm system, decides to spread the wire to get through, or presses down on the wire to get over the fence, the ring will make electrical contact with the fence wire and trigger the alarm.

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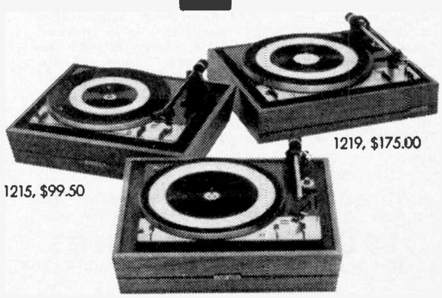

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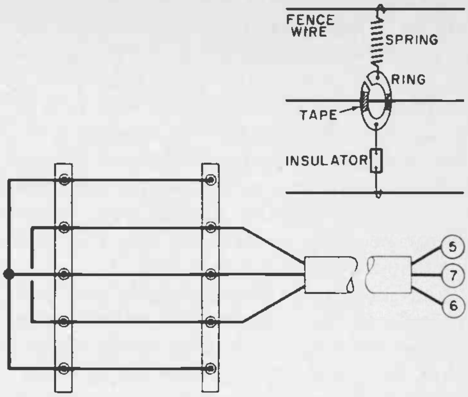

Fig. 2. Jiggle (top) triggers alarm if fence wires are compressed or spread. Numbered wires on 5-wire fence match same numbered lugs on terminal strip.

protect. The only limitation on the fence length is the total accumulated resistance of the fence wire presented to the circuit. This resistance must not exceed 500 ohms, which is the reason why soldering all splices and connections thoroughly is so important. Oxidation in only one unsoldered connection can increase the fence loop resistance beyond 500 ohms.

All that is left to do now is to connect the fence system to the electronics package, select an intrusion signaling device, and choose a battery supply that will adequately power the system with the signaling device chosen.

The interconnecting cable can be any three-conductor cable that will not short out in wet weather. You have several choices for the signaling device. If you just want to chase away intruders, a loud horn or siren can be used. However, if you want to catch intruders, a less noisy alarm can be rigged by substituting a low-current buzzer or pilot lamp for the horn. Since the horn and siren will require a great deal of current to power, you will have no alternative but to use an automobile storage battery. For the buzzer and lamp, a lantern battery setup will do.

Checkout and Use. Connect the fence to lugs 5 and 7 on the terminal strip but not to lug 6. Now, connect an ohmmeter to lug 1 and the end of the unconnected fence wire. Adjust *R4* for an indication of approximately 470 ohms on the meter. Note that this connection and adjustment procedure must be accomplished without the battery connected to the circuit.

Connect the last fence wire to terminal 6 and the battery to terminals 1 and 2 on the terminal strip. If the system is properly wired, the alarm should not trip. Touch a wire between lugs 5 and 6 on the terminal strip. The alarm should immediately trip and remain on when the jumper wire is removed. Open *S1* to reset the circuit. Then disconnect the wire from lug 5 or lug 7. Again, the alarm should immediately trip and remain on even after the wire is reconnected to the terminal strip lug from which it was removed. Reset the circuit.

Before putting the system into full operation, and if you are using lantern batteries, trigger the system and allow the battery to run down. Note how long the battery operated; then replace the battery with a new one and re-arm the system. For the automobile storage battery, do *not* perform this step. Just use a fully charged battery in which the distilled water covers the plates. Check the water level weekly, and replace the water as necessary.

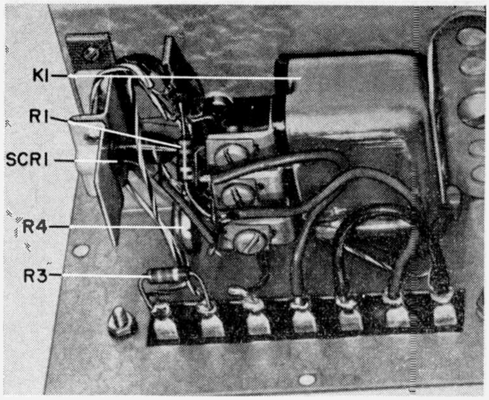

Photo shows parts mounting details, using a small aluminum utility box, for indoor installations.

A note of caution: Do not use the fence alarm system in connection with or close to a conventional electric fence. The gate of the SCR can be easily destroyed by the high-voltage surges present in conventional electric fences. If you must use an electric fence, keep it well away from the fence alarm wires. Disconnect the fence during electrical storms and ground the fence wires. —30—

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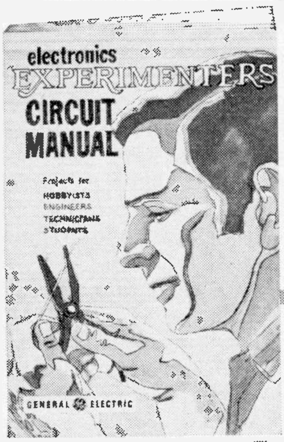

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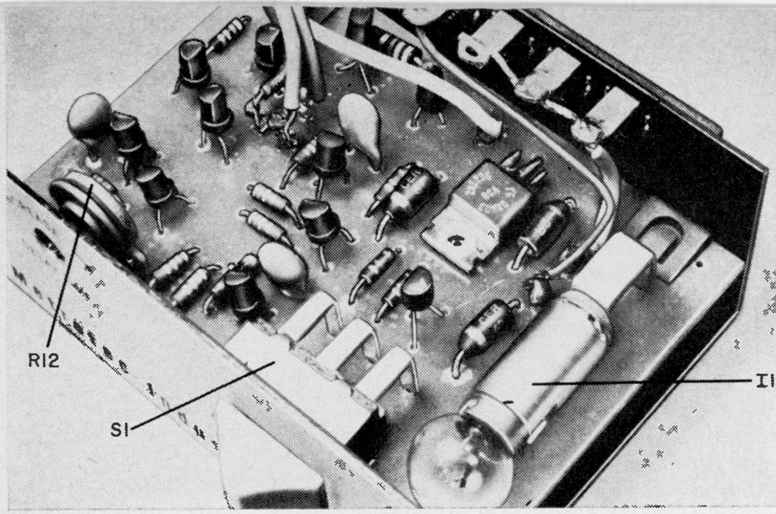

When mounting the PC board in the chassis make sure you can gain screwdriver access to R12 to that delay time can be adjusted as desired. If you have no need to vary this time, eliminate the hole.

BURGLAR ALARM

(Continued from page 112)

on. Then turn *S1* to the off position. Return the switch to the automatic position to re-actuate the alarm.

To use a siren or optional horn, replace *I1* with a 220-ohm 1-watt resistor and wire the circuit as shown in Fig. 4D. -30-

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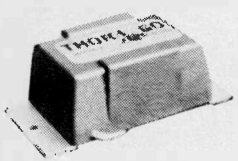

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CIRCLE NO. 19 ON READER SERVICE CARD

MOTION DETECTOR

(Continued from page 142)

Testing. The slugs in *L1* and *L2* should be flush with the top of the cans. Coil *L3* slug is set about 1/8" in from the top. Temporarily connect a 1000-ohm resistor between point A and the center of the transmitter phono plug. Connect an a.c. voltmeter (or scope) between the transducer side of this resistor and ground. Adjust *L3* slug with a non-metallic tuning tool until a dip is noticed on the readout. Remove the resistor and reconnect the lead. Coils *L1* and *L2* are used as r.f. chokes.

Installation. Since the transmit and receive transducers have 50-degree cones of usefulness, they must be "aimed" to achieve the best results. The sensitivity of the detector decreases with distance and air movement. The larger the area to be included, the more important it is to avoid air currents from heating and cooling ducts.

Once a location has been determined, connect the detector to the alarm circuit and apply power to the system. Set the gain control (*R5*) so that the external alarm is energized when a person takes about two steps into the protected area *at the maximum range.*

The external alarm circuit is activated for the time it takes *C14* to discharge. A small air disturbance in the area covered produces a short alarm signal and vice versa. The time the alarm is on can be reduced by lowering the value of *R12*—at the expense of sensitivity. -30-

AIR IONS

(*Continued from page* 114)

large ions in the air is not controlled. Work has been done in this field in an attempt to improve conditions in closed quarters (such as submarines).

European scientists were among the first to research the relationship between ions and human health. A great emphasis in clinical work with ions has developed within the past few years. The effects on tissue and cell life of animals and humans are increasingly popular areas of research. The field is attracting the physicist, biologist, climatologist, and medical researcher. In this country additional work has been done by the heating and air conditioning interests in an effort to determine the factors that are involved in human comfort.

The Air We Breathe. One area of research which has received considerable attention is the effect of ionization on hay fever, asthma and other respiratory troubles. Some of the early work in this field was done by Dr. Kornblueh in 1953. As a result of his early experiments he found that symptoms of hay fever and asthma were relieved when patients were exposed to negative air ionization in a closed room. However, the symptoms returned when the patients left the room. In later experiments he established a hay fever clinic at Northeastern Hospital in Philadelphia. Under controlled conditions 63% of the patients received complete or partial relief under negative ionization. The symptoms returned when patients returned to their normal environment. Positive ionization gave no relief and in some cases increased the distress of the patient.

Research has shown that negative ionization has an unusual effect on the bronchial tubes and trachea. These portions of the respiratory system are lined with tiny hairlike filaments called cilia which maintain a wave-like motion. With this motion they keep the air passages free of dust and pollen. When an excess of positive ions was maintained in the intake air, the wave-like motion decreased by several hundred beats per minute.

(*Continued on page* 152)

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When the tissue was exposed to an excess of negative ions the motion was accelerated above normal values. It was also found that under positive ionization the tissues were much more susceptible to bruise or damage.

The details of the picture puzzle are being filled in piece by piece but several important details are still missing. As one researcher put it, we do not know *why* ionized air has a physiological effect on living things but it does have an effect on all of us.

Another point on which most researchers agree is that negative air ions do not cure anything. During the time that they are being applied they apparently set up a favorable condition or perhaps supply something that is missing in the individual being treated. When the supply of negative ions is removed the condition returns. However, this does not diminish their value. They should be very useful in pointing the way to what is defective or lacking in the patient.

To solve the riddle of the ion and to apply the knowledge gained could be a breakthrough as important as the moon landing, at least to those who will get relief from a serious ailment. The fascinating thought is that some reader may just do it in his back-room laboratory. -30-

OMNI-EIGHT

(*Continued from page* 42)

economize by cutting a 1′-wide strip from one end of a square yard of cloth. Use this strip in a vertical position and wrap the 2′ × 3′ remaining strip around the enclosure. However you plan it, measure the distance around the enclosure before you buy the cloth or order an extra few inches to allow for mistakes

Fasten the cloth at one corner with tacks or staples. Stretch the cloth across each side, and add a few tacks or staples at each corner to hold it taut. The vertical wood strips will cover the corner staples.

The exact lengths of the top and bottom trim pieces will depend on the thickness of the grille cloth so they must be cut to fit. These pieces of trim can be made either from solid wood or plywood with veneer-covered edges. Use small finishing nails to attach them to the top and bottom of the enclosure.

Finally, cut outside corner molding to fit tightly between the top and bottom trim. Stain and finish this molding to match the other wood before attaching the pieces. (Other surfaces can be stained and finished in place.) When they are dry, attach the corner molding with small brads (see Fig. 7).

This completes the construction of your Omni-Eight. Connect the leads from your amplifier and give it a listening test. You may find that a change in position of the Omni-Eight in your listening room requires a different tweeter control setting. -30-

EXPERIMENTERS' LASER

(*Continued from page* 34)

sible that the voltage is too low to operate the laser.

When the laser does light, it will not burn holes in anything; but remember, DO NOT shine it into anyone's eyes. Although this laser is well below the theoretical threshold of eye damage, the light is extremely bright and temporarily blinding.

When you look at the laser spot on a wall, note the specular quality (diffuseness) of the spot. This is a characteristic of coherent light. It is essential to the laser's use in holography, which is described in the article on page 17. A future issue of this HANDBOOK will contain detailed plans for a brand-new all solid-state laser communicator such as that on the cover. -30-

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ELECTRONIC

EXPERIMENTER'S

HANDBOOK

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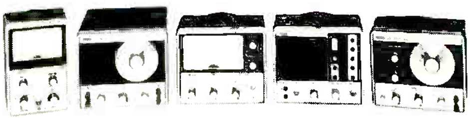

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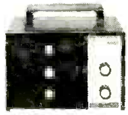

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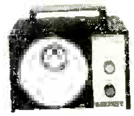

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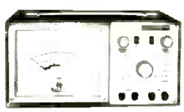

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