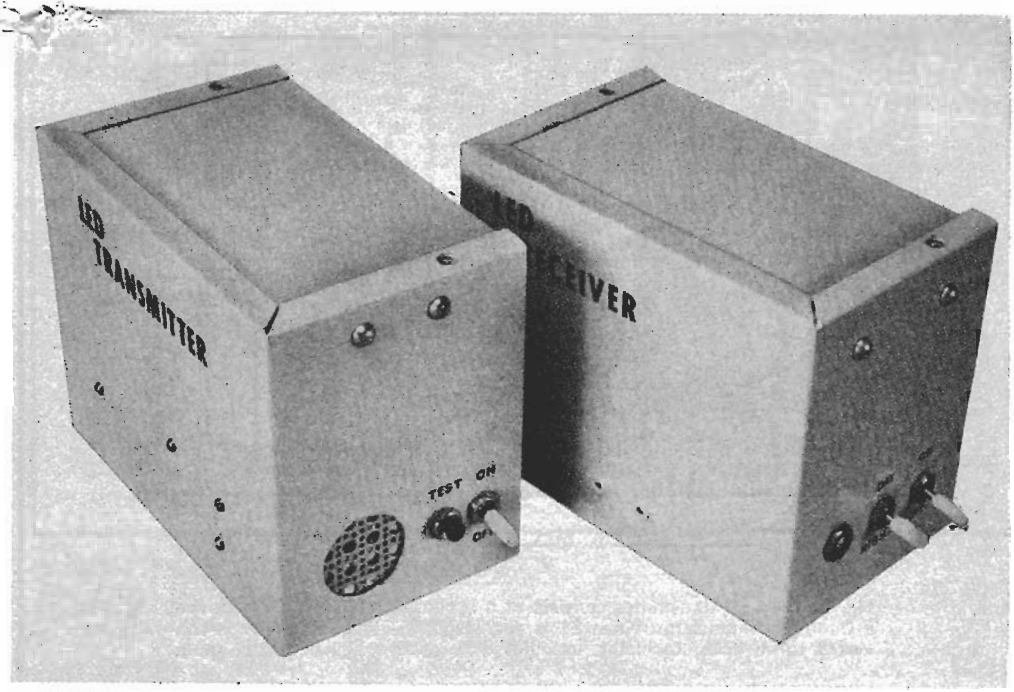

ASSEMBLE AN LED COMMUNICATOR—

THE OPTICOM

PRIVATE COMMUNICATIONS VIA AN INVISIBLE LIGHT BEAM

This optical communications system is a very practical and useful application of the light-emitting diode, the theory of operation of which is discussed elsewhere in this issue. The communicator operates at 9400 angstroms and has a range of over 1000' in darkness. Both the transmitter and receiver are simple to build and use relatively easy-to-find components.

Looking for a totally private, jam-proof, interference-free communications system? Try the "Opticom," the low-cost younger brother of the POPULAR ELECTRONICS Laser Communicator.

Using a light-emitting diode (see the article on page 35) in the transmitter and phototransistor in the receiver, the Opticom is a voice-modulated infrared optical communicator. It operates at 9400 Angstroms and has a range of over 1000 feet in darkness. The range is considerably less in daylight; but, depending on the angle of the sun and the cloud cover, it can easily reach 100 feet without the use of special filters or light shields.

The key to the amount of range obtainable is in the lenses used at the transmitter and receiver. In the prototype, simple, low-cost lenses were used. Employing a pair of binoculars or a low-cost telescope at each end would greatly increase the operating range.

Transmitter. The circuit of the transmitter is shown in Fig. 1. During voice operation, *Q1* and *Q2* provide amplification and impedance matching between the 20-mV signal from the crystal microphone and *Q3*. The am-

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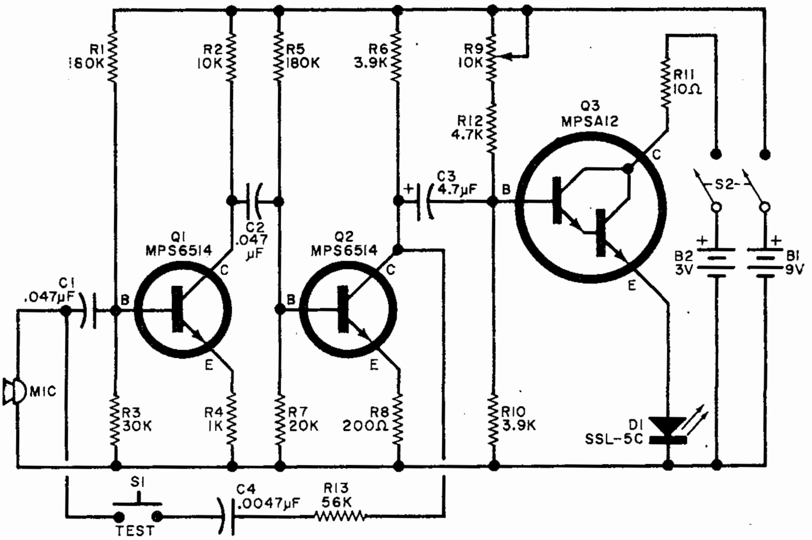


Fig. 1. The LED transmitter consists of a two-stage audio amplifier driving a Darlington modulator. When S1 is depressed, the audio amplifier is converted to an audio oscillator, used for making the original optical setup.

PARTS LIST
TRANSMITTER

B1—9-volt battery
B2—Two 1½-volt C cells
C1,C2—0.047-μF, 10-volt capacitor
C3—4.7μF, 10-volt electrolytic capacitor
C4—0.0047-μF, 10-volt capacitor
*D1—Light-emitting diode (GE SSL-5C)**
R1,R5—180,000-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R3—30,000-ohm, ¼-watt resistor
R4—1000-ohm, ¼-watt resistor
R6,R10—3900-ohm, ¼-watt resistor
R7—20,000-ohm, ¼-watt resistor
R8—200-ohm, ¼-watt resistor
R9—10,000-ohm, 1-watt potentiometer (Mallory MLC 14L or similar)
R11—10-ohm, ½-watt resistor
R12—4700-ohm, ¼-watt resistor
R13—56,000-ohm, ¼-watt resistor
S1—Normally open pushbutton switch
S2—Dpst slide or toggle switch
Q1,Q2—MPS6514 or HEP728 transistor
Q3—Darlington transistor (Motorola MPSA12)
Misc.—Suitable chassis, miniature crystal microphone, lens, battery holders, battery clips, mounting hardware, cement, wire, solder, etc.
**Available from Miniature Lamp Department, General Electric Co., P.O. Box 2422, Cleveland, OH 44112, $7.05, plus postage.*
Note—The following are available from MITS, 4809 Palo Duro N.E., Albuquerque, NM 87110: etched and drilled PC board, $2.50: PC board and all electronic items except switches, microphone, and batteries, $12.00: complete kit of all parts including lens, chassis, switches, and microphone, $17.00; all postpaid.

plifier formed by *Q1* and *Q2* is coupled to provide a low-frequency cutoff to minimize 60-Hz response. Darlington emitter follower *Q3* supplies bias current to the LED from *B2*. Potentiometer *R9* provides an unmodulated current-level adjustment for the LED and should be set so that ½ volt is read across *R11*. From Ohms law, ½ volt across 10 ohms indicates a current level of 50 milliamperes. This is well below the 100-mA capability of the SSL-5C LED without a heat sink.

Tone operation is provided by connecting the feedback circuit comprised of *R13* and *C4* to the input of *Q1* through *S1*. With *S1* depressed, the amplifier formed by *Q1* and *Q2* oscillates at about 500 Hz and supplies 100% modulation to the LED.

The transmitter circuit is assembled on a printed circuit board as shown in Fig. 2. In installing the semiconductors, use care—particularly with the LED, whose leads should have a heat sink attached while soldering. Make sure that the window of the LED is parallel to the PC board.

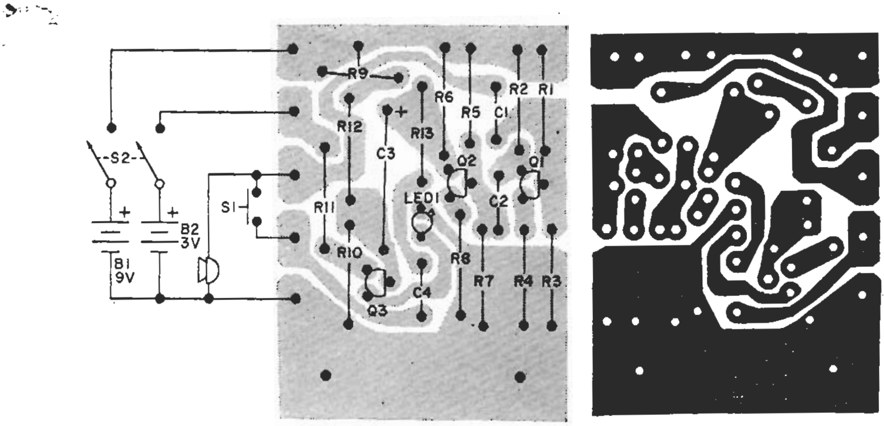
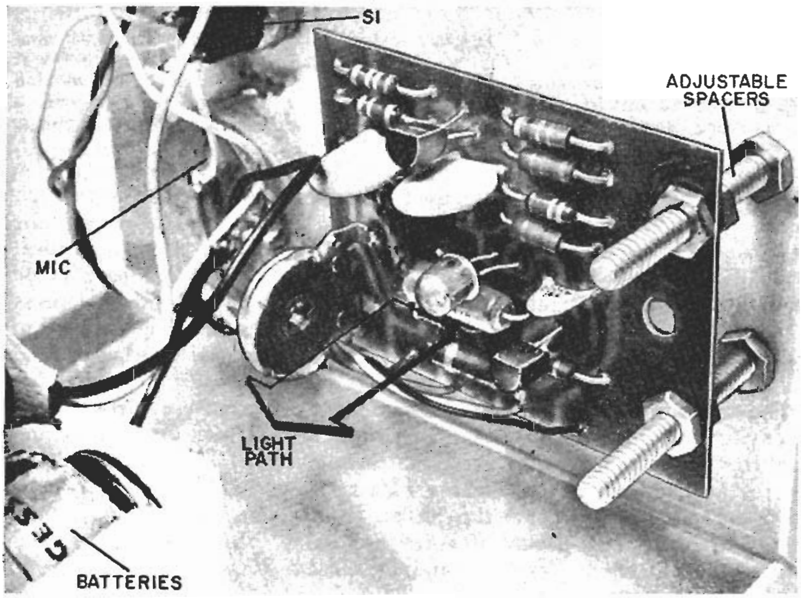
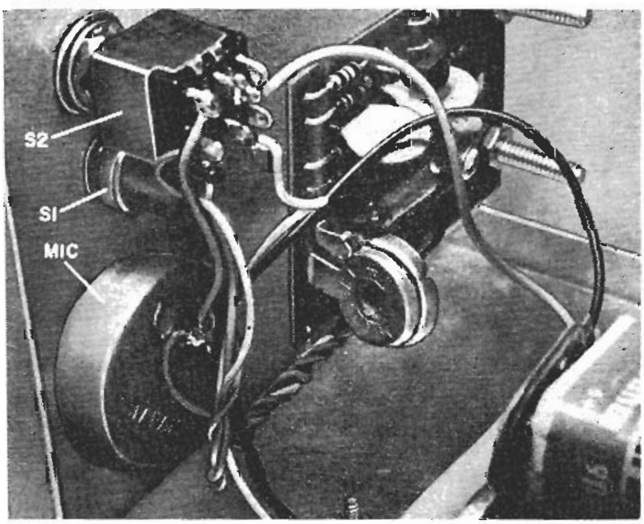
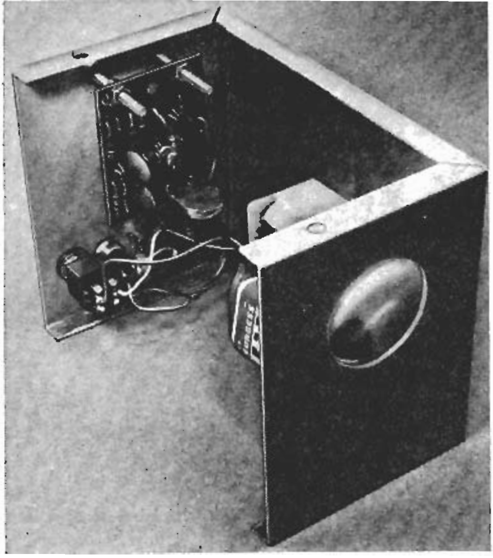


Fig. 2. The PC board foil pattern is shown actual size. When installing the components, use a heat sink on the LED (D1) and make sure that the window is facing the component side of the board. Make the board larger than the foil pattern to allow mounting holes.

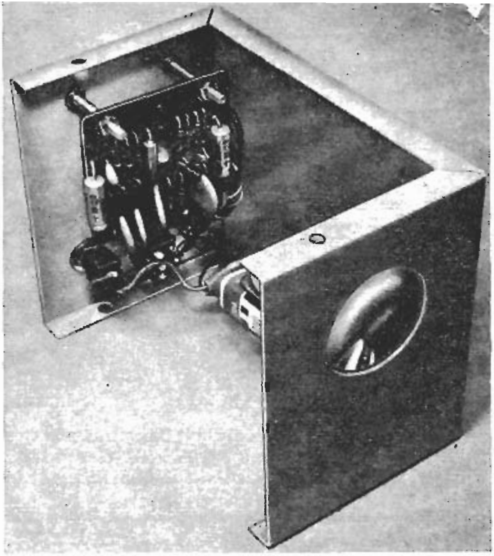


Assemble the transmitter on four adjustable spacers so that the window of the LED can be placed at the focal point of the lens. When assembling complete chassis be sure to mount the batteries so that they do not obstruct light path between the LED and the lens. Although the prototype has the microphone on chassis, a remote mike can be used. Even S2 can be mike-mounted push-to-talk switch. Oscillator switch S1 is rarely used, so can remain mounted on chassis.





In assembling the transmitter, arrange the board and lens mounting so that the LED window is on the center line of the lens. The text explains how to adjust the board to make the lens focus at the window of the light-emitting diode on board.



The receiver must be assembled in a manner similar to the transmitter—with the window of Q1 at the focal point of the lens. In both receiver and transmitter, once the focus has been attained, a drop of cement on screws will prevent slippage.

Receiver. A schematic of the receiver circuit is shown in Fig. 3. Phototransistor *Q1* passes a current proportional to the light intensity at its active surface. In essence, light replaces *Q1*'s base lead. Since *Q1* is quite light sensitive, even a moderate level of ambient illumination will drive it into saturation. Transistors *Q2* and *Q3* provide a dynamic load for *Q1*, preventing saturation or cutoff and extending useful daylight receiving range. The FET, *Q4*, matches the high impedance of the detection circuit to the audio amplifier formed by *Q5* and *Q6*. The complete receiver circuit provides a voltage gain of about 400.

A foil pattern and component layout for the receiver printed circuit board are shown in Fig. 4. Be very careful when installing phototransistor *Q1* because it has a plastic package and the leads are fragile. The collector of this transistor is indicated by a small arrow on the bottom. Place the transistor through the 0.175″ hole at the center of the receiver board (domed window to the component side), be sure the leads are properly oriented, and then solder them to the correct points. Use a clip-on heat sink when installing all semiconductors.

Assembly. Once both boards have been completed and checked for possible wiring errors, the system is ready for packaging. You can use the arrangement described here or you can strike out on your own. If, for example, you need only a 15-to-20-ft. range, an optical system is not required. All you have to do is aim the two boards at each other, depress the transmitter Test pushbutton, and align the two units. Then release the button and talk.

If you want a night range of up to 1000′, you must use a lens at both transmitter and receiver. Obtain two low-cost magnifying lenses at least one inch in diameter and remove the lenses from their housing or frames. Measure the focal length of each lens by placing it in the beam of a fairly distant light source. The sun is ideal, but an overhead lamp, about 10 feet away will do. The focal length is determined by placing the lens at a distance from a piece of white paper so that the smallest recognizable image is displayed on the paper. Measure the distance between the lens center and the paper—this is the focal length. The chassis to be used should be long enough so that, with the lens mounted at one end and the PC board carrying the LED or phototransistor at the other, the distance between the two can be adjusted to the focal length of the lens.

The chassis used must have a cover so that the interior is dark when the system is in use.

Drill four holes for mounting the PC board

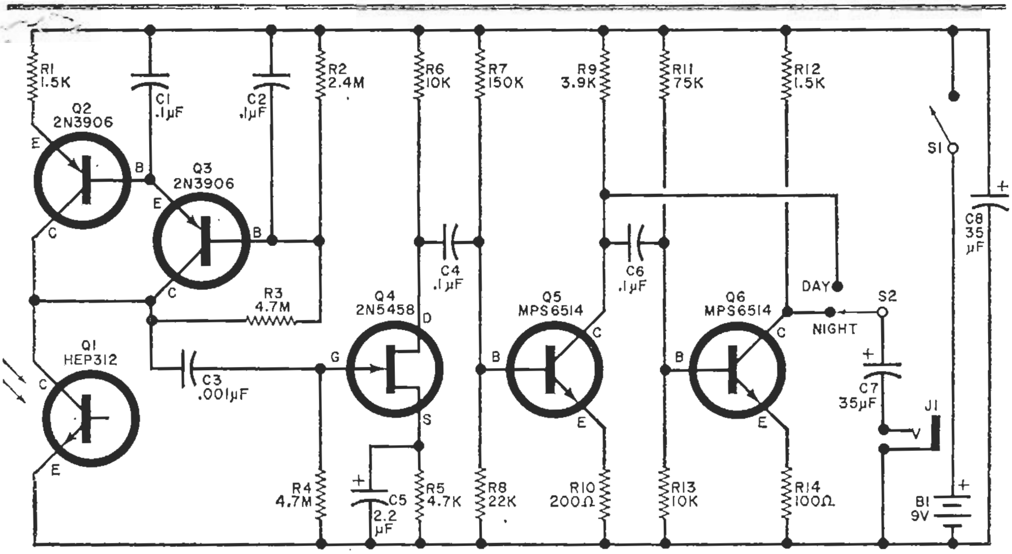


Fig. 3. Consisting of an audio amplifier driven by a phototransistor circuit, the receiver can use either two or three audio stages for day or night operation. There is no actual base connection to Q1 as this function is performed by light from LED.

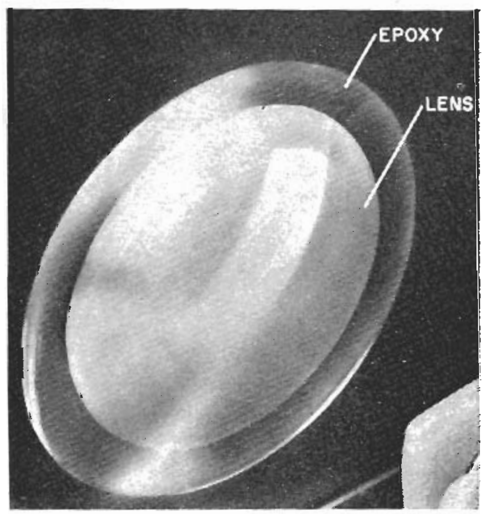
PARTS LIST
RECEIVER

B1—9-volt battery
C1,C2,C4,C6—0.1-μF, 10-volt capacitor
C3—0.001-μF, 10-volt capacitor
C5—2.2-μF, 10-volt electrolytic capacitor
C7,C8—35-μF, 10-volt electrolytic capacitor
J1—Earphone jack and plug
Q1—HEP312 phototransistor
Q2,Q3—2N3906 or HEP715 transistor
Q4—2N5458 or HEP801 FET
Q5,Q6—MPS6514 or HEP728 transistor
R1,R12—1500-ohm, ¼-watt resistor
R2—2.4-megohm, ¼-watt resistor
R3,R4—4.7-megohm, ¼-watt resistor
R5—4700-ohm, ¼-watt resistor
R6,R13—10,000-ohm, ¼-watt resistor
R7—150,000-ohm, ¼-watt resistor
R8—22,000-ohm, ¼-watt resistor
R9—3900-ohm, ¼-watt resistor
R10—200-ohm, ¼-watt resistor
R11—75,000-ohm, ¼-watt resistor
R14—100-ohm, ¼-watt resistor
S1—Spst slide or toggle switch
S2—Spdt slide or toggle switch
Misc.—Suitable chassis, lens, battery connectors, battery clips, mounting, hardware, cement, earphone (250 ohms or more), solder, wire, etc.
Note—The following are available from MITS, 4809 Palo Duro N.E., Albuquerque, NM 87110: etched and drilled PC board, $2.75; PC board and all electronic items except switches, earphone and batteries, $11.00; complete kit of all parts including lens, chassis, switches, and earphone, $15.00; all postpaid.

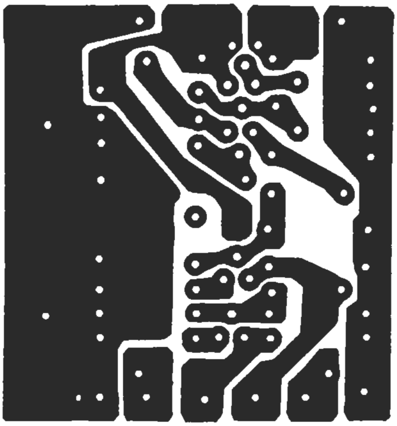
in one end of the chassis. Temporarily mount the chassis with four screws and nuts to allow for adjustments. Make measurements to determine the location of the center of the light-sensitive semiconductor with respect to its location on the chassis wall.

The center of the lens must be in the same position on the opposite end. Make the hole for the lens about ¼" smaller in diameter than the lens.

The crystal microphone and two switches for the transmitter are mounted on the same



The lens hole should be slightly smaller than the lens. Use epoxy cement to mount the lens to inside of the chassis to prevent accidental loosening.



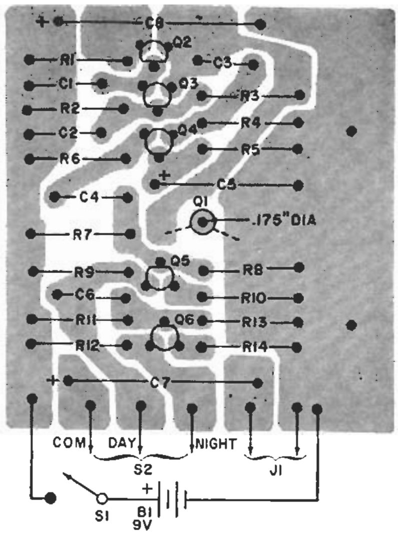


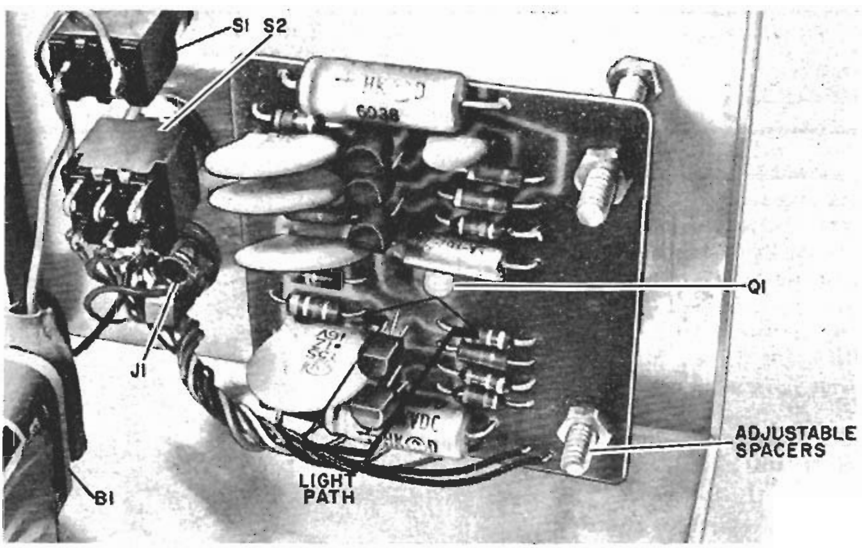
Fig. 4. When mounting Q1 make sure the window is facing the component side of the PC board. Connect collector to the foil that goes to R3 and Q1, and the emitter to the large common foil adjacent to the Q1 hole.

end as the PC board on the transmitter chassis. Cut a clean hole for acoustic access to the microphone, which is cemented to the inside of the chassis. The battery clips are mounted within the chassis, in a location where the batteries do not interfere with the light path from the lens to the LED.

On the receiver chassis use similar locations for the two switches and the earphone jack. Before mounting any components on the chassis, make sure that all mounting holes have been drilled and deburred; and, if desired, paint the chassis. Mount the PC boards with long screws to permit adjustment of focus. Put nuts on the screws on both sides of the boards to permit making the adjustment and locking the board in place.

When the wiring is complete and before mounting the lenses, test the units by aiming

(*Continued on page* 98)



Like transmitter, assemble receiver board on four adjustable spacers so that the window of Q1 is at the focus of the lens. Once again, make sure batteries do not obstruct light.

OPTICOM

(*Continued from page* 50)

the active elements at each other. Turn on the transmitter and measure the voltage across *R11*. Adjust *R9* until this voltage is ½ volt. With both units operating, depress the transmitter pushbutton *S1* and move the receiver slightly until a loud tone is heard in the earphone. If no tone is heard, test the receiver by aiming it at a 117-volt 60-Hz light. If the receiver is operating properly, you should hear a distinct 60- or 120-Hz hum. If you do not, troubleshoot the receiver. Once it is working, and you still get no signal from the transmitter, troubleshoot it.

With both units working, mount the lenses using a commercially available sealant. Mount them on the inside of the chassis so that they cover the holes and their centers are in line with the light-sensitive semiconductor elements on the PC boards.

Optical Alignment. Hold each unit in the beam path of a relatively distant light source. DON'T use the sun for this step—a common light bulb about 10 feet away will do. Align the chassis so that the light falls on the window of the active optical element. Move the PC board back and forth until the light comes to a sharp focus on the element window. Once this position has been located, lock the mounting screws; and, though it is not necessary, place a spot of cement on the screws to insure permanence. Once both units have been aligned optically, check that the batteries are firmly mounted and assemble the chassis covers.

Range Testing. Place the transmitter on a level mount and point it along a path unimpeded by obstacles for at least several hundred feet. With the Test pushbutton (*S1*) either depressed or temporarily shorted, walk about 10 or 15 feet away from the front of the transmitter carrying the receiver. Turn on the receiver and point it toward the transmitter, varying the aim until you hear the tone. You will notice the extreme directionality of the system. This is what makes it so private—you must be on the beam to get the signal. In daylight, the range will not be as great, but it can be improved by switching the receiver Day-Night switch (*S2*) to the Night position. If you find the tight beam too constraining, you can de-focus the receiver by moving the PC board slightly in toward the lens. One side effect of doing this is a reduction in range.

Of course, if two systems have been built for two-way communication, do not exceed the range of the worst pair.

Operation. If you are using a pair of communicators as a network, the transmitter at one end should be aimed at the receiver of the other end and the transmitter Test button pushed to tone-modulate the transmitter. Both ends should be positioned until the tone at each end is heard loud and clear. Once the link has been established, the pushbutton is released and the microphone is used for speech communication. Manipulation of the receiver Day-Night switch (*S2*) will affect the range and volume.

Modifications. There are numerous modifications and variations that can be used with the Opticom. Telescopes or binoculars at either, or both, ends greatly increase the range. Even low-cost plastic Fresnel lenses may be used. Since the light collecting area of a circular lens is proportional to the square of the diameter, a small increase in diameter results in a significant increase in the effective area. For example, a lens three inches in diameter has more than twice the light collecting area of a two-inch lens.

Since a diverging beam of light follows an inverse square law and produces a light energy density dependent on the square of the distance from the light source, doubling the lens light area will, in theory, double the range of the Opticom. Of course, operation in daylight or over paths having varied thermal conditions will limit the range. Longest ranges can be obtained on clear, cool nights, with a telescope at each end.

The Opticom system may also be used as a short-distance rangefinder. Mount a bicycle reflector on the target and aim the tone-modulated transmitter at it. From a short distance away from the transmitter, aim the receiver at the reflector until the transmitter tone can be heard. The transmitter, target and receiver should form a triangle. Once the tone has been heard, simple geometry can be used to solve the triangle and calculate the distance.

Daylight range can be improved if the interior of the receiver chassis is painted flat black. Also, a long focal plane lens can be used to narrow the field of view and reduce background illumination. This tightens the beam and makes more accurate alignment necessary. Also consider the use of a black interior tube or shield protruding from the lens to reduce ambient light to the phototransistor.