LIGHT BEAM COMMUNICATOR

Now, using our top-secret device, you and a partner can communicate across a void at the speed of light—on a beam of light!

ROGER SONNTAG

IF YOU'RE LOOKING FOR A purely *fun* project, then this light beam communciator is for you. It not only contains the usual electronics, it also has an ingenious mechanical assembly whose operation is interesting in its own right. You're sure to find it a refreshing change from the usual board-in-a-box project. But don't think that this light-beam communictor is just for fun. The powerful transmitter and extremely sensitive receiver take this project out of the realm of toys—you can do some pretty serious work with our device!

A complete *L*ight-*B*eam *C*ommunicator (LBC) consists of a transmitter and a receiver, installed inside 2 tube-like assemblies, along with various optical components. Two complete LBC's are required for two-way communication, but you will need only one transmitter and one receiver for one-way communication. Full-duplex operation is provided, meaning that you can talk and listen at the same time—there is no transmit/receive switch.

Figure 1 shows the block diagram of the transmitter. The transmitter houses a high-intensity LED, powered from a constant-current source, as well as the circuitry necessary to modulate an audio signal from a microphone onto the LED's light output. Using the optics, the modulated light from the LED is focused into an intense, narrow beam.

That narrow light beam travels a surprisingly long distance. The standard unit has about a ¼-mile range. The high-power unit has an amazing range of better than ½-mile! (When testing the range of the units, we used small "toy" 100-mW walkie talkies to assist with setup and aiming—the walkie talkies "ran out of gas" long before the LBC did!) At the end of its travel, the beam is received by another identical LBC that turns the modulated light beam back into the original audio signal. The receiver's block diagram is shown in Fig. 2. Let's examine the individual sections more closely.

The difference between the standard LBC and the high-power LBC is the LED that is used. The standard unit has a high-intensity 3-candela-power (3,000 milli-candela or mcd) LED manufactured by Hewlett Packard (a *candela*, formerly candle, is a measure of luminous intensity). The high-power unit has a very-high-intensity 12-candela (12,000 mcd) LED, also manufactured by Hewlett Packard. Both of those LED's are much brighter than a normal LED, and they have a focusing rather than a diffusing lens. However, *any* LED will work but the useful range of the LBC will be greatly reduced if a high intensity LED is not used.

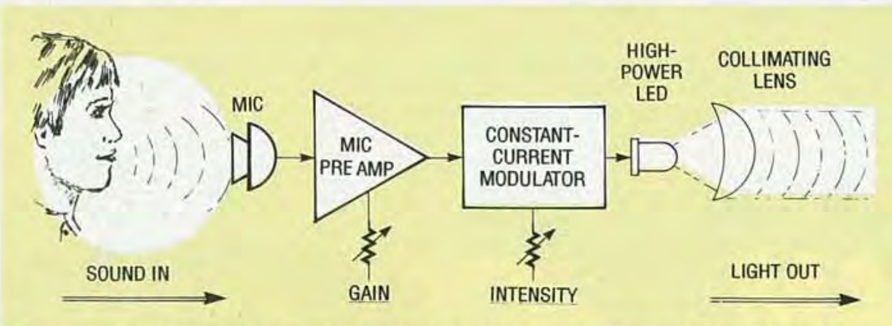

FIG. 1—BLOCK DIAGRAM OF THE TRANSMITTER. This circuit contains a high-intensity LED, powered from a constant-current source, and the circuitry necessary to modulate an audio signal onto the LED's light output.

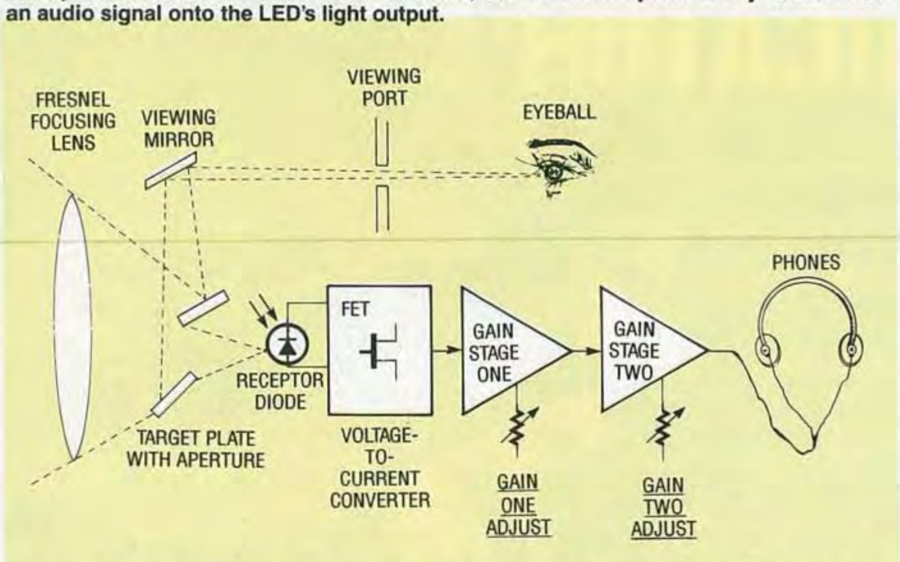

FIG. 2—RECEIVER BLOCK DIAGRAM. This circuit turns the modulated light beam back into the original audio signal.

The transmitter

There are two stages in the transmitter: a microphone preamplifier and a constant-current modulator (see Fig. 3). Each stage uses half of a 5532, which is an internally compensated, dual low-noise op-amp. After the microphone output is preamplified by IC1-a, the output signal from pin 1 is fed through C6 to pin 5 of IC1 where it is further amplified.

An adjustable constant-current source is fed to Q1, an NPN transistor capable of handling at least 3 amps. The audio signal at pin 7 of IC1 drives the base of Q1, modulating the signal onto the LED's light output. (An infrared LED can be used for this project, and will, in fact, increase the range. Unfortunately IR light is invisible, so it is not easy to work with. However, among the interesting things you can "hear" with the LBC are IR remote controls and IR burglar-alarm sensors.) Basically, the AC signal either adds or subtracts from the average DC level. Transistor Q1 and LED1 are in the feedback loop of the op-amp, and the DC current flowing through the LED remains constant due to the setting of R9. The DC current can be adjusted via R9 through a range from 1 to 50 mA.

The transmitter assembly, shown in Fig. 4, is fitted inside one end of a rugged cardboard tube that has a collimating lens at the other end. That lens focuses the light beam into a very narrow, intense beam, giving the light from an LED such an unusually long range.

FIG. 4—THE TRANSMITTER ASSEMBLY. It is fitted inside one end of a rugged cardboard tube that has a collimating lens at the other end.

The receiver

The schematic for the receiver section of the LBC is shown in Fig. 5, and the receiver assembly is shown in Fig. 6. The receiver assembly is mounted inside one end of a large tube, which has a fresnel lens at the other end. The fresnel lens concentrates the light beam, and directs it to the photodiode, D1. The photodiode provided in the kit is actually a Kodak part, and not available to the general public. That part is well suited for this application, and it is more sensitive to infrared light than most photodiodes; but if you don't buy the kit, any silicon photodiode or phototransistor

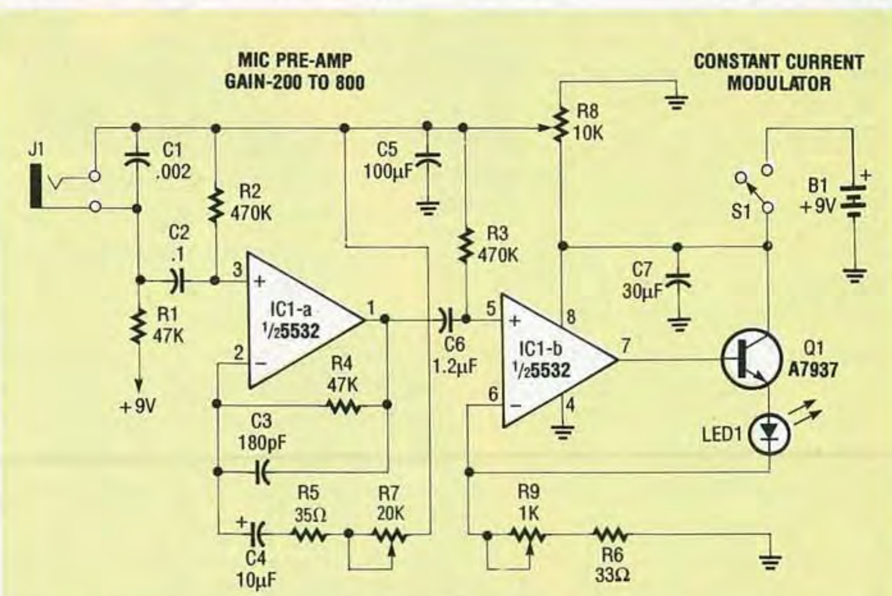

FIG. 3—THE TRANSMITTER CONTAINS TWO STAGES: a microphone preamplifier and a constant-current modulator. Each stage uses half of a 5532 op-amp.

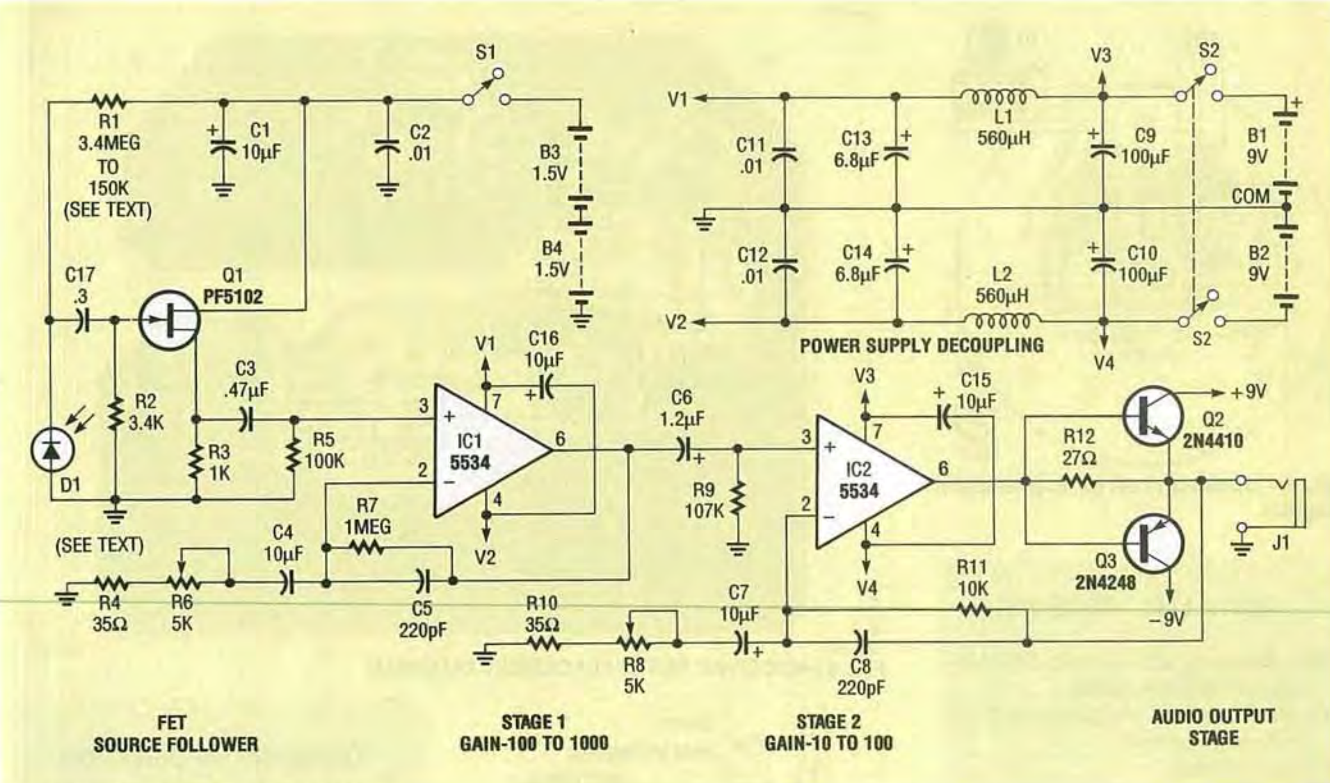

FIG. 5—THE RECEIVER SCHEMATIC.

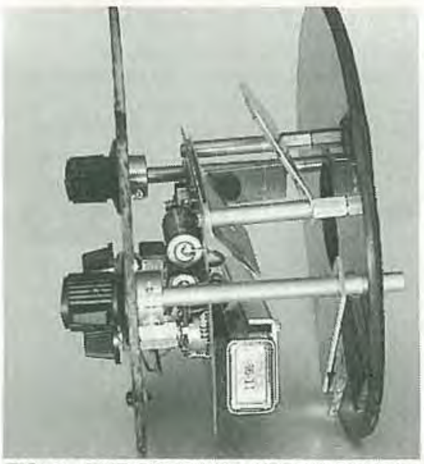

FIG. 6—THE RECEIVER ASSEMBLY. It is mounted inside one end of a large tube, which has a fresnel lens at the other end.

should do. The small signal that is generated by D1 is fed to pin 3 of IC1 via FET Q1.

Op-amp IC1 is the first gain stage in the receiver, and it amplifies the signal from Q1 100 to 1000 times, depending on the setting of gain-control potentiometer R6. The signal from pin 6 of IC1 is then fed through C6 to pin 3 of IC2, which is the second gain stage; the gain of the second stage is variable from approximately 10 to 100 via gain-control potentiometer R8. Two gain-control potentiometers are used to help improve stability, because stray oscillation is hard to avoid in a circuit with so much gain.

The signal at pin 6 of IC2 is then fed to R12, which is connected across the base-emitter junction of both Q2 and Q3. The voltage across R12 turns Q2 and Q3 on and off; those transistors are capable of driving a pair of low-impedance headphones.

Note that R1 is listed as being 3.4 megohms or 150 kilohms. That's because, if you use a value near 3.4 megohms, the receiver will be extremely sensitive, resulting in the greatest possible range. On the other hand, a value near 150K will decrease the sensitivity while providing a wide bandwidth, giving the unit higher fidelity. You can use any value between 3.4 megohms and 150 kilohms, but do not use a potentiometer, as it will be a source of noise in the circuit.

Construction

Let's start by building the transmitter board. Foil patterns for both boards are provided in PC Service. Figure 7 is the Parts-Placement diagram for the transmitter. First install the resistors, then the capacitors (bend the leads, solder, and then trim), and then the potentiometers. Cut some ribbon cable into 6 2-conductor pieces (3 for now and 3 for later), 1½-inches long, and then separate and strip the ends. (Any thin,

PARTS LIST—TRANSMITTER

All resistors are ¼-watt, 5%, unless otherwise noted.

R1, R4—47,000 ohms
R2, R3—470,000 ohms
R5—35 ohms
R6—33 ohms
R7—20,000 ohms, PC-mount potentiometer
R8—10,000 ohms, PC-mount potentiometer
R9—1000 ohms, combination potentiometer/switch (incorporates S1)

Capacitors

C1—0.002 µF, 50 volts, ceramic
C2—0.1 µF, 50 volts, ceramic
C3—180 pF, 100 volts, ceramic
C4—10 µF, 10 volts, electrolytic
C5—100 µF, 10–25 volts, electrolytic
C6—1.2 µF, 20 volts, electrolytic
C7—30 µF, 20 volts, electrolytic

Semiconductors

IC1—NE5532 dual low-noise op-amp
Q1—7937 3-amp NPN transistor
LED1—high-intensity light-emitting diode, can be Hewlett Packard HLMP-8103 (3000 mcd) or HLMP-8150 (12,000 mcd), or any other high-intensity LED.

Other components

B1—9-volt battery
S1—SPST switch (part of R9)
J1—mono phone jack

Miscellaneous: 9-volt-battery clip, 8-pin DIP socket, wire, solder, etc.

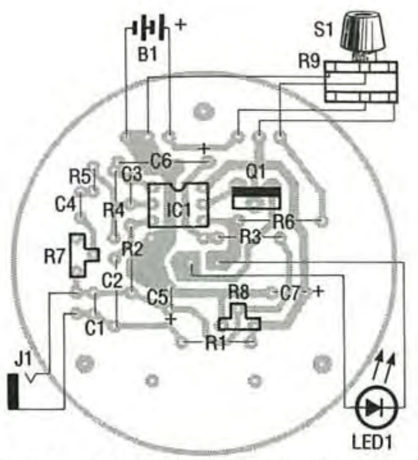

FIG. 7—TRANSMITTER parts-placement diagram.

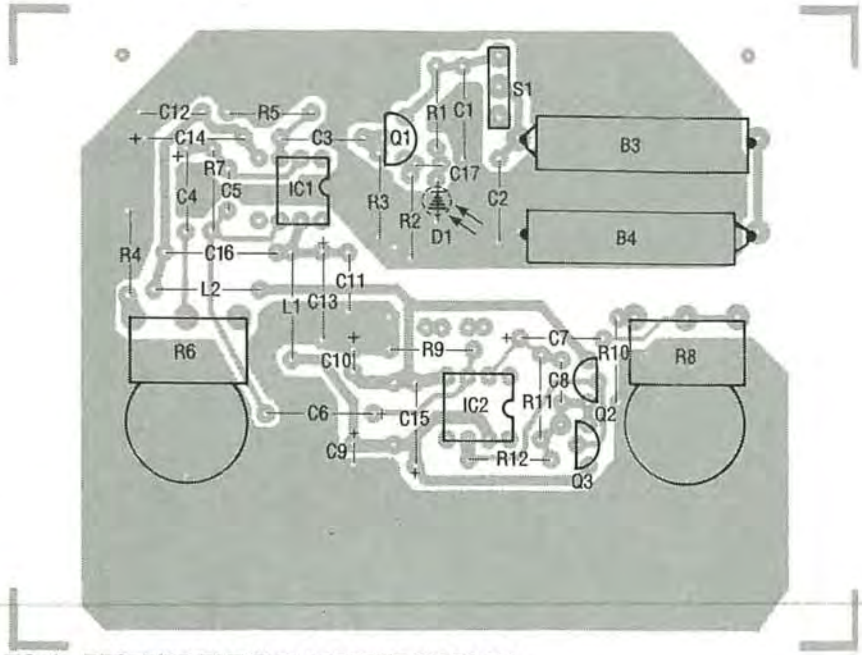

FIG. 8—RECEIVER PARTS-PLACEMENT DIAGRAM.

PARTS LIST—RECEIVER

All resistors are ¼-watt, 5%, unless otherwise noted.

R1—between 3.4 megohms and 150 kilohms (see text)
R2—3.4 ohms
R3—1000 ohms
R4—35 ohms
R5—100,000 ohms
R6, R8—5000 ohms, potentiometer
R7—1 megohm
R9—107,000 ohms
R10—35 ohms
R11—10,000 ohms
R12—27 ohms

Capacitors

C1—10 µF, 50 volts electrolytic
C2, C11, C12—0.01 µF, 10 volts, ceramic
C3—0.47 µF, 20 volts, ceramic
C4, C7—10 µF, 10 volts, electrolytic
C5, C8—220 pF, 100 volts, ceramic
C6—1.2 µF, 20 volts, electrolytic
C9, C10—100 µF, 15 volts, electrolytic
C13, C14—6.8 µF, 20 volts, electrolytic
C15, C16—10 µF, 25 volts, electrolytic
C17—0.3 µF, 50 volts, ceramic

Semiconductors

IC1, IC2—NE5534 single low-noise op-amp
D1—Siemans BPW-33 silicon photodiode (see text)
Q1—PF5102 field-effect transistor
Q2—2N4410 NPN transistor
Q3—2N4248 PNP transistor

Other components

L1, L2—560 µH
S1—SPST switch
S2—DPDT switch
B1, B2—9-volt battery
B3, B4—1.5-volt N-size battery

Miscellaneous: 2 9-volt-battery clips, DIP sockets, wire, solder, etc.

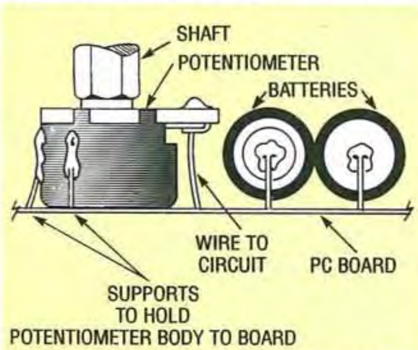

FIG. 9—YOU MUST USE PIECES of bus wire to attach potentiometers R4 and R6 securely to the PC board.

stranded wire will do if you don't have ribbon cable.) Then use one piece to connect the microphone jack, J1, to the pads indicated in Fig. 7, and two more to connect R8/S1.

Connect a 9-volt battery clip to the appropriate pads on the board, and then install IC1. (It's a good idea to use a socket for IC1.) Last, position LED1 (observe its polarity) so that it is standing perfectly straight off the PC board, then solder it in place.

For the assembly of the receiver board, see Fig. 8. First install resistors R1–R12, and then install the capacitors observing polarity where indicated. Then install L1 and L2, and sockets for IC1 and IC2. Using pieces of bus wire, attach potentiometers R4 and R6 securely to the PC board as shown in Fig. 9. Prepare B3 and B4 by soldering a short length of bus wire to each terminal (see Fig. 9) so that each battery can be PC mounted. PC-mount S2 and solder it in place. Now turn the board over, and solder D1 (the photodiode) in place observing its polarity indicated by a painted dot on its anode.

ORDERING INFORMATION

The following are available from General Science and Engineering, P.O. Box 447, Rochester, NY 14603 (716-338-7001): Kit of all parts, including all electronic and mechanical components, $98; Set of two PC boards, $12.00; 6-inch Fresnel lens, $15.00; A headset with built-in microphone, $12.00; Telephone-type handset, $5.00; Siemans BPW-33 photodiode, $3.50; HLMP-8150 12-cd LED price to be determined (call GSE for information); Assembled and tested communicator, $198. Note: the spotting scope is not available from GSE.

Take two 9-volt-battery clips and, on one of them, clip the red lead down to 1 inch and the black one to 2½-inches; on the other battery clip, cut the black lead down to 1 inch and the red to 2½ inches. Solder the leads to the PC board as shown. Using three more pairs of leads (as was shown in Fig. 8), connect J1, the headphone jack, and S2.

Well, the boards are finished, but that's all we have room for this month. Next month we'll finish the project by detailing the mechanical assemblies. We'll also present a list of the necessaray mechanical components. **R-E**