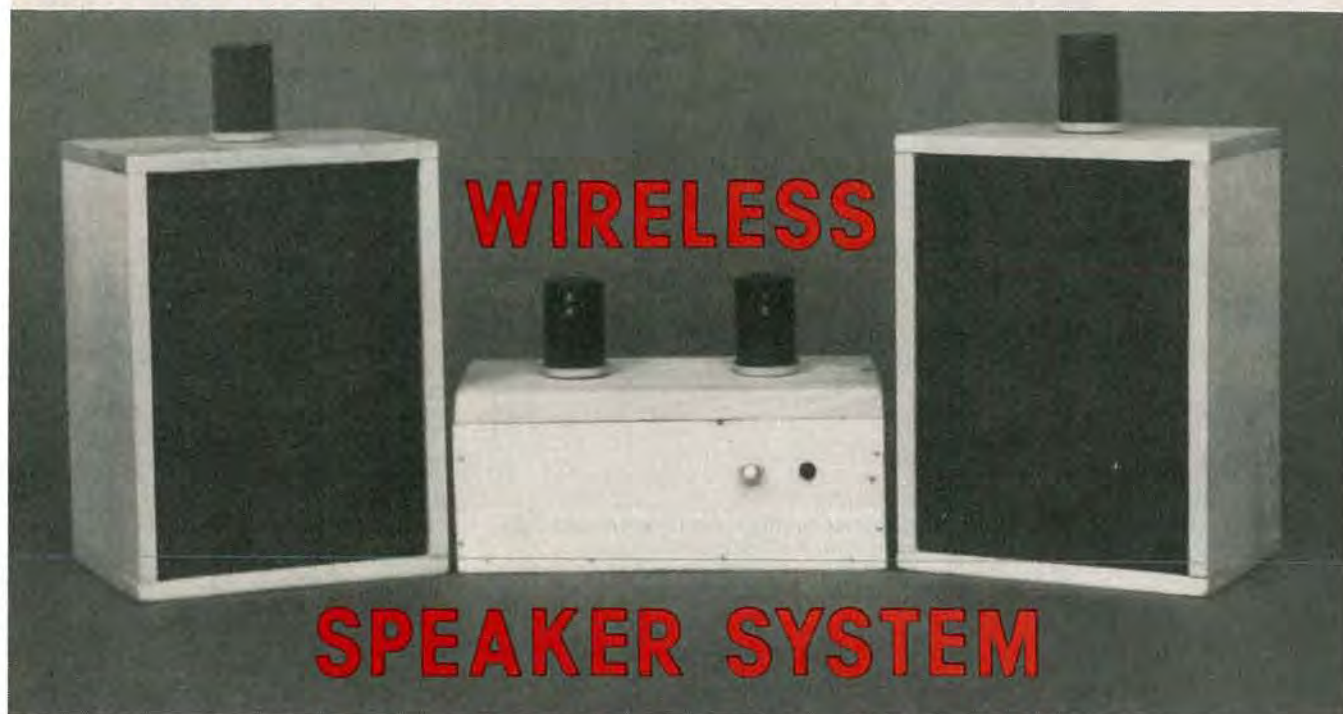




FOR MANY YEARS, INFRARED TECHNOLOGY was used mainly in military and industrial applications. Those included such things as snooperscopes, night-vision equipment, thermal cameras, missile-guidance systems, and satellites. More recently, however, infrared technology has found its way into a wide variety of consumer and hobby applications. It will undoubtedly be used to a greater extent in the future.

Before we go on, it would be useful to define exactly what *InfraRed* (IR) radiation is. It can be broadly defined as any radiation lying between the low (red) end of the visible spectrum, and the upper limit of the radio spectrum. That includes the very short wavelengths from about 700 nanometers to about 1000 nanometers.

The advent of hobbyist-priced IR-LED devices and integrated circuits makes it possible for us to build control and communication devices that operate in the near-IR (around 900 nanometers) portion of the spectrum. Several applications that are suitable for IR technology are:

- Wireless links between audio equipment
- Remote controllers
- Computer-data interfaces
- Wireless intercoms
- Aids for the hearing-impaired
- Cordless headphones

Many modern devices make use of infrared technology for communications. In this article we'll show you how to build one of those devices—a wireless speaker system.

**WILLIAM SHEETS and
RUDOLF F. GRAF**

In this article we are going to look at one of those applications: a wireless audio link.

IR communications

Although the IR region is free from radio interference, it is subject to interference from incandescent lamps, fluorescent lamps, stray reflections, and other sources; that is especially true of the near-infrared region.

A simple way to overcome that problem is to create a "carrier" by chopping the IR radiation at a rate of 100 kHz. The audio can then modulate the carrier by modulating the chopping rate. A receiver can then detect the IR beam as a 100-kHz FM signal. The only disadvantage is that instead of a simple audio amplifier, a high-gain FM receiver is necessary. However, with the IC's that are now

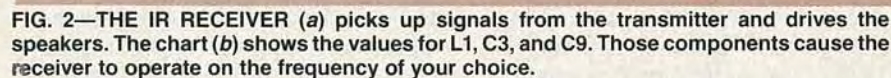
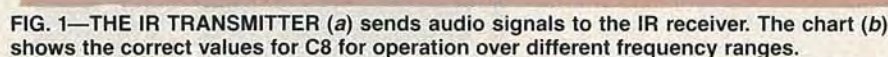
available, an FM receiver is easy to build, and contains little more circuitry than a high-gain audio amplifier.

The transmitter

A schematic for a suitable IR transmitter is shown in Fig. 1-a. Basically, it is a voltage-controlled oscillator that drives up to four LED emitters. A line-level (1-volt p-p, maximum) audio signal is fed to J1 (an RCA jack), and appears across R1. The audio is coupled to the base of Q1, which has a voltage gain of about five. It is then coupled to pin 5 of oscillator IC1, which operates in the 30- to 250-kHz range, depending on the application. Capacitor C8 sets the oscillation-frequency range, and then the exact frequency is adjusted by R9. Values for C8 for several frequencies are shown in Fig. 1-b. A square wave at pin 3 of IC1 drives Q2, which in turn switches Q3 on and off. The collector current through R15 and R16 bias the IR emitters (LED1 and LED2). Up to four IR LED's can be used, depending on the output level required; depending on the number of LED's used, the value for R15 and R16 may be between 100 and 330 ohms. Our prototype, which has two LED's, uses 150 ohms for both R15 and R16.

The receiver

The schematic for a companion IR



to conduct a small reverse current. The received modulated signal is coupled to amplifier Q1. Low-frequency noise is somewhat attenuated by a tuned circuit (L1/C3) that is broadly resonant between 30 and 150 kHz; that circuit allows the desired operat-

The signal at the collector of Q1 is coupled to Q2, which amplifies the signal and feeds Q3. The signal at the

PARTS LIST—TRANSMITTER

All resistors are 1/4-watt, 5% unless otherwise noted

R1—4700 ohms
R2—22,000 ohms
R3—10,000 ohms
R4—100,000 ohms
R5—5000 ohms, standard trimmer potentiometer
R6, R11—R13—1,000 ohms
R7—6800 ohms
R8—47,000 ohms
R9—10,000 ohms, standard trimmer potentiometer
R10—2200 ohms
R14—100 ohms
R15, R16—150 to 300 ohms, see text

Capacitors

C1—0.0033 μ F, 10%, mylar or ceramic disc
C2, C4—C6—10 μ F, 16 volts, radial electrolytic
C3—47 pF, 10%, ceramic or mica
C7—0.001 μ F, 20%, mylar or ceramic disc
C8—470 to 2,200 pF, mylar, mica, or npo ceramic (see text)
C9—0.01 μ F, 25 volts, ceramic disc

Semiconductors

IC1—NE566 VCO
Q1—2N3565 NPN transistor
Q2—2N3904 NPN transistor
Q3—2N3906 PNP transistor
LED1, LED2—IR155 LED

Other components

J1—RCA jack
S1—SPST switch
Miscellaneous: PC board, wire, solder, etc.

PARTS LIST—RECEIVER

All resistors are 1/4-watt, 5% unless otherwise noted

R1—1 megohm
R2, R3, R7, R10, R24—100,000 ohms
R4, R6, R9, R14, R18, R23—10,000 ohms
R5, R8, R11—R13, R15, R20, R25—4700 ohms
R16—10,000 ohms, standard trimmer potentiometer
R17, R31—2200 ohms
R19, R26—1000 ohms
R21—50,000 ohms, potentiometer
R22—22,000 ohms
R27—47,000 ohms
R28—10 ohms
R29—100 ohms
R30—47 ohms
R32—470 ohms

Capacitors

C1, C2—1 μ F, 16 volts, radial electrolytic.
C3—see text
C4, C6, C8—0.01 μ F, 25 volts, ceramic disc
C5, C7, C10, C13, C15—C17—10 μ F, 16 volts, electrolytic
C9—see text

C11, C12—0.01 μ F, 20%, mylar
C14—0.1 μ F, 20%, mylar
C18, C19—470 μ F, 16 volts, radial electrolytic

Semiconductors

IC1—LM565 phase-locked loop
IC2—LM386N low-voltage audio power amplifier
Q1—Q4—2N3565 NPN transistor
D1—PD600 photodiode
D2—D4—1N914 diode
LED1—Red light-emitting diode (see text)

Other components

L1—see text
S1—SPST switch
Miscellaneous: PC board, wire, solder, etc.

PARTS LIST—POWER SUPPLY

Resistors

R1, R2—47 ohms, 1 watt

Capacitors

C1—0.01 μ F
C2—C4—2200 μ F, 16 volts, radial electrolytic

Semiconductors

D1—D4—1N4002 diode

Other components

F1—0.5-amp fuse
S1—SPST switch
T1—12 volt, 1 amp transformer (Radio Shack 273-1365 or equivalent)
Miscellaneous: 3-prong line cord, fuse holder, perforated construction board or terminal strip

collector of Q3 is limited to 1 volt, peak-to-peak (via D3/D4), and coupled to pin 2 of IC1, an NE565 phase-locked loop. That IC consists of a phase detector and a VCO; the input to pin 2 causes the internal VCO to lock on to the input-signal frequency.

An internally generated DC voltage controls the VCO. The internal phase detector's output (pin 5) is connected to the internal VCO-control input (pin 4) via an external jumper wire. The

tuning-control resistor, R16, is adjusted so that the VCO's free-running frequency is approximately the same as the signal frequency. The recovered audio signal is obtained at pin 7.

The recovered audio is first coupled to R21, the AF gain control, and then to the AF-amplifier, Q4. The gain of the Q4 stage is limited by R22 to about five, and a 0.5-volt audio signal is available at its collector. Audio from the collector of Q4 is coupled to

IC2, an audio power amplifier, which can provide over 1/2 watt of audio to a loudspeaker. The audio is also coupled to R29, which is a limiting resistor used to avoid damaging low-impedance headphones.

The project can be powered from either a 12-volt power supply or battery pack. Eight alkaline AA-cells in series can be used if desired. An optional pilot lamp formed by R31 and LED1 should be left out for battery-powered applications to minimize power drain. So for battery applications use headphones instead of speakers to conserve power.

Figure 3 shows a schematic for a 12-volt power supply to operate the modules from the power line. It has two separate outputs, each with its own filtering.

Construction

During construction, you should take the same precautions as you would with any high-gain circuit. The

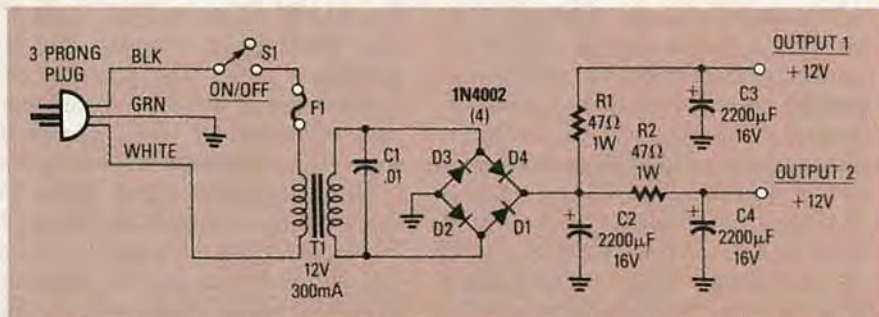


FIG. 3—USE THIS POWER SUPPLY to power your modules from the AC power lines if you want to avoid using batteries.

low-level leads to the detector photodiode should be shielded cable, and try to keep them short to minimize capacitance. Be sure to use the specified transistors and capacitors to keep the noise levels low. For best results, use a physically small coil for L3 to reduce stray inductive coupling.

The LED's can be mounted on the space provided for them at the end of the PC board, or you can mount them as you see fit. We used old 35-mm film cases to mount the LED's for the transmitter and the photodiodes for the receiver. You can use an RCA jack for J1. Just attach the jack to the cabinet, and wire it to the board. Follow Fig. 4 when building the transmitter, and Fig. 5 when building the receiver.

The PC-board layouts in the PC Service can be used to make your own PC boards. However, a pre-drilled and etched set is available from the source listed in the sources box. A kit containing all PC-board-mounted parts, including the photodiode and two LED's, is also available. (We recommend using two IR-LED's for each transmitter; one will do the job, but using two will extend the range.) You can mount the components for the power supply (if used) on a terminal strip using point-to-point wiring; otherwise, perforated construction board can be used.

Final adjustments

A frequency counter is helpful when tuning the completed modules, but is not strictly necessary. All voltage measurements are DC. Referring to Fig. 1 (the transmitter), check for about 12 volts on pin 8 of IC1. Next, check for about 6 volts on the collector of Q1, although anything between 5 and 8 volts is ok. There should be between 8 and 10 volts on pin 3 of IC1. With the LED's connected to the circuit, there should be about 6 volts on the collector of Q3.

Place an AM radio tuned to a low frequency (around 600 kHz) close to the transmitter and rotate R9. You should hear some squeals from the radio if IC1 is oscillating. Set R9 around midrange. Now, by listening for harmonics on the AM radio, you can tell the frequency of the transmitter. For example, if you hear a signal at 610 kHz, another at 720 kHz, and another at 830 kHz, the transmitter frequency is close to 110 kHz. That is because the harmonic spacing is 110 kHz, which is equal to the fundamen-

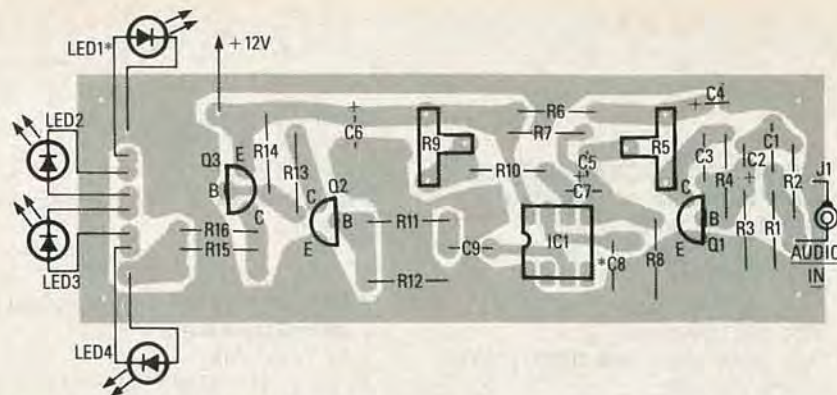


FIG. 4—USE THIS PARTS-PLACEMENT DIAGRAM to build the IR transmitter.

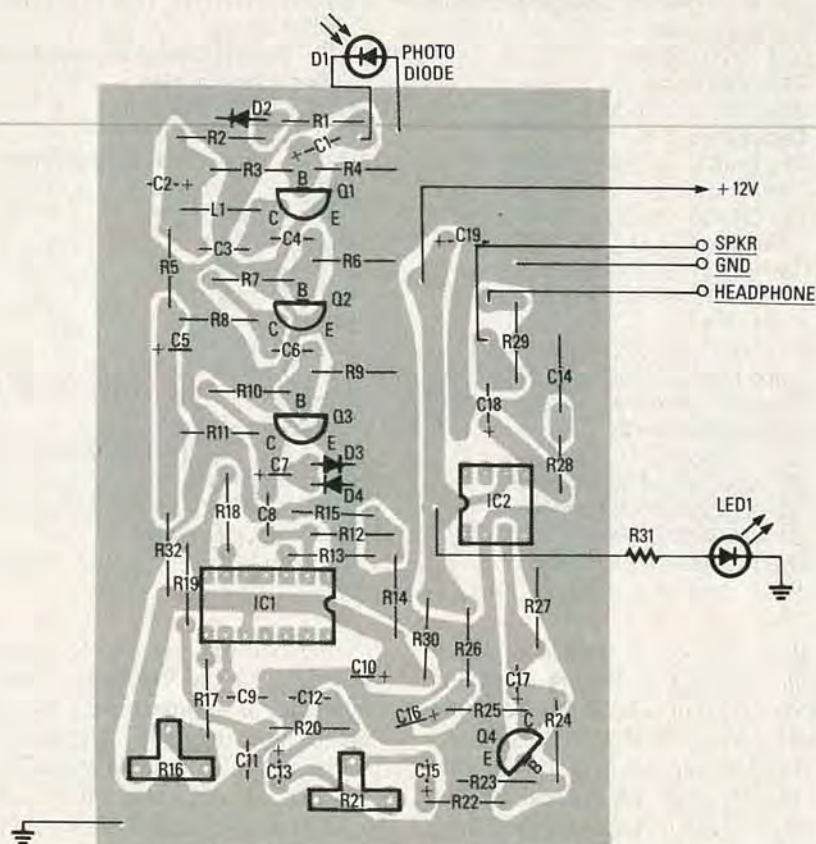


FIG. 5—THE IR RECEIVER is built using this parts-placement diagram.

tal frequency.

To check out the receiver's operation, connect an 8-ohm speaker to the audio-output terminal. Set both R16 and R21 to about midrange, and apply power to the receiver. You will hear a rushing noise if everything's working properly. You can check for 6 volts at the collectors of Q1-Q4, and on pin 5 of IC2. You should be able to measure 11 volts at pin 10 of IC1, and about 4 volts at pin 2. If you have access to a signal generator with a calibrated attenuator, you can check the receiver's sensitivity. About 1 mV on the base of

Q1 (use a 0.1 μ F coupling capacitor) should cause the receiver to quiet down by about 10 dB. If the generator can be FM modulated, set it for 25-kHz deviation and adjust R16 for maximum audio. The generator frequency should be tuned to the resonant frequency of L1/C3 (generally from 50 to 150 kHz).

Next, set up the transmitter a few feet from the receiver and turn it on. The receiver should instantly quiet itself. Adjust R9 in the transmitter and/or R16 in the receiver to set them both for the same frequency. That should

be equal to the resonant frequency of $L1/C3$. Now, apply a 1-kHz, 0.5-volt signal to the transmitter-audio input. A 1-kHz tone should be heard at the receiver, and should cease when the IR beam is interrupted. (Note that sometimes IR radiation will penetrate visually opaque materials.)

Applications

Before discussing the various applications for the IR transmitter and receiver, it should be noted that one transmitter can send a monaural signal to one receiver; therefore two of each circuit will be necessary if a stereo-audio transmission is desired.

One application for the IR transmitter and receiver is in a wireless-speaker setup that's similar to the prototype shown in the opening of this article. It can be used in conjunction with a pocket stereo. Audio from the headphone jack can be used to feed two separate transmitters—left and right. In our prototype, two inexpensive speakers were mounted in separate wood cabinets, with a receiver module and battery pack in each. The inside of one of our prototype speakers is shown in Fig. 6. If you like, you can use speakers from a small hi-fi set; there should be plenty of room inside the cabinet to mount the receiver module, battery pack, and on/off switch.

The two audio channels in our stereo prototype operate at frequencies of 80 kHz and 140 kHz; you can use any frequencies you choose, but make them as widely spaced as possible. Frequencies from 30 to 250 kHz have been tried with good results. Just make sure that you do not operate at exactly 100 kHz because there is a powerful loran-navigation signal on that frequency and the receiver might pick it up. (That may not be a problem away from the east coast of the US.)

If you wish to install the modules in an opaque plastic housing, a visually-opaque filter that transmits IR can be made from stock red and green plexiglass sandwiched together. The plexiglass is also available from the source listed in the Source box.

Figure 7 shows the inside of our prototype stereo transmitter. Two transmitter boards have been mounted along with the power-supply components. You can build a similar cabinet or make your own design.

Figure 8 shows a mono IR transmitter. Since it's a mono unit, it can be

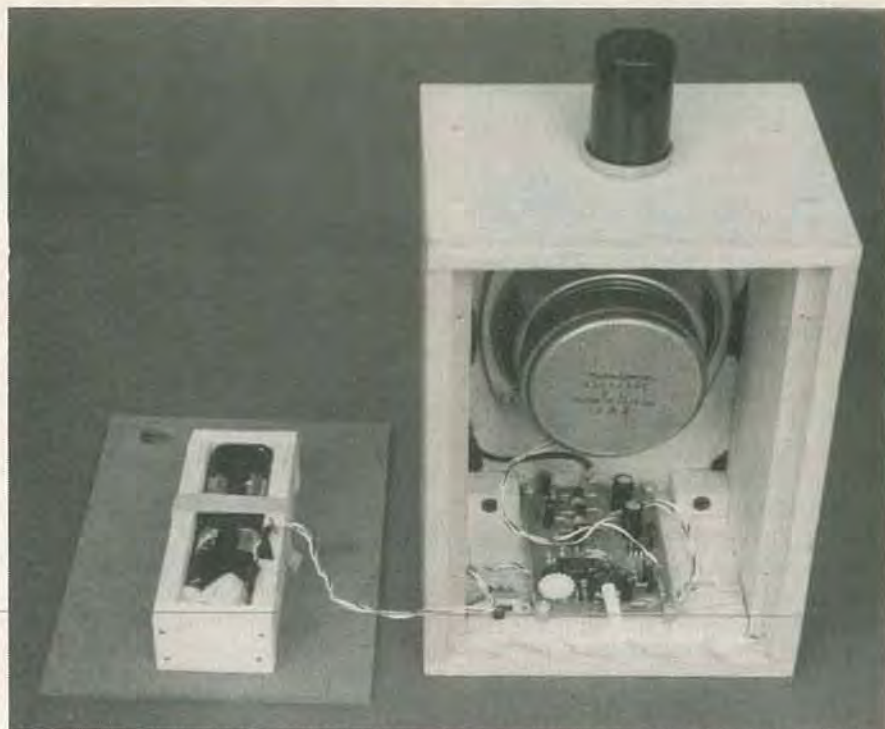


FIG. 6—AN INEXPENSIVE SPEAKER can be mounted in a wood cabinet along with a receiver module and battery pack.



FIG. 7—MOUNT THE MODULES for the stereo transmitter in a cabinet along with the power-supply components or a battery pack if you so desire.

mounted in a more compact case. The unit only requires that you build one transmitter circuit and one receiver circuit. If you're on a budget, you might prefer building a mono unit.

Another application for the IR transmitter and receiver is in a wireless-headphone setup, which can be used to watch television without disturbing others. The audio signal for



FIG. 8—A MONO TRANSMITTER can be built that will fit in a smaller cabinet.

the transmitter is obtained from the TV's speaker or earphone jack. If your television doesn't have an earphone jack, you'll have to open up the set and tap the audio directly off the speaker terminals.

WARNING: Do not open your television set if you don't know what you're doing. There are high voltages that could be hazardous to yourself, and you could damage the set itself. Do not install on any set that has any conductive path between ground and the AC powerline.

The receiver module can be mounted in a small plastic case fitted with a headphone jack. Just make sure to include R29 (for use with

SOURCES

The following items can be purchased from North Country Radio, P.O. Box 53, Wykagyl Station, NY 10804.

A kit of parts for one mono system consisting of the receiver and transmitter PC boards, all components that mount on the boards, including LED1, LED2, and D1 is available for \$39.95 plus \$2.50 for postage and handling.

A kit of parts to build two systems (for stereo) is available for \$74.95 plus \$2.50 for postage and handling.

Red and green plexiglass (2" x 2" x 1/8") to make an IR filter can be purchased for \$12.50 plus \$1.75 for postage and handling.

One receiver PC board and one transmitter PC board are available for \$12.50 plus \$2.50 for postage and handling.

LED1, LED2, and D1 are available for \$16.95 plus \$2.50 for postage and handling.

NY residents must add sales tax.

headphones) in the receiver's output section and connect the headphone jack to it. Headphones from a pocket

stereo are excellent for use in a wireless-headphone setup because of their light weight.

Fiber optics are a good conductor of IR transmissions. A length of fiber-optic cable (with suitable terminations) can be used to connect the transmitter and receiver, and will enable you to "bend" signals around corners or through a floor to another level of your home. The setup is particularly useful for experimenting with fiber optics, and you can use your imagination to come up with the many possible applications for that unique medium.

Figure 9 illustrates an IR perimeter-security system. If no audio is used to modulate the transmitter, the receiver's audio output will be zero. When the IR beam is broken, the re-

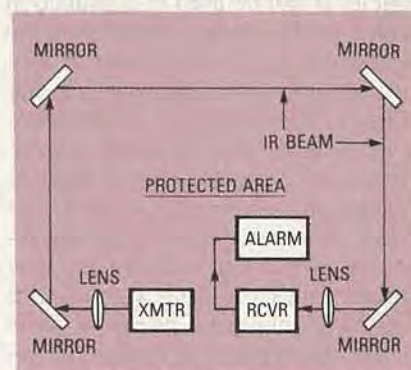


FIG. 9—THE IR MODULES can be used as a perimeter-security system for path lengths up to 1,000 feet.

ceiver's output will produce a noisy signal. That noise can be rectified with a diode and an RC filter; the DC level that is produced can drive a relay circuit or some other type of alarm. The IR beam is completely invisible, and path lengths of several hundred feet can be obtained using special optics. Those optics are desirable anyway because they help to keep the IR beam as narrow as possible so it is more easily broken. The specifics of the perimeter-security system are left to the experimenter.

You should get a range of at least 20 feet from the system, however you will find the range to be somewhat directional. If you have white ceilings, aiming the LED's at the ceiling should give you complete room coverage. If you position a magnifying lens in front of the detector, you may be able to extend the useable range to as much as 100 feet. With optics at both ends, an even greater range might be possible.

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