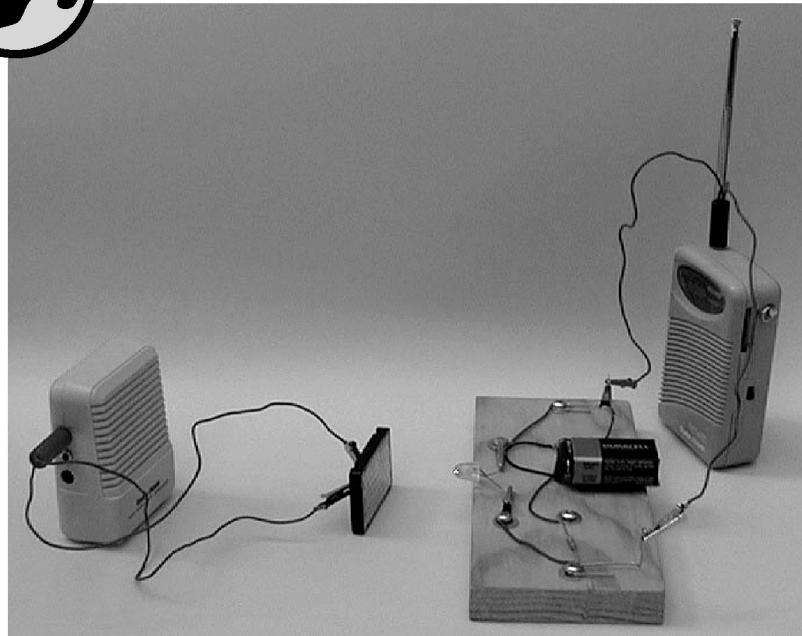


Modulated LED

Listen to a beam of light.



on a beam of light traveling between a light-emitting diode (LED) and a solar cell.

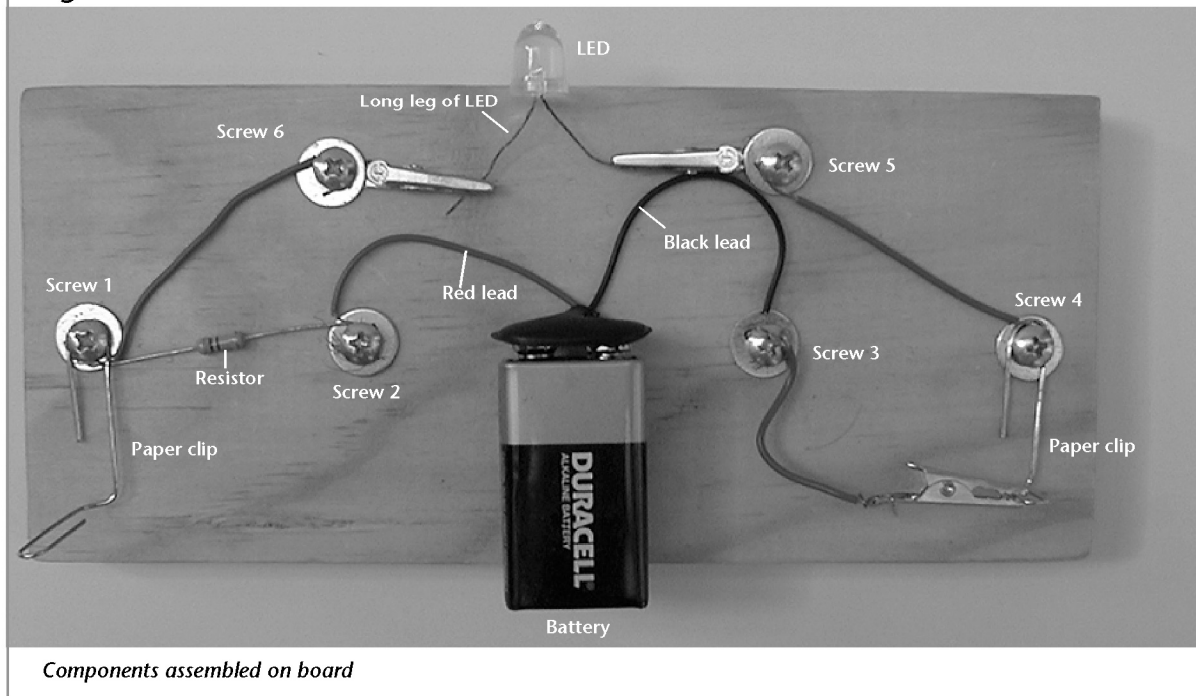
Materials

- 7 alligator clips (e.g., RadioShack #270-380 mini alligator clips)
- needle-nose pliers
- insulated copper wire, 22- or 20-gauge solid copper, 5 ft (1.5 m)
- wire stripper
- wooden board for base, approximately $3\frac{1}{2}$ in \times 8 in (9 cm \times 20 cm), can be made from $\frac{3}{4}$ -in standard shelving or plywood
- 470-ohm resistor (RadioShack #271-1317)
- 2 paper clips
- 9-volt battery
- Velcro with adhesive back, approximately 1 in \times 1 in (2.5 cm \times 2.5 cm), to hold the battery to the board
- 9-volt battery snap connector (e.g., RadioShack #270-325 or #270-324)
- 6 sheet-metal screws, #8 \times $\frac{5}{8}$ in
- 6 small flat steel washers (SAE #10)
- light-emitting diode (LED) (e.g., RadioShack #276-066 High Brightness Red LED)
- 2 phone plugs, $\frac{1}{8}$ in (e.g., RadioShack #274-286 or #274-287, sometimes called mini plugs; see Helpful Hint on page 52)
- amplified speaker (e.g., RadioShack #277-1008)
- solar cell (e.g., Edmund Scientific Co., 800-728-6999, www.edsci.com, #30398-09)
- small radio with headphone jack (e.g., RadioShack #12-799)

NOTE: Two premade 6-ft audio cables with a $\frac{1}{8}$ -in phone plug on one end and two alligator clips on the other end (e.g., RadioShack #42-2421) can be substituted for the two phone plugs, about 3 ft (1 m) of the wire, and four of the alligator clips in the list of materials above. One of the cables will have to be altered slightly so that its alligator clips are far enough apart to be connected to the paper clips at screws 1 and 4 (see figure 1 on next page).

ASSEMBLY

Figure 1



Components assembled on board

1 Flatten the ends of two of the alligator clips by bending the tabs outward with the needle-nose pliers (see figure 2).

4 Assemble components on the board as shown in figure 1. The ends of the short wires, the ends of the resistor, the paper clips, and the battery leads are all held in place between a screw head and its washer.

c. The alligator clip on the wire coming from screw 3 is used as a switch; when it's connected to the paper clip and the battery is in place the LED should be lit.

The alligator clips with the flattened ends are held in place under their washers (at screws 5 and 6). Note the following:

a. The red lead from the battery should be attached to screw 2, and the black lead to screw 3.

b. The long leg of the LED should be attached to the jaws of the alligator clip at screw 6 and the shorter leg to the jaws of the alligator clip at screw 5. The LED will allow current to flow in only one direction, so it's important to connect the leads properly. The longer lead from the LED is the positive lead.

➔ Helpful Hint

Be sure you have a mono plug.

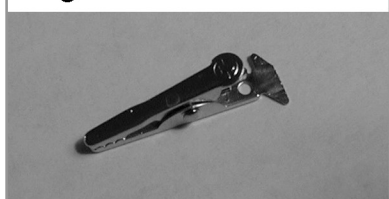
A mono plug can only be wired one way, and it will work with either a mono or stereo radio. A stereo plug can be wired in different ways, some of which may not work with particular radios (see figure 3 and step 6).

Figure 3



A mono plug (right) has one black band. A stereo plug (left) has two.

Figure 2



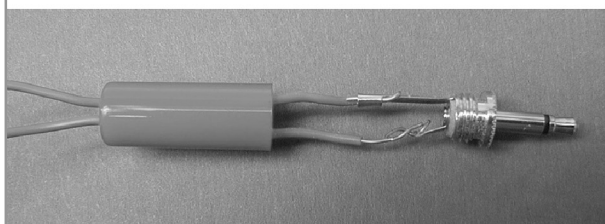
A flattened alligator clip

2 Cut the wire into three 3-inch-long (8-cm) pieces and four 12-inch-long (30-cm) pieces. Strip about a half inch (1.2 cm) of insulation off all the ends.

3 Attach one of the short wires to an alligator clip.

ASSEMBLY (continued)

Figure 4



Close-up of phone plug

5 Note where the battery lies on the board, and use the Velcro to hold it in place.

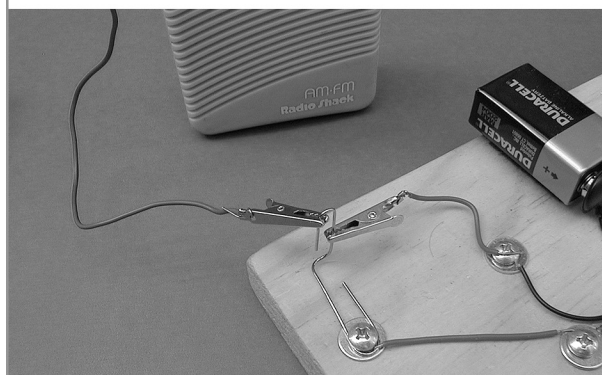
6 (**NOTE:** Skip this step if you are using the premade audio cables described in the Materials section.) Unscrew the plastic cover from one of the phone plugs (see Helpful Hint on page 52). Attach a 12-inch (30-cm) wire to the center terminal of the plug, and another 12-inch (30-cm) wire to the outer terminal (see figure 4). Slide the plastic plug cover onto the two wires and screw it back onto the plug. Be sure that the wire ends at the terminals don't touch each other—you may want to wrap a little tape around one of them to prevent contact. Attach an alligator clip to the other end of each of the wires. Repeat this process with the other phone plug, using two more wires, and two more alligator clips.

7 Insert one of the phone plugs into the input jack on the amplified speaker. Attach the two alligator clips to the contacts on the solar cell. Turn on the speaker and hold the

solar cell toward the light. You should hear static from the speaker. Turn the speaker off while you finish the assembly process.

8 Turn on the radio and find a loud, clear signal. Attach the alligator clips of the second phone plug assembly to the paper clips on the board (see figure 5). It doesn't matter which alligator clip is connected to

Figure 5



Attach the alligator clips from the radio to the paper clips on the board.

which paper clip. Plug the phone plug into the earphone jack on the radio. Once you insert the plug into the jack, you won't be able to hear the radio anymore. You may now be able to see the LED flickering, although it may fluctuate so quickly that you perceive it as a steady light.

➔ Helpful Hint

To test the solar cell and amplifier, turn on the amplifier and hold the solar cell in the light from a fluorescent bulb. If the system is working, you should hear a loud hum. Most fluorescent bulbs flicker on and off 120 times a second; the hum is produced by this fluctuation. (Some modern high-frequency fluorescent bulbs flicker on and off much faster and will not produce a hum.)

You can also test the solar cell by moving a comb back and forth between a small light source such as a glowing LED and the solar cell. Because of the spaces between the teeth, the comb alternately blocks the light and lets it pass. This creates pulses of electric current in the solar cell that, when passed through the amplified speaker, produces a "sawing" sound.

To Do and Notice

Hold the solar cell about 12 inches (30 cm) from the LED and point it directly at the LED. Turn on the amplified speaker again. You should now be able to clearly hear the radio signal coming from the amplified speaker. If you have difficulty, or if there seems to

be significant static, block peripheral light from hitting the solar cell, or turn off the room lights if possible.

Put your hand or a piece of paper between the LED and the solar cell. The radio signal should stop.

Try reversing the connections on the LED, attaching the long leg to screw 5 and the short leg to screw 6. You will find that the LED won't light.

What's Going On?

The battery provides a steady DC current to light the LED. Under the influence of the battery alone, the LED glows with a fixed brightness. The resistor limits the current so the LED does not burn out.

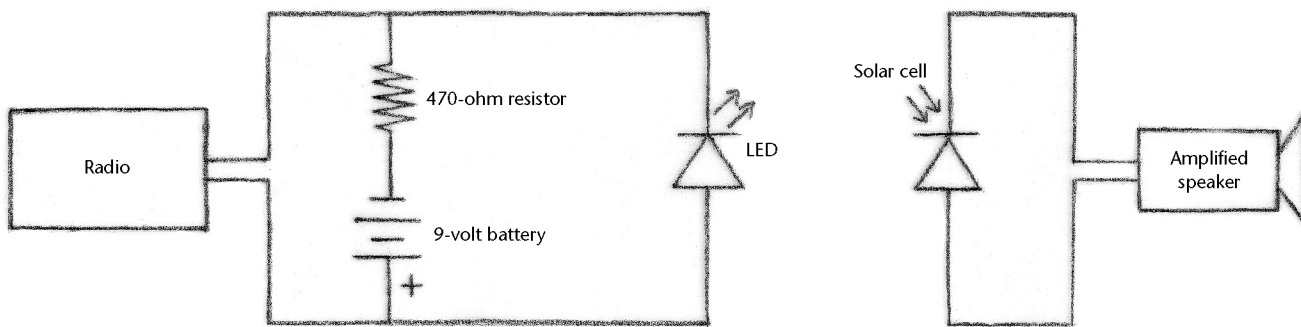


Figure 6 Circuit diagram with components labeled

When the radio is turned on, the weak but fluctuating radio signal is added to the constant signal from the battery. The LED still glows, but now it flickers in synchronization with the radio signal, as the amount of current passing through it varies.

The flickering light hitting the solar cell causes it to generate electrical signals which again vary in synchronization with the original radio signal. These signals are amplified and fed to the speaker, recreating the original sounds from the radio. (The preceding process is represented in figure 6.)

Placing an opaque barrier between the LED and the solar cell cuts off the light, and the solar cell is unable to generate any electrical signals.

So What?

Modern communications systems, such as long-distance phone lines and high-bandwidth communication lines for computers, commonly use modulated signals carried on a beam of light. The relatively high frequencies of visual light can carry a lot more information than lower frequency radio waves. The light that is used is normally from a laser, not an LED, and the signals are carried by a clear fiber-optic cable, rather than through air, but the principle is the same.

Going Further

Which LED Works Best?

Try several different LEDs and find out which results in the clearest sound or transmits the sound farthest. Does the relative brightness of an LED affect the results?

Cancel the Noise

It can be hard to use your system in a room lit by fluorescent lights because the lights flicker on and off, producing an annoying hum. To get rid of the hum, you can make a noise-canceling receiver with two identical solar cells.

Hook the solar cells together in a series, attaching the positive side of one to the positive side of the other. Attach the amplifier to the two negative terminals.

Shine the light from the LED on only one of the solar cells while the room light shines on both. The signal from the LED is converted to electricity by one of the cells, and the signal from the room light is converted into electricity by both of the cells. Because the cells are hooked together so that they oppose each

other, the two signals from the room light cancel each other. This allows you to hear the radio signal in a noisy environment.

Credits & References

This snack is based on the Exploratorium exhibit Modulated Laser.

Macaulay, David. *The Way Things Work*. Boston: Houghton Mifflin, 1988.

Mims, Forrest M. III. *Getting Started in Electronics*. RadioShack, 2000. (RadioShack #62-5004)



In World War II, navy signalmen used flashing lights to send messages between ships.