Experimenter's Corner

By Forrest M. Mims

EAVESDROPPING ON LIGHT

WE ARE literally surrounded by modulated sources of light, both natural and artificial. Seeking them out can be an enlightening and entertaining experience. This month we're going to do just that.

We ordinarily discuss circuits that are *not* available as preassembled commercial products. This column, however, marks a departure from our general practice in that it calls for the use of a commercially available, battery-powered audio amplifier. Of course, you can use a home-brew audio amplifier that you have on hand, or you can build one using an audio IC or a few transistors. You can then begin tracking down modulated light sources within minutes of reading this column, assuming you already have a few common components.

Suitable Detectors and Amplifiers. Silicon solar cells, photodiodes, phototransistors and other photovoltaic devices can all be employed as sensors in the detection of modulated light sources. Whatever sensor is employed can usually be directly connected to the input of the audio amplifier. In some cases, however, a transformer or other impedance-matching device or circuit will be required.

Although the high-fidelity amplifier found in any home audio system can be used with excellent results, a portable amplifier is best suited for this application because it can be readily used outdoors and in automobiles. Shown in Fig. 1 is a Realistic Micro-Sonic battery-powered amplifier I have used with suitable sensors to detect many different modulated light sources over the past several years.

Notice the miniature plug inserted into the amplifier's microphone jack. This plug contains a small silicon photodiode whose two leads are soldered directly to the plug's terminals. The opening in the plastic cap intended for the connecting cable was enlarged slightly with a reamer so that as much light as possible could strike the photodiode.

You might be able to save a little money by using one of the transistorized amplifier modules sold by some electronic parts suppliers. Mount the amplifier in a plastic case along with a battery, volume-control potentiometer and speaker. Incidentally, defective portable tape recorders are a good source of amplifier modules.

Many different kinds of light detectors can be connected to the audio amplifier. For very low light levels, I've found that a large-area silicon solar cell works best. However, this type of cell is easily broken so you will need to attach the cell you select to a rigid substrate of plastic, metal or wood. A few drops of cement will secure it in place. You can give additional protection to the cell as well as provide a directional detection capability by installing it at one end of a (10 to 30 cm) plastic, aluminum or cardboard tube. A lens is not necessary if the surface area of the cell is about the same as that of the tube's aperture. Use a long tube and paint its inside surface flat black for best results.

Most inexpensive, large-area silicon solar cells available on the surplus market are *not* supplied with connection leads. It is very important to use care when soldering connection leads to these cells because improper soldering procedures will cause the fragile electrodes to peel away from the cell.

The thin upper electrode is more difficult to solder than the large electrode that covers the entire bottom of the cell. For best results, heat a portion of the upper electrode near a corner of the cell if it is rectangular or near the perimeter if it is circular. Apply heat for only a few seconds with a low-power iron and then apply a small amount of solder. Next remove ⅛" (3.2 mm) of insulation from one end of a length of Wire-Wrap wire and place the exposed conductor along the electrode adjacent to the solder. Reheat the solder for a moment. It will suddenly flow over and around the wire to provide a perfect solder connection. Use this same procedure to solder a wire to the cell's bottom electrode.

You will have to provide a means for protecting the wire leads after the cell is mounted on a card or in a tube. I prefer to attach a shielded phono cable to the tube or card and then solder the cell's leads to the cable. This prevents the leads attached to the cell from being broken by a sudden jerk. The shielded cable reduces unwanted noise from nearby ac power lines and other sources.

For special-purpose detectors, try light-emitting diodes instead of solar cells. The peak response of a LED is confined to a much narrower group of wavelengths than that of a solar cell, and roughly corresponds to the wavelength emitted by the diode when forward biased. For example, a high-efficiency, GaAs:Si near-infrared emitter

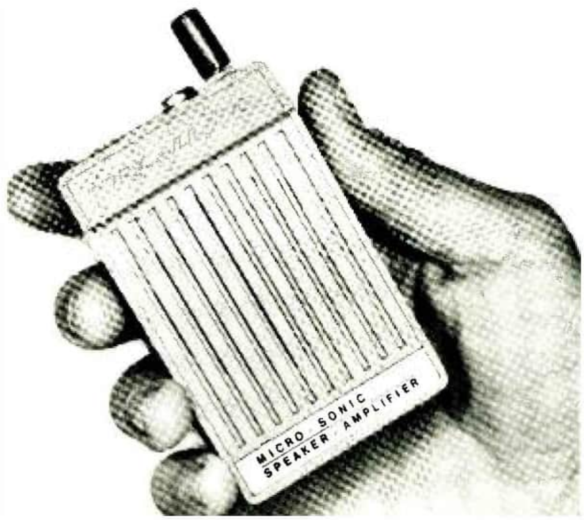

Fig. 1. Portable battery powered amplifier suitable for monitoring modulated light. Plug inserted into microphone jack incorporates a miniature silicon photodiode.

has a peak spectral response at about 940 nanometers.

Visible LEDs work as detectors also, but they are not as efficient as near-infrared LEDs. Figure 2 shows a GaAs

Fig. 2. Infrared emitting diode connected to miniature phone plug.

infrared emitter soldered to a miniature plug that can be inserted directly into a modular amplifier's input jack.

Whatever detector you select, tune in as many different light sources as possible. Many LED clock, watch and calculator displays are multiplexed at relatively low-frequencies and will usually produce a buzz or hum. Fluorescent lamps and neon lights produce a very strong 120-Hz buzz. Several years ago, a long-range light-beam communications experiment I was conducting was interrupted by a persistent buzz originating from a large neon advertising sign more than two miles away! Flickering candles, matches, lighters, campfires and fireplaces produce a variety of interesting sounds.

Electrical storms are particularly fascinating to monitor, especially at night. Lightning flashes produce the same crackling and popping sounds as those heard over a radio during a storm. The light detector, however, finds line-of-sight discharges which makes it possible to identify areas of peak activity.

Although the photodetector's sensitivity is reduced in daylight due to the unwanted dc bias which is produced, lightning can still be detected. Often, in fact, you'll detect with a solar cell lightning that you cannot see with your eyes.

Steady light originating from the sun and dc-powered lamps normally produces only a hiss. Movement, however, adds a new dimension to steady light sources. You will discover its effect the first time you "hear" light from the sun interrupted by a picket fence or overhead branches. You will even be able to pick up the hum of a flying insect by capturing the sunlight reflected from its oscillating wings. Similarly, you will detect the wing beats of a hummingbird when you position your detector so as to form a straight line with the sun and a bird hovering at a feeder.

To liven up the otherwise uninspiring hiss produced by a flashlight, tap its reflector with a pencil. This will cause a pleasant chime-like sound as the filament vibrates in and out of the reflector's focal point.

Calvin R. Graf, an acquaintance who shares my interest in monitoring modulated light sources, has described some of these and many other observations in a recently published book entitled *Listen to Radio Energy, Light and Sound* (Howard W. Sams & Co., Inc., 1978). Calvin's book reports on many of his personal observations and suggests experiments that can be conducted easily.

Op Amp Preamplifier. The circuit shown in Fig. 3 will serve as a crude but effective preamplifier for a battery-powered portable amplifier. The preamplifier can be assembled on a small perforated board. Insert the leads from a pair of 9-volt battery connector clips through a ¼" hole drilled in the board and tie a knot in the leads to keep them from pulling loose. Then solder them to the appropriate circuit nodes. (Red is positive and black is negative.) Connect the preamp to the amplifier with shielded cable.

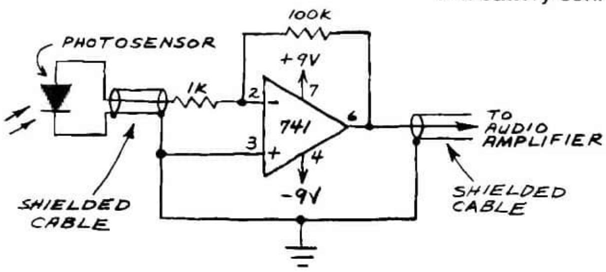

Fig. 3. Simple op-amp preamplifier for monitoring modulated light sources.

The voltage gain of the preamp is the quotient of *R2* divided by *R1*. With the values shown on Figure 3, its gain is 1000. This should be more than adequate for most sensors. Too high an input signal will overdrive the audio amplifier, so keep the volume control set to a low level when using the preamp.

A word of caution is in order for those who want to eavesdrop on light in noisy areas. An earphone will prove very helpful when the ambient sound level is high, but be sure the volume is turned to a low level until you have focused in on a light source you wish to monitor. Unexpected flashes of light can produce very *loud* sounds! ◇