The Optical Isolator (Part 1)

In this first of a two-section focus on optical isolators, our emphasis is on the various types of optical couplers available to experimenters and hobbyists, their technical characteristics, and typical applications. In the second half, which will appear next month, will be construction details for building an inexpensive and versatile tester that can be used in conjuction with a dual-channel oscilloscope and a digital multimeter to test all types of optical isolators in dual-inline packages, low-voltage zener diodes and 9-volt batteries.

Exploring Optical Couplers

By Ralph Tenny

Optical couplers—or optoisolators, as they are commonly called—have been available in one form or another for more than 25 years. The earliest such devices consisted of a light bulb and a light-sensitive sensor, both housed inside a container with a tube to couple them together. The sensor was usually a photoconductor like a light-dependent resistor, and the bulb was matched to the voltage that drove it. Over the years, advances in technology and the need to meet special requirements forced development of a wide variety of optically linked devices that solve tough design problems at very low cost and with high reliability.

In this article, we will explore the various types of solid-state optical isolators that are commonly available to the designer and experimenter. Our basic intent here is to familiarize you with the various devices available.

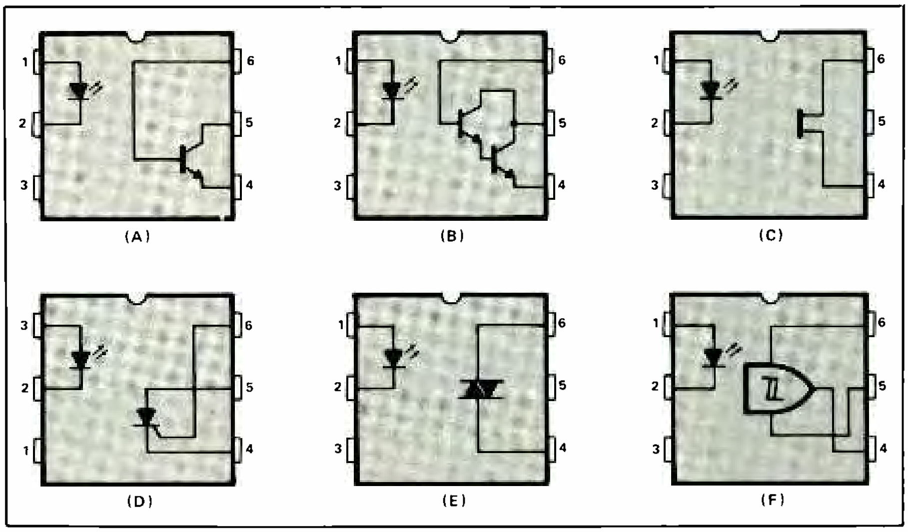


Fig. 1. Schematic symbols and pinouts for: (A) general-purpose transistor; (B) Darlington transistor; (C) bilateral FET; (D) light-activated silicon controlled rectifier (LASCR); (E) triac; (F) Schmitt trigger.

"Plain-Vanilla" Devices

Although the early lamp/photoconductor (a photoconductor is a light-sensitive resistor) optical coupler is still available, it has long since been eclipsed in availability, popularity and reliability by devices in which are a light-emitting diode (LED) and a phototransistor, shown in Fig. 1A in the 6-pin dual-inline package (DIP) that typifies the optoisolator family of devices. Note that this is a 6-pin IC-like device.

A LED is a common element in virtually all types of optoisolators. Most optoisolators use a single gallium-arsenide LED and all use a plastic device for light coupling. The coupler conducts the LED's output radiation (which can be visible light or invisible infrared radiation) to the photosensitive surface of the output device.

Figure 1's output device is a phototransistor, which is shown with the traditional transistor symbol. This transistor's functional base lead is frequently not used. Instead, the transistor is turned on by the beam from the LED through the light coupler. The same principle applies with whatever output device is used in the optoisolator. Each type of output device beyond the basic transistor has its own specific characteristics and was designed to meet one or more specific application needs that previous optical isolators could not handle.

Advanced Output Devices

Other output devices that are available include: Darlington transistors, bilateral FETs, light-activated silicon-controlled rectifiers (LASCRs), triacs and Schmitt triggers.

• *Darlington Transistor.* Shown in Fig. 1B is the schematic representation of the optical coupler with a Darlington-transistor output. Note that the Darlington arrangement consists of two transistors. The emitter of the input transistor drives the base of the output transistor.

Two effects result from use of the Darlington arrangement. The first is that much lower LED drive current is needed to turn on the Darlington output device with a given load. The second is that the Darlington stage has a much slower response time than the single-transistor output device. Response time refers to the period beginning when a drive-current pulse is fed to the LED in the optoisolator and ending when the output device switches on. A good transistor will typically switch on in 3 to 5 microseconds, while a Darlington arrangement of similar quality will require about 50 microseconds.

In terms of cost, you can obtain the single-transistor optoisolator for just slightly less than $1.

• *Bilateral FETs.* Shown in Fig. 1C is the schematic representation of the bilateral-FET-output optical isolator in its 6-pin DIP package with pinout information. The bilateral FET output stage is symmetrical so that it is not polarity sensitive. This is one of the more recent developments in optical coupler technology.

Two types of applications dictated

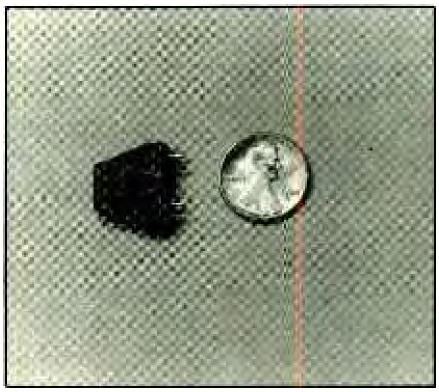


Fig. 2. Reflective optical sensor.

development of the bilateral FET optical isolator. One was the need for a remote variable resistor in automatic gain and similar applications. The other was the need for an isolated switch to turn on/off power-Darlington transistors and other devices that must be isolated from the switching system.

Bilateral FET optical isolators have a linear resistance range from 100 ohms to beyond 10,000 ohms and a 60-volt peak-to-peak signal-handling capability. Unit cost is about $4, which is a bargain, considering the versatility of the device.

• *Light-Activated SCR.* Shown in Fig. ID is the schematic/package representation of the optical isolator with light-activated SCR output. This device shares the normal characteristics of any discrete silicon-controlled rectifier. Its gate lead is usually connected to the cathode through a resistor to improve immunity to noise.

With a 300-mA current capability, the LASCR optical isolator provides remote switching control for relays, lamps and other low-to-medium-power devices. For the average LASCR device that can be used with 117-volt ac circuits, one can expect to pay just a bit more than $1.

• *Triac.* With a triac output stage (Fig. IE), isolated control of low-power lamps and other ac loads is possible using digital-logic circuits. The most common use for triac output is for triggering higher-power triacs, since the same digital-logic circuits can now control thousands of watts of power. This type of device retails for about $1.50.

• *Schmitt Trigger.* Shown in Fig. 1F is the logic/package representation for the Schmitt-trigger-output optical isolator. A Schmitt trigger is a special logic element that rejects noisy input signals. Additionally, it tolerates slow-rising input signals and switches reliably with them—a feature not possible with ordinary logic devices.

Isolation of high-speed digital signals (a 1-MHz data rate is typical) is the most popular use for the Schmitt-trigger optical isolator. High-speed capability in any optical isolator is always premium priced; hence, Schmitt-trigger optical isolators will usually cost about $4 apiece.

Technical Details

From the designer's point of view, the two most important technical specifications of an optical isolator are current transfer ratio (commonly abbreviated CTR) and voltage isolation. In transistor-output optical isolators, current transfer ratio is the ratio of the output current developed by the transistor to the drive current needed by the internal LED to produce the output current. The optical isolators discussed above have a 20% CTR, which means that 10 mA of LED drive current will develop 2 mA of output current from the transistor.

For about a 20% increase in price, you can obtain optical isolators with 100% CTR, in which input and output current are equal. Where the slower speed of a Darlington device is acceptable, CTRs of 500% (output current is five times input current) can be had for about the same price as the better single-transistor optical isolators.

(The "Opto Tester" article that will appear next month will contain details on construction of an acces-

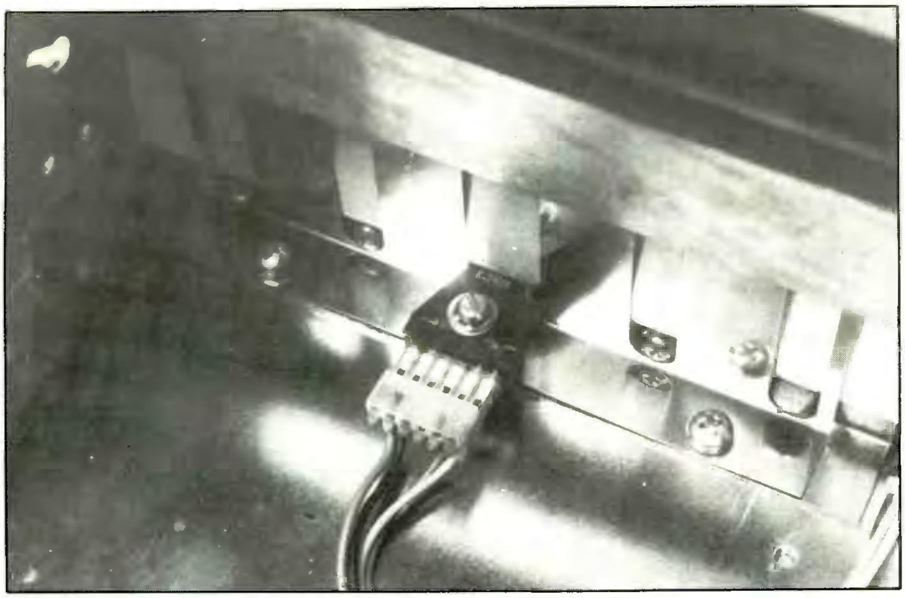


Fig. 3. *Reflective sensor signals when a ticket is placed in a ticket printer.*

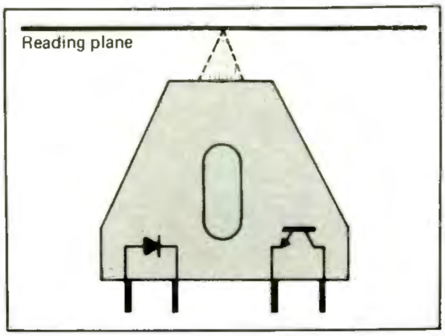


Fig. 4. Internal and package details of a typical reflective sensor.

sory that tests all types of optical isolator, including their CTRs.)

Isolation ratios for most optical couplers will be typically 1,500 volts minimum. However, optical isolators with up to 5,000 volts of isolation are available. Ratings are expressed for dc voltages or peak-to-peak ac voltages or the sum of both.

Bilateral FET devices are rated for isolation voltage, maximum and minimum resistance (output FET off and on, respectively), and turn-on and turn-off times. Important characteristics of LASCR optical isolators are output current capability and voltage isolation. Triac devices do not offer a wide variety of choices except with regard to higher voltage isolation. Their output is suitable for driving most power triacs. Schmitt trigger units are rated according to turn-on current (less is better, with 1.6 mA being about typical) and maximum data rate.

When choosing an optical isolator for a particular application, select one with at least 25% excess capability, more if you can afford it.

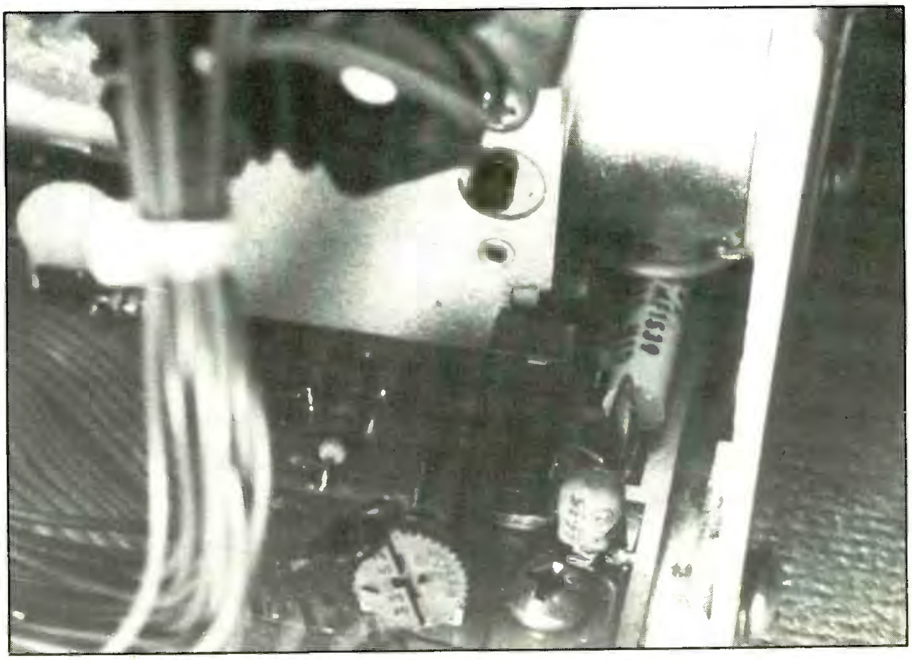
Related Devices

Two types of industrial sensors use the same type of technology as the optical isolator. These are interrupter modules and reflective sensors. Shown in Fig. 2 is a reflective sensor that gives some idea of size. Figure 3 shows the sensor in use.

A sketch of this sensor is shown in Fig. 4. Its internal structure contains a LED emitter whose energy is directed at a slight angle out through a slot in the device's housing. Any reflective substance that appears at the LED beam's focal point is reflected at an incident angle back through the slot onto the photosensitive surface of and turns on the internal transistor. Figure 3 shows this device being used to signal when a ticket has been placed into a ticket printer.

An interrupter module is similar in size to the reflector module but is shaped like a "C" with the LED emitter and transistor output device in opposite "jaws." Transparent plastic windows in each jaw allow the LED's radiation to reach the transis-

Fig. 5. An interrupter module detects the edge of a printer's carriage.



tor's photosensitive surface. Between the jaws is a narrow open slot through which thin items like cards can pass.

Figure 5 shows the interrupter module at the sensing edge of a printer carriage. The printer also has an interrupter module that "looks" through the spokes of a serrated wheel. Each wheel spoke causes a pulse signal to be generated by the interrupter module. These pulses are counted by a microprocessor to compute carriage speed and position and uses this data to print characters with precisely controlled spacing.

The reflective module has two other common uses besides detecting paper in a printer. If a narrow reflective stripe is attached to a rotating shaft and the sensor is placed the proper distance from the stripe, a pulse will be generated for each revolution of the shaft. Counting these pulses reveals how many revolutions are made over a given period of time. Adding a time measurement can then give speed in rpm.

In some punched-card readers, a bank of eight reflective sensors are used to detect data holes punched in the cards. Reflective sensors can also be used in home security systems. Window and door sensors are usually magnet/relay devices that can be defeated relatively easily. Replacing these with reflective sensors that require critical alignment of reflective tabs greatly adds to the effectiveness of the system. An intruder must work within a $\frac{1}{16}$" margin to defeat the sensor—assuming he is aware such a sensor is being used in the system.

From the foregoing, it should be obvious that the optical isolator, in its many guises, is an important and exciting component to use in electronic circuits. It is also one of the best buys in electronic devices on the market. With a firm understanding of optical isolators, you can design circuits and systems that would otherwise be impossible without them.

Automatic Telephone Ringer Silencer

Have you ever wished that the phone wouldn't ring while you're sleeping? One solution is to add a ringer on/off switch. Besides the trouble of turning the switch on and off, there is also the possibility of forgetting to turn it back on and missing calls. A better solution is described here. With it, the ringer automatically silences when the room lights go off and turns back on when the lights go on.

A photocell installed in line with the ringer circuit of an inexpensive electronic telephone does the trick. To make the modification, simply open the phone's case and drill a ½" hole through the top half to provide an opening for the photocell to show through. Cement the photocell with its sensitive surface facing outward over the hole, using plastic cement or silicone adhesive. Then connect and solder an 8" hookup wire to each lead.

Snip one of the wires going to the ringer's piezo buzzer. Trim the wires attached to the photocell as needed and connect and solder them to the ends of the wire you just cut.

For best results, place the phone directly under the source of light, for example a bedroom lamp. When light hits the cadmium-sulfide (Cds) photocell (Radio Shack Cat. No. 276-116 or equivalent), the resistance decreases and the phone rings normally. In the absence of light, the resistance increases to the point where the phone will not ring. The calling party will get the normal signal just as if the phone was ringing and you didn't answer it. You can rest assured that your sleep will not be interrupted.

As always, no modification should be made to telephone company property.

—Rich Vettel