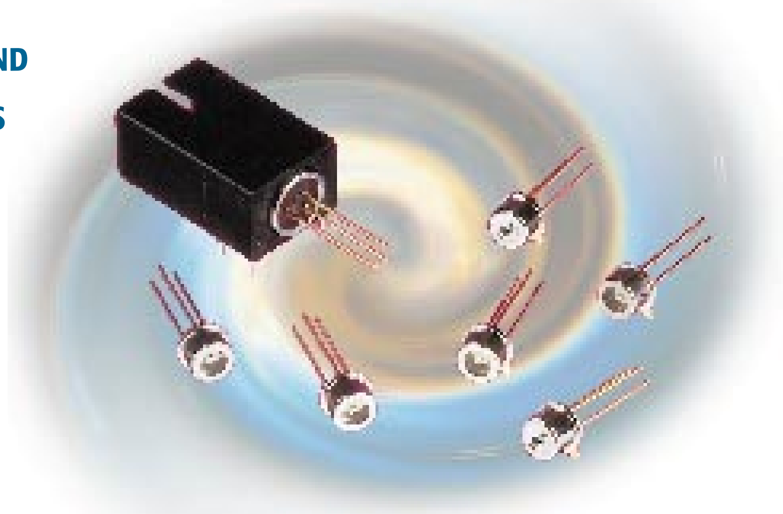
 By Bill Travis, Senior Technical Editor

Phototransmitters and receptors abound in flavors and capabilities

SEMICONDUCTOR LASERS, LEDs, AND VARIOUS PHOTOSENSITIVE DEVICES SUIT A VARIETY OF TRANSMISSION AND DETECTION APPLICATIONS. CHOOSING THE OPTIMUM DEVICE ENTAILS CAREFUL SCRUTINY OF OPTICAL AND ELECTRICAL SPECS.



Opto receivers and emitters from Hamamatsu come in easy-to-use, optically efficient packages.

At a glance **78**
For more information **80**

PHOTOTRANSMITTING AND PHOTOSENSITIVE semiconductors are available in great variety, to suit a wide range of transmission and detection applications. Semiconductor lasers, LEDs, and infrared-emitting diodes provide efficient illuminating sources, and variously configured pn-junction structures constitute sensitive light-detection devices. By using controlled doping and providing special filtering and lensing arrangements, photodevice manufacturers can fine-tune light wavelength, angle of dispersion (directivity), illumination intensity, and other parameters. You can obtain matched phototransmitter/photoreceptor pairs with parameters on the sending and receiving sides optimized to complement each other.

Vishay Telefunken, for example, offers a wide array of IR-emitting diodes and photoreceptors. The emitting diodes use various Ga/Al/As formulations, and most emit infrared light at 870- or 950-nm wavelength. The photoreceptor devices include transistors, Darlington transistors, Schmitt triggers, and pn and PIN (pn-junction-with-isolation-region) diodes. Some devices have no optical filter; others have a filter with an optical bandwidth of 870 to 1050 nm. An example of a matched phototransmitter/photoreceptor pair is the TSK5400 GaAs IR-emitting diode and the TEK5400 Schmitt-trigger photodetector.

AN IDEAL MARRIAGE

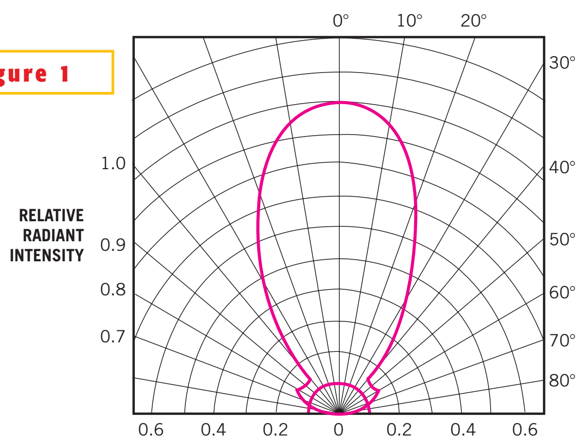
The TSK5400 IR-emitting diode uses a flat, side-view plastic package. It includes a small, recessed, spherical lens to enhance radiant intensity. The TEK5400 photosensitive Schmitt trigger uses the same package and lensing arrangement. The Schmitt trigger includes an infrared filter with peak response at 950 nm. The total power output of the TSK5400 IR-emitting diode is typically 10 mW, with intensity of 2 to 7 mW/sr (a sphere contains 4π steradians, or sr). **Figure 1** shows the relative radiant intensity of the emitted IR light from the TSK5400 as a function of angle. Because of the matched lensing arrangement, the relative sensitivity of the TEK5400 versus angle exactly matches the pattern in **Figure 1**. The TSK5400 emitter has a temperature coefficient of intensity like that in **Figure 2**. The device emits approximately 60% more light at −45°C than at 25°C and 40% less light at 90°C. The Schmitt trigger has almost exactly the same temperature coefficient, so the light response of the matched pair is relatively invariant with temperature.

Vishay Telefunken, in its data book for infrared emitters and detectors, provides various considerations for using pn-junction photodiodes. **Figure 3a** shows a photodiode connected in the "photovoltaic" mode, operating with a voltage amplifier. The arrangement provides an output voltage that's a strong logarithmic function of the input (light) signal. The extremely high shunt/dark resistance (more than 15 GΩ) combined with a high-impedance op amp and a junction capacitance in the picofarad range can result in slow switch-off time constants of some seconds. Moreover, the dark (leakage) current of the photodiode is highly temperature-dependent. **Figure 3b** uses a transimpedance amplifier with the photodiode in short-circuit mode. In this arrangement, the temperature dependence of the output signal is much lower than that of the circuit in **Figure 3a**. Moreover, the output voltage is directly proportional to the incident radiation. **Figure 3c** also uses a transimpedance amplifier with the photodiode connected in reverse-biased mode. This circuit improves the speed of the photodiode, because the reverse bias reduces the junction capacitance of the diode.

AT A GLANCE

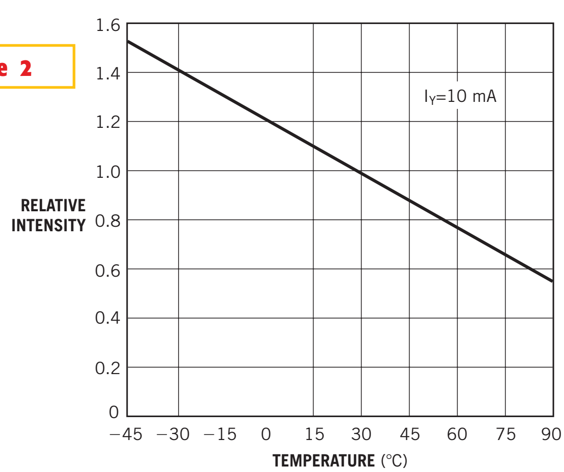
- ▷ LEDs and photodiodes are available in matched pairs.
- ▷ The connection of a photodiode in an amplifier circuit depends on the application.
- ▷ VCSELs outperform edge-emitting laser diodes; they're cheaper to produce, too.

Figure 1



IR-emitting diodes from Vishay Telefunken have sharp directivity.

Figure 2



The emitters and receptors from Vishay Telefunken have matching temperature coefficients, so they're relatively insensitive to temperature.

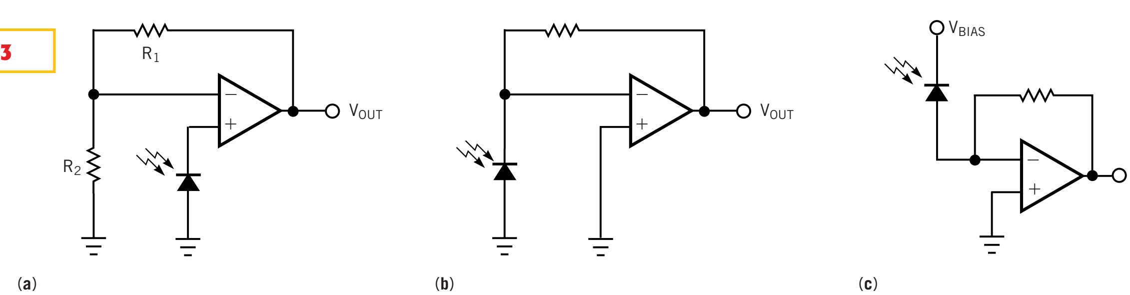
Vishay Telefunken combines IR-emitting diodes and phototransistors in a line of products called "reflex sensors" (**Reference 1**). The operating principles of reflex sensors are similar to those of transmissive sensors. An object or a medium influences the light that the transmitter emits on its way to the detector. The change in the light signal that the interaction with the object causes produces a change in the electrical signal in the optoelectronic receiver. The main difference between reflex sensors and transmissive sensing systems is the relative position of the transmitter and the detector. In the case of the transmissive system, the receiver is opposite the transmitter in the same optical axis, yielding a direct light coupling between the two. In a reflex sensor, the detector is next to the transmitter, avoiding direct light coupling.

Another specialist in optical components, Hamamatsu Corp, makes matched transmitter/receptor pairs. For example, the L7140 red LED and the S7141 photo IC work together to provide light emission and detection in optical-data-link applications at 650-nm (red) wavelength. The L7140 operates at 650 nm with a tight spectral half-width of 20 nm. Its data-transfer speed is dc to 50 Mbps, with a rise and fall time of less than 8 nsec. The LED's light output is greater than −7 dBm. The S7141 photo IC operates with a minimum receiving level of −17.5 dBm.

LASER DIODES EMIT CONCENTRATED LIGHT

A laser diode emits a narrow beam of concentrated light (**Reference 2**). The beam is usually elliptical because of astigmatism in the chip. Just as with the hu-

Figure 3



A pn photodiode in photovoltaic mode (a) yields a logarithmic response, whereas in short-circuit mode (b), the response is linear. The reverse-biased mode (c) gives the fastest response time.

man eye, external lensing can compensate for the astigmatism and accurately focus the beam. Laser diodes come in various colors, ranging from visible red (660 nm) to infrared (850, 1310, and 1550 nm). PIN photodiodes are the detectors of choice for laser-diode light. In many laser diodes and photodiode packages, a glass window collimates the laser light. The glass window can be either flat or in the shape of a ball lens. The ball lens, popular in fiber-optic applications, can focus the maximum amount of light into a small glass-fiber cable. A relatively new laser-diode technology has emerged, called VCSEL (vertical-cavity, surface-emitting laser) (**Reference 3**).

A VCSEL, unlike traditional laser diodes, uses standard microelectronics processing, allowing a yield of tens of thousands of diodes from a 76-mm wafer. Also, the standard processing permits integrating the VCSELs with other circuitry. The advantages of VCSELs include photolithographically defined geometries, circular output beams, high fiber-optic coupling efficiency, low power consumption, and high modulation rates. Because a VCSEL is nonastigmatic, its beam-divergence angle is less than 12°. A VCSEL ideally suits multimode-fiber applications. **Reference 4** discusses Spice models for VCSELs, and **Reference 5** gives techniques for modulating VCSELs.

Lumex and Honeywell are two major producers of laser diodes. Honeywell's recently announced HFE4181 VCSEL is an 850-nm device. The laser incorporates a power-monitor diode that you can use with appropriate feedback circuitry to set a maximum power level for the VCSEL. The HFE4181 accepts direct drive from PECL or ECL circuits. The device is a prealigned and focused fiber-optic transmitter designed for interface with 50/125 and 62.5/125 multimode fiber. Data rates can vary from dc to greater than 2 GHz. Honeywell has also announced a GaAs detector and preamplifier optimized for use with VCSEL devices, The HFD3X81-102 Series contains an 850-nm detector and a preamplifier targeting data rates of 622 Mbps to 2.5 Gbps. As the light intensity increases, the output voltage of the device increases, limiting at input powers greater than −10 dBm. The differential output is designed for ac coupling to a data amplifier. Laser Diode Inc also offers optical-receiver modules. The PinAmp product line integrates a high-speed InGaAs photodiode with a GaAs transimpedance amplifier. The product

FOR MORE INFORMATION...

For more information on optical transmitters and receptors, such the ones discussed in this article, go to our information-request page at www.rscahners.ims.ca/ednmag/. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

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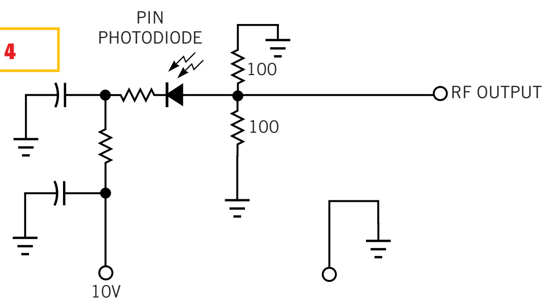
line is designed to meet the requirements of synchronous SONET, SDH, and Gigabit Ethernet systems. Standard data rates are 55 Mbps to 2.5 Gbps.

Virtually simultaneously, two organizations have announced the first practical 1.3-µm VCSELs. Sandia National Laboratories, in collaboration with Cielo Communications, uses InGaAsN material to produce the VCSEL. The 1.3-µm wavelength is ideal for high-speed, long-distance communications, but the only laser diodes formerly available for this band were expensive and complicated edge-emitting types. Nova Crystals Inc has also announced the development of a producible 1.3-µm VCSEL. By applying a number of design and process innovations to traditional InP VCSEL technology, the company can produce a VCSEL with continuous power output of 1 mW (without active cooling), bandwidth of 2.5 Gbps, and an operating voltage lower than 2V.

InGaAs-based PIN photodetectors from Discovery Semiconductors are eminently suitable as receptors for the 1.3-µm VCSELs. The DCS Series of photodetectors targets applications at 1310 and 1550 nm and use front-illumination, maximum-coupling efficiency and response. The devices' low capacitance allows detection of direct modulation at frequencies to 60 GHz. The photodiodes have coplanar waveguide outputs with 50Ω output impedance. The DCS Series finds application in various SONET and SDH systems, as well as in cable-TV-distribution systems and satellite links. A Finnish company, Detection Technology, specializes in the development of low-leakage-current photodiodes. The company's PDA Series of photodiodes features typical leakage (dark) currents of 0.5 to 5 pA. The peak sensitivity of the PDA Series is at 920 nm, but the diodes are relatively broadband, covering the visible and infrared regions from 270 to 1120 nm.

The advantages of VCSELs notwithstanding, many applications use traditional edge-emitting laser diodes. A major player in edge-emitting laser chips is Coherent Inc, which has recently announced a line of high-power, 980-nm lasers. These devices take 40A drive current and feature a spectral width of less than 3 nm. The diodes use an industry-standard, 25×25-mm, conduction-cooled package. The laser diodes are available in stand-alone "bar" form or mounted in fiber-array packages. The fiber-array package delivers its laser energy via an 800-mm diameter fiber bundle.

Figure 4



PIN photodiodes from Lucent feature high bandwidth and tight impedance matching.

Stanley Electric's top-view LEDs have a wide viewing angle and come in a variety of colors.

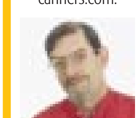
Agilent and Lucent are two major producers of modules and components for fiber-optic communications. Both companies make laser and receiver modules and modulation circuitry for the laser transmitters. They also both offer a wide line of photodiodes, for both analog and digital optical communications. For example, Lucent's R2560A is a high-power, 12-GHz PIN photodiode that has a bandwidth greater than 12 GHz (**Figure 4**). The photodiode has a 1280- to 1580-nm optical wavelength. The 100V resistors provide 50V matching to the RF output for a greater than 10-dB return loss.

LEDs COME IN MANY COLORS AND SHAPES

The humble LED has made many advances since its early days. Blue LEDs, formerly a rarity, are now commonplace. Once available only in dome-shaped plastic packages, LEDs now come in surface-mount formats with sizes of 0402 to 2832, plus various small-outline package styles. Lumex, Ledtronics, and Bivar, for example, offer tricolor (RGB) LEDs that you can use to configure full-color signs and displays. Several manufacturers offer light pipes that allow you to mount an LED in a convenient place on the circuit board, while the light pipe transports the emitted light to the desired location in a panel or display. Speaking of displays, Stanley Electric's 1140B Series of LEDs is a top-view, surface-mount device with a 120° viewing angle. It comes in a rainbow of colors: red, orange, yellow, green, blue-green, and blue. As an example of recently available blue LEDs, Infineon's Blue Line Series uses GaN material to produce light with a wavelength of 465 nm. The family has a 50° viewing angle and an optical efficiency of 1 lm/W.

As with ICs and other components, phototransistors and receptors are growing steadily in variety and performance. You face some tough choices in matching up transmitter/receiver pairs for optimum performance. Thankfully, opto manufacturers offer plenty of application assistance on their Web sites in informative catalogs, application notes, and technical papers.□

You can reach Senior Technical Editor Bill Travis at 1-617-558-4471, fax 1-617-558-4470, e-mail b.travis@cahners.com.



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