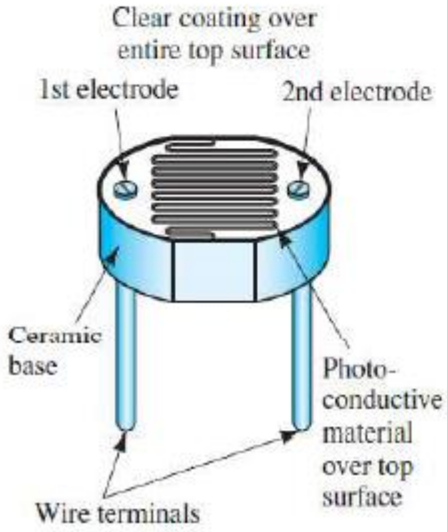
Al-Mustaqbal University
College of Engineering and Technologies
Medical Instrumentation Technique Engineering Department
Class: 2nd
Subject: Electronic Circuits
Lecturer: Dr. Rami Qays Malik
Lecture: 13- Optoelectronics devices

Optoelectronics devices



PHOTODIODES

The photodiode is a semiconductor p – n junction device whose region of operation is limited to the reverse-bias region. The basic biasing arrangement, construction, and symbol for the device appear in Fig. 16.19 . Recall from Chapter 1 that the reverse saturation current is normally limited to a few microamperes. It is due solely to the thermally generated minority carriers in the n - and p -type materials. The application of light to the junction will result in a transfer of energy from the incident traveling light waves (in the form of photons) to the atomic structure, resulting in an increased number of minority carriers and an increased level of reverse current. This is clearly shown in Fig. 16.20 for different intensity levels. The dark current is that current that will exist with no applied illumination. Note that the current will only return to zero with a positive applied bias equal to V T . In addition, Fig. 16.19a demonstrates the use of a lens to concentrate the light on the junction region.

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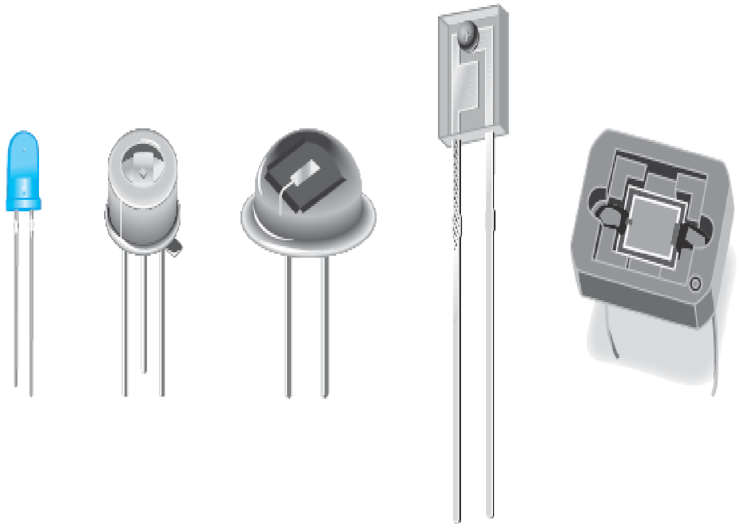

FIG. 16.21
Photodiodes

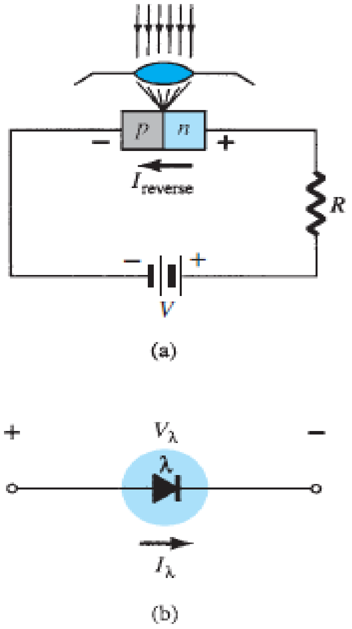

FIG. 16.19
Photodiode: (a) basic biasing arrangement and construction; (b) symbol.

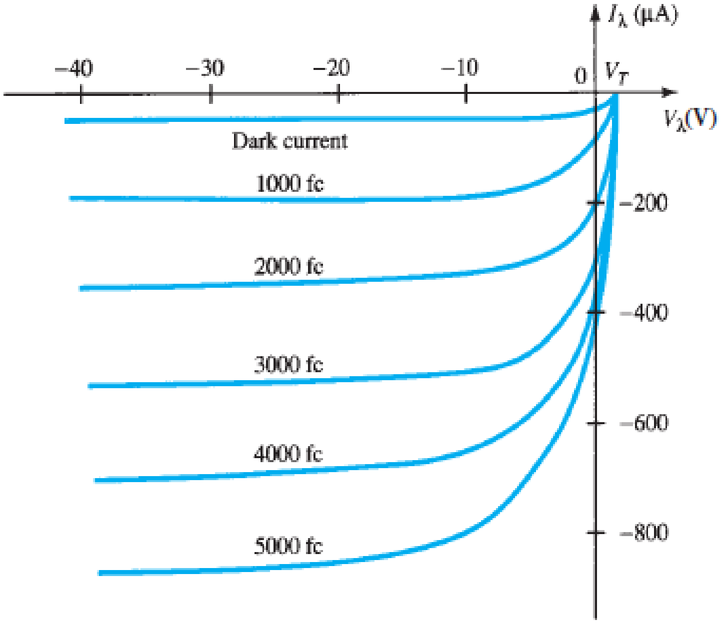

FIG. 16.20
Photodiode characteristics.

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PHOTOCONDUCTIVE CELLS ●

The photoconductive cell is a two-terminal semiconductor device whose terminal resistance varies (linearly) with the intensity of the incident light. For obvious reasons, it is frequently called a photoresistive device. The typical construction of a photoconductive cell is provided in Fig. 16.25 with the most common graphical symbol. The photoconductive materials most frequently used include cadmium sulfide (CdS) and cadmium selenide (CdSe). The peak spectral response occurs at approximately 5100 Å for CdS

and at 6150 Å for CdSe. The response time of CdS units is about 100 ms and of CdSe cells is 10 ms. The photoconductive cell does not have a junction like the photodiode. A thin layer of the material connected between terminals is simply exposed to the incident light energy. As the illumination on the device increases in intensity, the energy state of a larger number of electrons in the structure will also increase because of the increased availability of the photon packages of energy. The result is an increasing number of relatively "free" electrons in the structure and a decrease in the terminal resistance. The sensitivity curve for a typical photoconductive device appears in Fig. 16.26 . Note the linearity (when plotted using a log–log scale) of the resulting curve and the large change in resistance (100 kΩ 100 Ω) for the indicated change in illumination. To see the wealth of material available on each device from manufacturers, consider the CdS (cadmium sulfide) photoconductive cell described in Fig. 16.27. Note again the concern with temperature and response time.

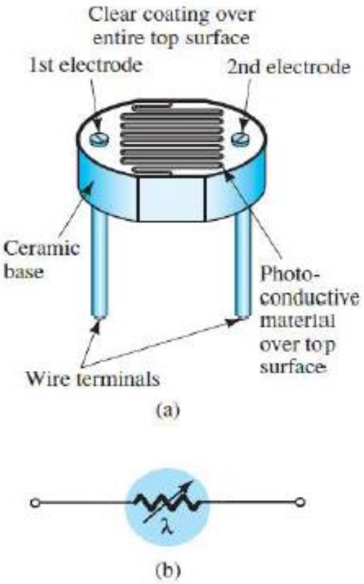

FIG. 16.25
Photoconductive cell: (a) construction; (b) symbol.

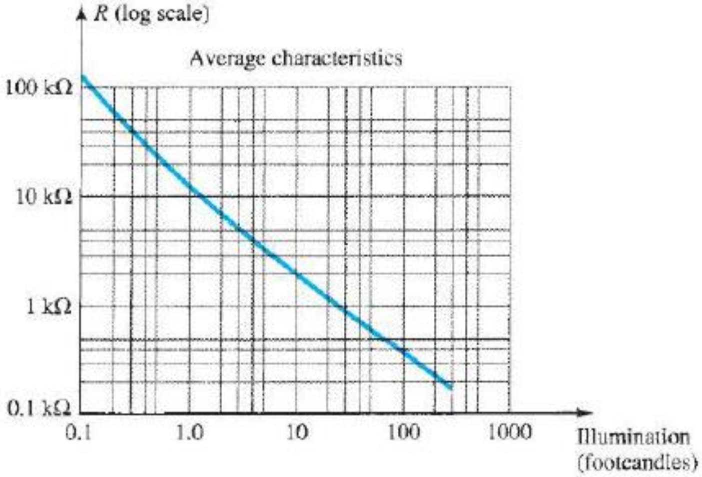

FIG. 16.26
Photoconductive cell-terminal characteristics.

LIQUID-CRYSTAL DISPLAYS ●

The liquid-crystal display (LCD) has the distinct advantage of having a lower power requirement than the LED, typically on the order of microwatts for the display, compared to the order of milliwatts for LEDs. It does, however, require an external or internal light source, and is limited to a temperature range of

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about 0°C to 60°C. Lifetime is an area of concern because LCDs can chemically degrade. The types of units of major interest are field effect and dynamic-scattering units. Each will be covered in some detail in this section. A liquid crystal is a material (normally organic for LCDs) that flows like a liquid but whose molecular structure has some properties normally associated with solids. For light scattering units, the greatest interest is in nematic liquid crystal, which has the crystal structure shown in Fig. 16.33 . The individual molecules have a rodlike appearance as shown in the figure. The indium oxide conducting surface is transparent, and under the condition shown in the figure, incident light will simply pass through and the liquid-crystal structure will appear clear. If a voltage (for commercial units the threshold level is usually between 6 V and 20 V) is applied across the conducting surfaces, as shown in Fig. 16.34 , the molecular arrangement is disturbed, with the result that regions are established with different indices of refraction. The incident light is therefore reflected in different directions at the interface between regions of different indices of refraction (referred to as dynamic scattering —first studied by RCA in 1968), with the result that the scattered light has a frosted-glass appearance. Note in Fig. 16.34, however, that the frosted look occurs only where the conducting surfaces are opposite each other; the remaining areas remain translucent.

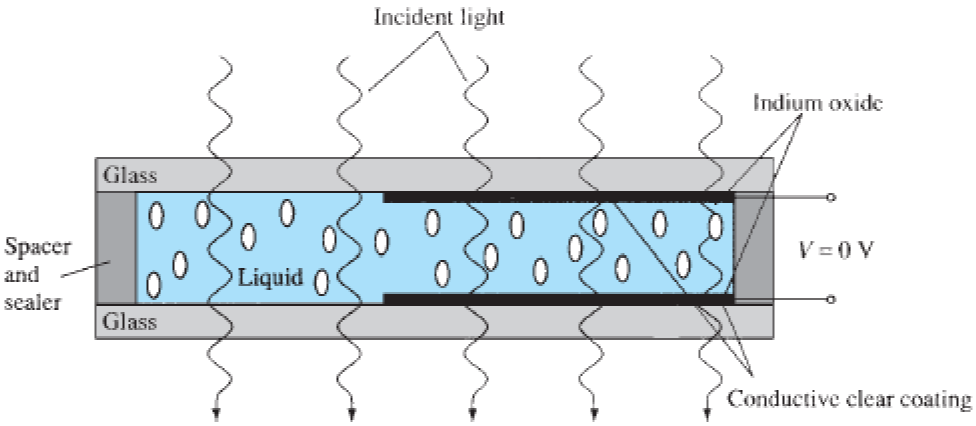

FIG. 16.33
Nematic liquid crystal with no applied bias.

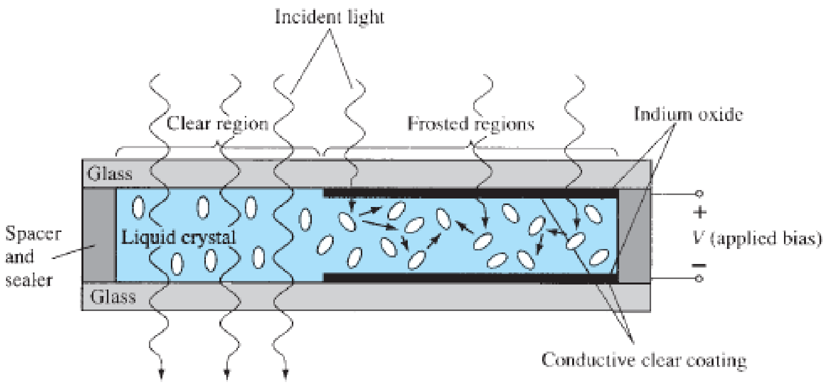

FIG. 16.34
Nematic liquid crystal with applied bias.

A numeral on an LCD display may have the segmented appearance shown in Fig. 16.35. The black area is actually a clear conducting surface connected to the terminals below for external control. Two similar masks are placed on opposite sides of a sealed, thick layer of liquid-crystal material. If the number 2 were required, the terminals 8, 7, 3, 4, and 5 would be energized, and only those regions would be frosted, whereas the other areas would remain clear.

As indicated earlier, the LCD does not generate its own light, but depends on an external or internal source. Under dark conditions, it would be necessary for the unit to have its own internal light source either behind or to the side of the LCD. During the day, or in lighted areas, a reflector can be put behind the LCD to reflect the light back through the display for maximum intensity. For optimum operation, watch manufacturers use a combination of the transmissive (own light source) and reflective modes called transflective operation. The field-effect or twisted nematic LCD has the same segmented appearance and thin layer of encapsulated liquid crystal, but its mode of operation is very different. Similar to the dynamic-scattering LCD, the field-effect LCD can be operated in the reflective or the transmissive mode with an internal source. The transmissive display appears in Fig. 16.36 . The internal light source is on the right, and the viewer is on the left. This figure is most noticeably different from Fig. 16.33 in that there is an addition of a light polarizer . Only the vertical component of the entering light on the right can pass through the vertical-light polarizer on the right. In the field-effect LCD, either the clear conducting surface to the right is chemically etched or an organic film is applied to orient the molecules in the

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liquid crystal in the vertical plane, parallel to the cell wall. Note the rods to the far right in the liquid crystal. The opposite conducting surface is also treated to ensure that the molecules are 90° out of phase in the direction shown (horizontal) but still parallel to the cell wall. In between the two walls of the liquid crystal there is a general drift from one polarization to the other, as shown in the figure. The left-hand light polarizer is also such that it permits the passage of only the vertically polarized incident light. If there is no applied voltage to the conducting surfaces, the vertically polarized light enters the liquid-crystal region and follows the 90° bending of the molecular structure. Its horizontal polarization at the left-hand vertical light polarizer does not allow it to pass through, and the viewer sees a uniformly dark pattern across the entire display. When a threshold voltage is applied (for commercial units from 2 V to 8 V), the rodlike molecules align themselves with the field (perpendicular to the wall) and the light passes directly through without the 90° shift. The vertically incident light can then pass directly through the second vertically polarized screen, and a light area is seen by the viewer. Through proper excitation of the segments of each digit, the pattern will appear as shown in Fig. 16.37 . The reflective-type field-effect LCD is shown in Fig. 16.38 . In this case, the horizontally polarized light at the far left encounters a horizontally polarized filter and passes through to the reflector, where it is reflected back into the liquid crystal, bent back to the other vertical polarization, and returned to the observer. If there is no applied voltage, there is a uniformly lit display. The application of a voltage results in a vertically incident light encountering a horizontally polarized filter at the left, through which it will not be able to pass, and so it will be reflected. A dark area results on the crystal, and the pattern shown in Fig. 16.39 appears. Field-effect LCDs are normally used when a source of energy is a prime factor (e.g., in watches, portable instrumentation, etc.) since they absorb considerably less power than the light-scattering types—the microwatt range compared to the low-milliwatt range. The cost is typically higher for field-effect units, and their height is limited to about 2 in., whereas light-scattering units are available up to 8 in. in height.

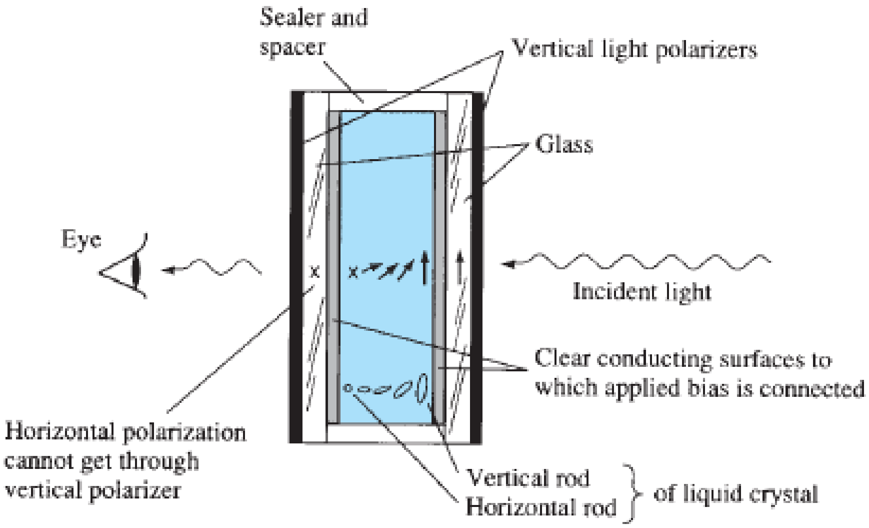

FIG. 16.36
Transmissive field-effect LCD with no applied bias.

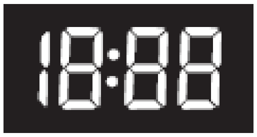

FIG. 16.37
Reflective-type LCD.

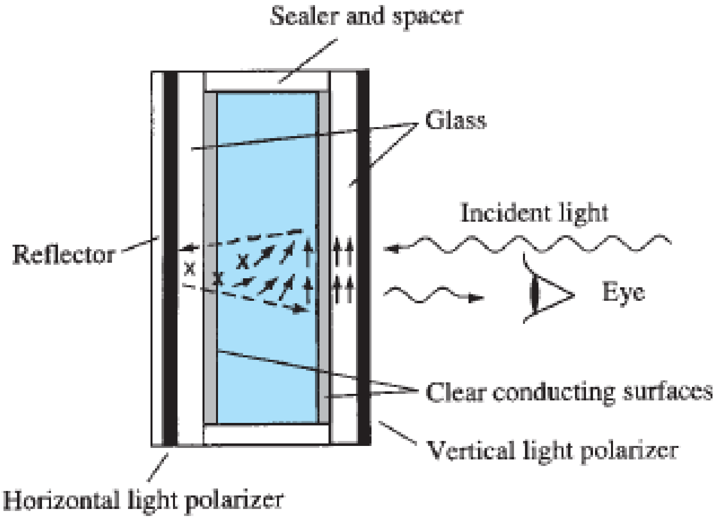

FIG. 16.38
Reflective field-effect LCD with no applied bias.

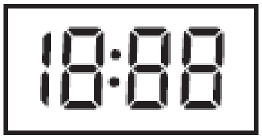

FIG. 16.39
Transmissive-type LCD.

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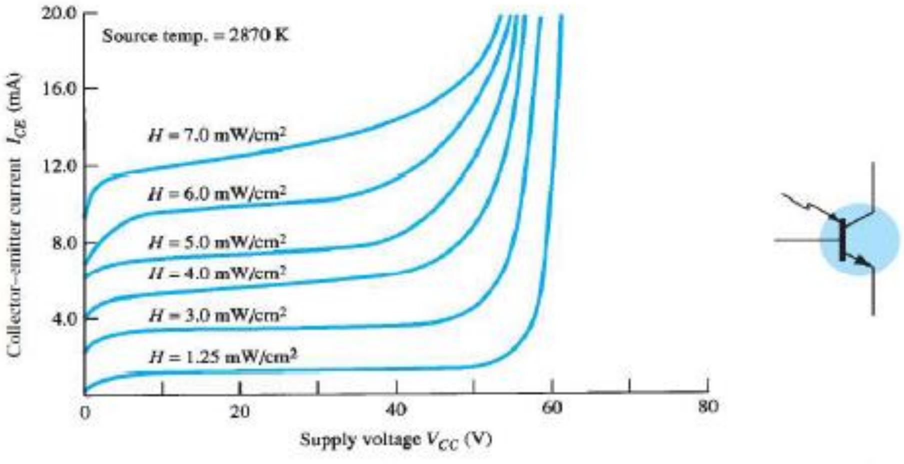
PHOTOTRANSISTORS ●

The fundamental behavior of photoelectric devices was introduced earlier with the description of the photodiode. This discussion will now be extended to include the phototransistor, which has a photosensitive collector–base p – n junction. The current induced by photoelectric effects is the base current of the transistor. If we assign the notation I_λ for the photoinduced base current, the resulting collector current, on an approximate basis, is

$$\boxed{I_C \cong h_{fe} I_\lambda}$$

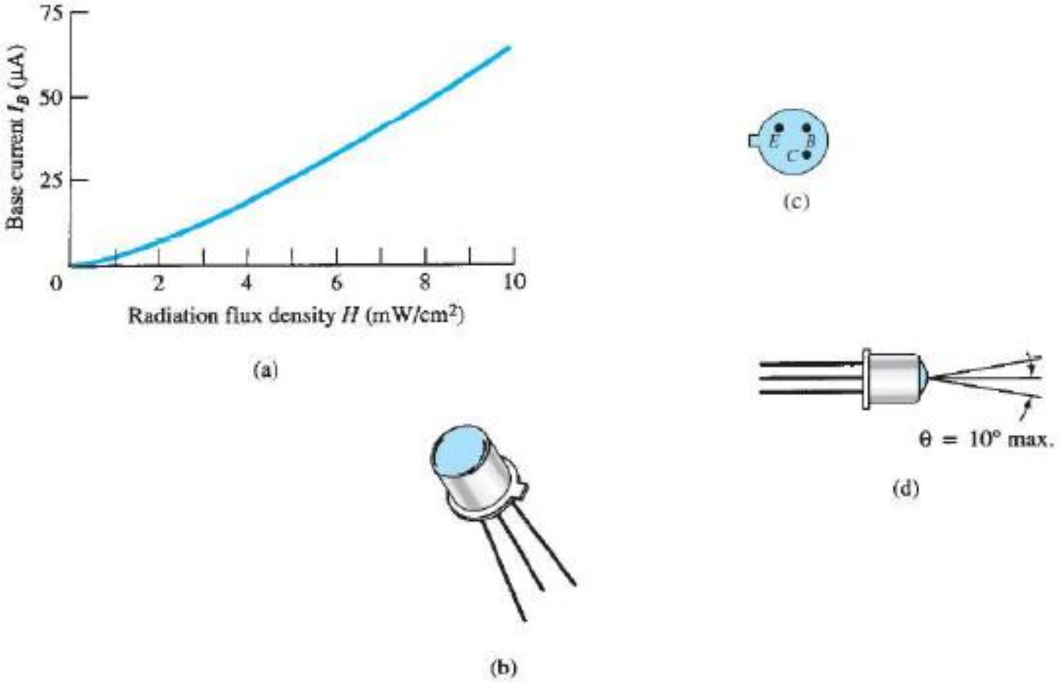
A representative set of characteristics for a phototransistor is provided in Fig. 17.49 along with the symbolic representation of the device. Note the similarities between these curves and those of a typical bipolar transistor. As expected, an increase in light intensity corresponds to an increase in collector current. To provide a greater degree of familiarity with the light-intensity unit of measurement, milliwatts per square centimeter, we give a curve of base current versus flux density in Fig. 17.50a . Note the exponential increase in base current with increasing flux density. In the same figure, a sketch of the phototransistor is provided with the terminal identification and the angular alignment. Some of the areas of application for the phototransistor include computer logic circuitry, lighting control (highways, etc.), level indication, relays, and counting systems.



(a) (b)

FIG. 17.49

Phototransistor: (a) collector characteristics; (b) symbol.



(a) (b) (c) (d)

FIG. 17.50

Phototransistor: (a) base current versus flux density; (b) device; (c) terminal identification; (d) angular alignment.

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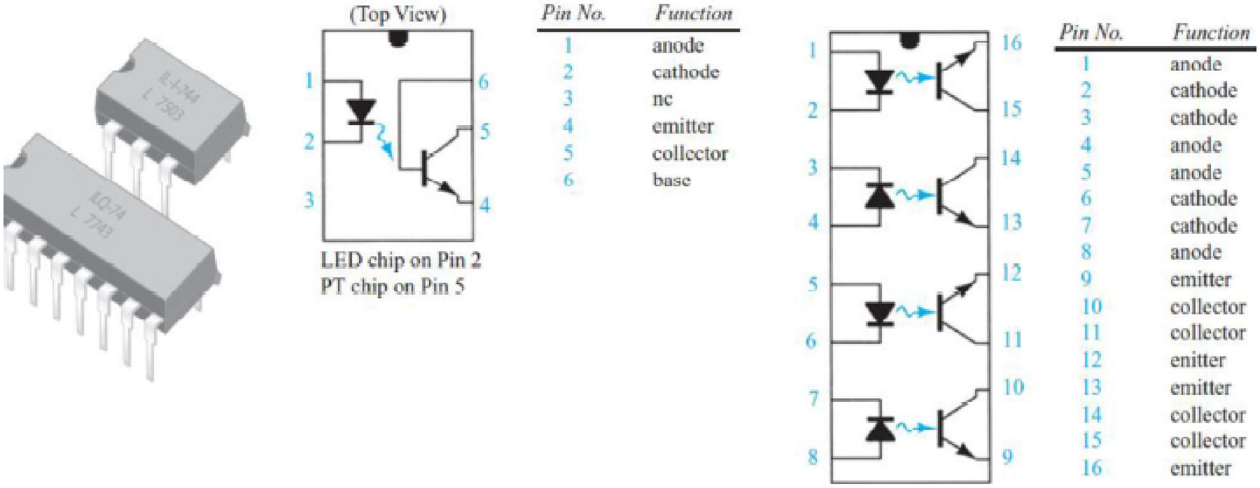
OPTO-ISOLATORS ●

The opto-isolator is a device that incorporates many of the characteristics described in the preceding section. It is simply a package that contains both an infrared LED and a photodetector such as a silicon diode, transistor Darlington pair, or SCR. The wavelength response of each device is tailored to be as identical as possible to permit the highest measure of coupling possible. In Fig. 17.52 , two possible chip configurations are provided,



Pin No.	Function
1	anode
2	cathode
3	nc
4	emitter
5	collector
6	base

Pin No.	Function
1	anode
2	cathode
3	cathode
4	anode
5	anode
6	cathode
7	cathode
8	anode
9	emitter
10	collector
11	collector
12	enitter
13	emitter
14	collector
15	collector
16	emitter

FIG. 17.52
Two Litronix opto-isolators.

with a drawing of each. There is a transparent insulating cap between each set of elements embedded in the structure (not visible) to permit the passage of light. They are designed with response times so small that they can be used to transmit data in the megahertz range. The maximum ratings and electrical characteristics for the 6-pin model are provided in Fig. 17.53 . Note that I CEO is measured in nanoamperes and that the power dissipation of the LED and transistor are about the same.