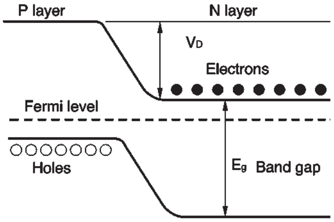
Sensors

● Emitters

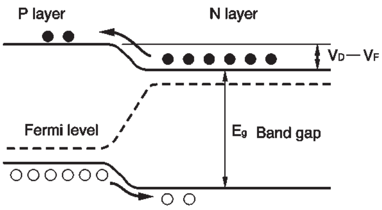
(1) Infrared LEDs

1) Principle

In the absence of an externally applied voltage, the P-N junction of a diode will be at thermal equilibrium and the Fermi levels of the P layer and N layer will be equal (Fig. 1 (a)). In this case, the height of the potential barrier will be V_D.



(a) Thermal equilibrium



(b) Forward voltage VF is applied

Fig.1 PN junction

When an external voltage V_F is applied, the potential barrier falls to V_D - V_F and electrons flow into the P layer and holes into the N layer.

As carriers (holes and electrons) flow, they recombine, and at that time the difference in energy before and after recombination is released as light. The wavelength of the emitted light is given by the following equation :

$$Eg \fallingdotseq \Delta E = h\nu$$

$\nu = c / \lambda$ thus

$$\lambda = \frac{hc}{Eg} \fallingdotseq \frac{1.24}{Eg} \times 10^3 \text{ (nm)}$$

where λ is the wavelength of the emitted light, E_g is the energy band gap (1.35 ev in the case of GaAs), ΔE is the energy difference before and after recombination, h is Planck's constant, ν is the frequency of the emitted light, and c is the speed of light. The result is a peak emission wavelength for GaAs of 940 to 950 nm.

The structure of a GaAs infrared chip is shown in Figure 2. The P-N junction of the GaAs-doped silicon is formed by LPE (liquid crystal growth method). The luminous efficiency of the chip is 8 to 16%, the emitted wavelength is 940 to 950 nm, and the response time is approximately 1µs.

GaAlAs infrared chips designed for higher output are shown in Figure 3. The emitted wavelength of the chip of Figure 3 (a) is 940 to 950 nm and the output is approximately 1.3 to 1.5 times that of the GaAs chip of Figure 2.

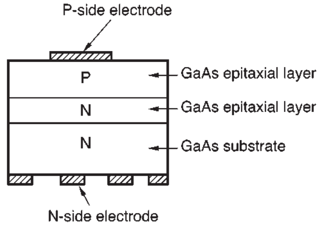


Fig. 2 GaAs infrared chip

The chip of Figure 3 (b) is a so-called N-side up chip with an emission wavelength of 880 nm. It produces a high output, approximately 1.5 times that of the GaAs chip of Figure 2. The response times of both chips of Figure 3 are approximately 1µs, the same as the chip of Figure 2.

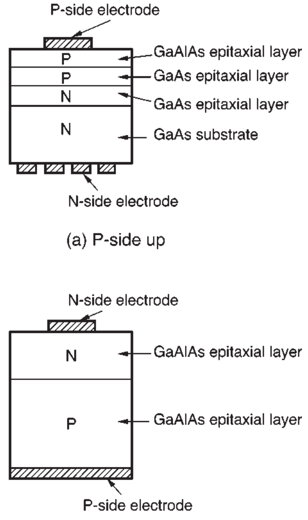


Fig. 3 GaAlAs infrared chip structures

2) Structures

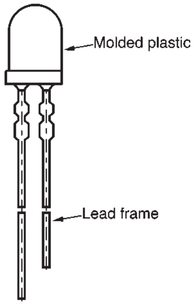
The structures of infrared LEDs can be divided into the two following types.

1. Cast type

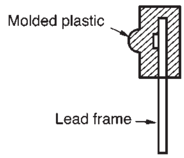
The chip is mounted on a lead frame and then liquid resin is poured into the mold and allowed to harden.

2. Molded type

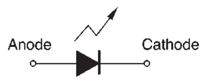
This type is packaged by transfer molding.



(a) Cast type



(b) Molded type



Infrared LED symbol

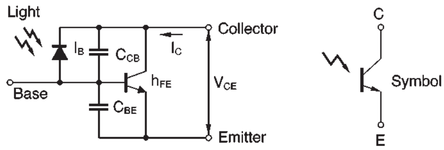
Fig. 4 Infrared LED structures and symbo

●Detectors

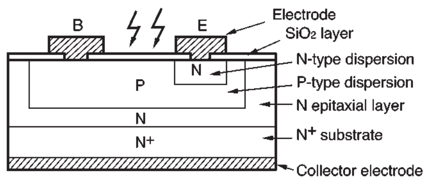
(1) Phototransistors

1) Principle

As shown by the equivalent circuit in Figure 5 (a), a phototransistor can be thought of as a photodiode connected to a normal silicon planar transistor.



(a) Phototransistor equivalent circuit and symbol



(b) Single phototransistor

Fig. 5 Phototransistor

Actual phototransistor structures are as shown in (b) of Figure 5, and consist of a single type. The principle of operation is essentially amplification by an NPN transistor of photo current generated by light irradiation.

$I_C \fallingdotseq h_{FE} \times I_B$

I_B : Photo current of photodiode

h_{FE} : Transistor amplification of direct current

Like photodiodes, phototransistors are sensitive to a wavelength of approximately 1100 nm.

2) Structure

Like photodiodes, phototransistors are housed in the following three types of packages :

1. Cast type
2. Mold type

These are explained in detail on the infrared LED page.

(2) Photo ICs

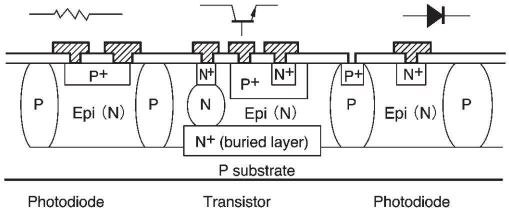


Fig. 6 Photo IC structure

1) Principle

A photo IC is an integration of a photodiode, constant voltage circuit, Schmitt trigger and other elements into a single chip using bipolar IC technology. The structure of a photodiode is shown in Figure 6 and a block diagram is shown in Figure 7.

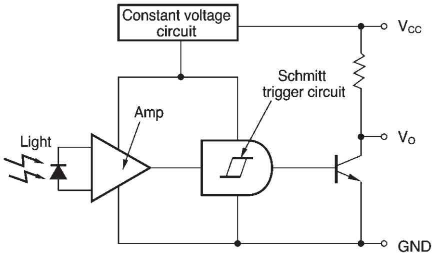


Fig. 7 Photo IC block diagram

This photo IC is a detector with digital output. When irradiated by light, one type has high transistor output and another type has low output. Both types can be directly connected to TTL, CMOS and other logic circuits with the advantages of easy circuit design, space conservation, and low cost.

2) Structure

The external dimensions of a photo IC are shown in Figure 12. As there are normally three leads, V_{CC}, V_O and GND, molded packages are the most common.

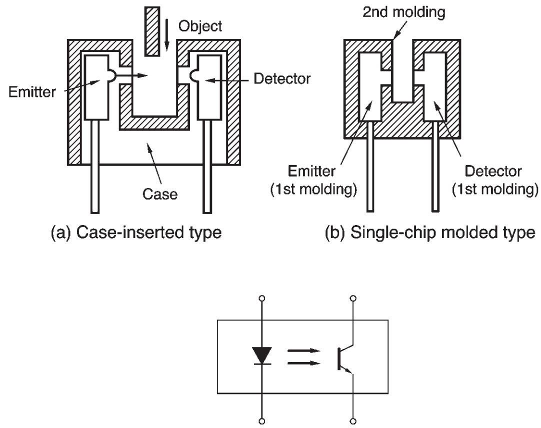
●Multi-element devices

(1) Photointerrupters

Photointerrupters are also called transparent photosensors, and they consist of an emitter and a detector facing each other. Detection occurs when an object interrupts the light beam passing from the emitter to the detector. ROHM calls this transparent type of photosensor an interrupter.

The emitter is a high-output GaAs infrared LED with long life, and the detector is normally a single phototransistor or a photo IC.

Interrupters are generally housed in case-insertion packages or double-layer molding packages (Figure 8). Case-insertion types are most commonly used, and consist of an emitter and detector inserted in an injection molded case. The double-layer molding package responds to recent needs for increasingly compact devices.



(a) Case-inserted type (b) Single-chip molded type

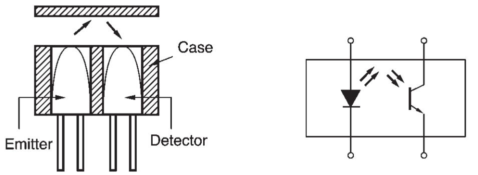
(c) Interrupter symbol

Fig. 8 Photointerrupter structure and symbol

The double-layer molding is carried out by injection which makes it easy to achieve a compact package. This device is ideal for cameras, floppy disk drives, handy copy machines, and other applications where compactness is required.

(2) Photoreflectors

Photoreflectors are reflective-type photosensors consisting of an emitter and a detector facing the same direction. As light reflected from an object is detected, the output level is generally low. Thus a single silicon phototransistor is used for the detector. The principal structures are shown in Figure 9.



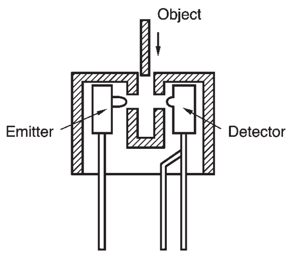
(a) Case-insertion type (b) Photoreflector symbol

Fig. 9 Photoreflector structures and symbol

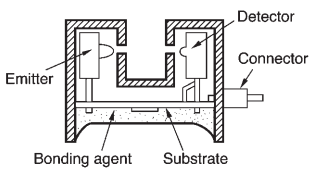
(3) Photo IC interrupters

Photo IC interrupters essentially take the output of a phototransistor (single or Darlington) and convert it to photo IC output. The output is digital, with one type high and another type low when irradiated with light.

In addition, there is a type with a connector attached for easy handling as shown in (b) of Figure 10, and these are used in facsimile machines and copiers.



(a) Case-inserted type



(b) Photo IC interrupter with connector

Fig. 10 Photo IC interrupter structures

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