KALINGA INSTITUTE OF INDUSTRIAL TECHNOLOGY (KIIT)

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Activity Report
On

Phototransistor

(Basic Electronics)

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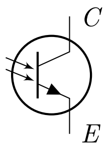
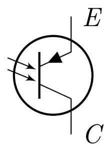
1 Introduction

A photo-diode can generate photocurrent because its junction is exposed to incident light. A phototransistor functions in a similar way, except that the exposed semiconductor material is the base of a bipolar junction transistor (BJT).



(a) NPN Phototransistor



(b) PNP Phototransistor

Figure 1: Types of Phototransistor

Fig. 1 depicts phototransistor as a BJT with the base terminal removed, and the arrows imply that the base is sensitive to light.

There are two ways to think about the behavior of a photo-transistor. First, you can mentally replace the amount of current flowing into the base of a normal transistor with the intensity of incident light. In the basic model of active-mode BJT behavior, the output current (i.e., the collector current) is the input current (i.e., the base current) multiplied by the gain parameter called beta(β). With a phototransistor, incident light is like a weak signal applied to the base, and the output current is much higher than what we would expect from a photo-diode, because of the transistor's ability to internally amplify the signal applied to the base. Second, you can imagine that a phototransistor is a BJT with a photo-diode connected to the base, such that the input signal to the transistor is the photocurrent generated by the photo-diode as shown in Fig. 2. In this conceptualization, the BJT is like an additional semiconductor device that applies current gain to the output signal of a photo-diode.

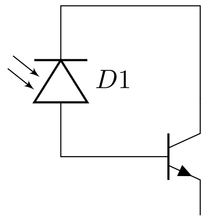


Figure 2: Equivalent of a Phototransitor

A phototransistor is conceptually equivalent to a photo-diode that drives the base of a bipolar junction transistor. Note the orientation of the photo-diode:

Figure 3: Phototransistor

photocurrent is always reverse current, and the photo-diode is oriented such that photocurrent is flowing into the base.

2 Theory

There are 2 regions of operation of a phototransistor. They are:

- **Active Mode:** In this mode the phototransistor behaves as a analog element with linear output that is proportional to the intensity of the incoming light.
- **Switch Mode:** In this mode, the phototransistor acts as a digital element, i.e., either in cutoff(off) or saturated(on).

Below saturation, the phototransistor uses the normal equations for a BJT transistor [1].

$$I_C = \beta I_B \tag{1}$$

where, I_C is collector current, I_B is base current and β is the transistor's gain. Also

$$I_E = I_B + I_C \tag{2}$$

where I_E is the emmiter current.

In a typical phototransistor, the β is around 100. They usually have higher gain than photodiodes [1].

3 Contruction

The phototransistor is just an ordinary BJT transistor with the base terminal exposed for illumination. It can be found of both PNP and NPN types. It has more base and collector regions than a conventioncal BJT [2].

Mechanical issues of placement of the phototransistor or photodiode are dictated by the application, modes of use, user interaction, and many other factors which must be carefully considered in the product design. Consistency of this optical path is critical. Even minute variations due to manufacturing tolerances, board flexing, dust, and other expected and/or somewhat abnormal use must be considered. Mechanical issues of placement of the phototransistor or photodiode are dictated by the application, modes of use, user interaction, and many other factors which must be carefully considered in the product design. Consistency of this optical path is critical. Even minute variations due to manufacturing tolerances, board flexing, dust, and other expected and/or somewhat abnormal use must be considered. [2]

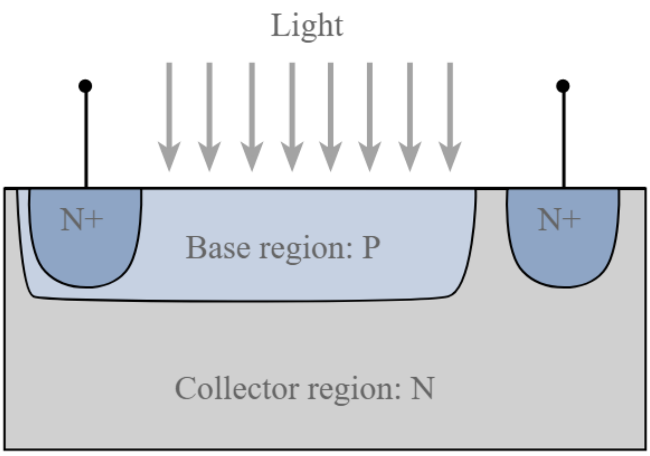


Figure 4: Construction of an NPN Phototransistor

Fig. 4 shows the construction of a phototransistor of NPN type. When compared to normal transistor, in photo transistor the base and collector area is large. The base area is increased to increase the amount of current generated. Because more the light falls more the current is generated. Earlier it was made up of single semiconductor material like silicon or germanium. Recently photo transistors are made up of Gallium and Arsenic to obtain higher efficiency. Finally photo transistor is placed inside a metallic case and a lens is kept at the top of the case to absorb the incident radiation. [3]

4 Circuit Diagram

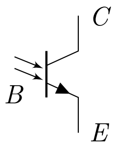


Figure 5: NPN Phototransistor

Fig. 5 is the symbol for an npn phototransistor. Here the B represents the base terminal, C represents the collector terminal and E represents the emitter terminal. The base terminal is exposed to light and that generates current.

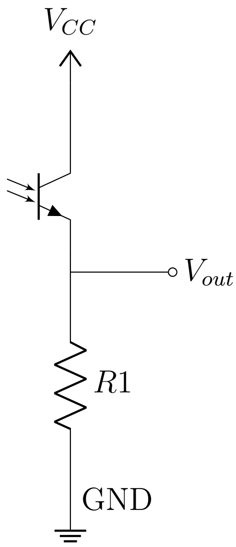


Figure 6: A Simple Light Detector Circuit

Fig. 6 shows a very simple light detector circuit. When there is no light, V_{out} remains very close to zero (there is a small amount of voltage present due to dark current). When light falls on the phototransistor, V_{out} rises and has some positive voltage. This voltage can be picked up and used in microcontrollers.

5 Operation Principle

The operation of a phototransistor can be explained in four steps:

1. **Light generation of electron-hole pairs:** When light strikes the base region of the phototransistor, it generates electron-hole pairs. The energy of the light photons must be greater than the bandgap energy of the semiconductor material in order to generate electron-hole pairs.

2. **Diffusion of charge carriers:** The electron-hole pairs diffuse into the emitter-base junction. The electrons are attracted to the positive charge on the base, and the holes are attracted to the negative charge on the emitter.

3. **Separation of charge carriers:** The electric field across the emitter-base junction separates the electron-hole pairs. The electrons are injected into the emitter, and the holes are collected by the collector.

4. **Current flow:** The injected electrons flow from the emitter to the collector, and the collected holes flow from the base to the collector. This results in a small current flowing between the emitter and collector.

The current gain of a phototransistor is determined by the following factors:

- The efficiency of light generation of electron-hole pairs
- The diffusion length of the charge carriers
- The electric field across the emitter-base junction
- The current gain of the transistor itself

6 Application

Phototransistors are semiconductor devices that convert light energy into electrical energy. They are used in a wide variety of applications, including:

- **Light detection:** Phototransistors are commonly used in light detectors, such as those found in smoke detectors and security alarms. When light falls on the phototransistor, it generates an electrical current that can be used to trigger an alarm or turn on a light.

- **Optical communication:** Phototransistors are used in optical communication systems to receive infrared (IR) signals from remote controls, fiber optic cables, and other devices. The phototransistor converts the IR signal into an electrical signal that can be processed by the device.

- **Isolation:** Phototransistors are used in optocouplers to isolate two electrical circuits. The optocoupler consists of an LED and a phototransistor that are optically coupled. When the LED is turned on, it emits light that is detected by the phototransistor. This allows the two circuits to be electrically isolated, but still allows for communication between them.

- **Counting and measurement:** Phototransistors can be used to count objects, measure distances, and measure the intensity of light. For example, phototransistors are used in encoders, which are devices that convert rotary motion into electrical signals. Encoders are used in a variety of applications, such as robotics, automation, and instrumentation.

- **Medical applications:** Phototransistors are used in a variety of medical applications, such as pulse oximeters and heart rate monitors. Pulse oximeters use phototransistors to measure the amount of oxygenated blood in the patient's bloodstream. Heart rate monitors use phototransistors to measure the patient's heart rate by detecting the changes in blood volume in the patient's finger.

These are just a few of the many applications of phototransistors. Phototransistors are versatile and reliable devices that are used in a wide variety of industries.

7 Conclusion

In conclusion, this report has delved into the fascinating realm of phototransistors, shedding light on their principles, applications, and performance characteristics. Phototransistors play a pivotal role in the field of optoelectronics, serving as sensitive detectors of light with the ability to convert optical signals into electrical currents. As demonstrated in this report, their versatility makes them integral components in various applications, ranging from simple light-sensing circuits to more complex systems such as optical communication and automation.

The thorough exploration of phototransistor specifications, including sensitivity, response time, and spectral range, has highlighted the importance of selecting the right device for specific applications. Engineers and researchers must carefully consider these parameters to optimize the performance of phototransistor-based systems.

Moreover, advancements in technology continue to drive innovation in the design and manufacturing of phototransistors, leading to improved performance and expanded application possibilities. Future developments may further enhance their sensitivity, reduce response times, and increase their compatibility with emerging technologies.

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