UNIT V

OPTOELECTRONIC DEVICES

Classification of optoelectronic Devices

Optoelectronic devices can be categorized into two different types – light detecting devices and light generating devices. Some examples of light-sensitive devices are photodiodes, phototransistors, and photo resistors.

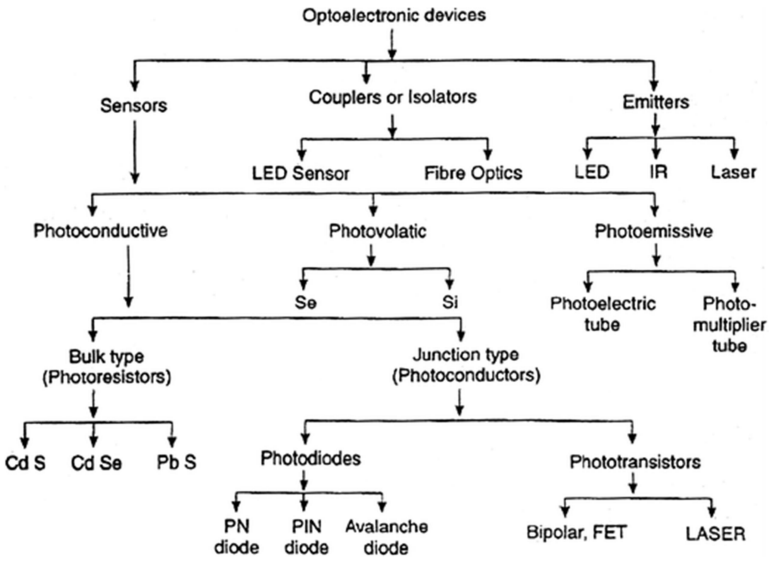
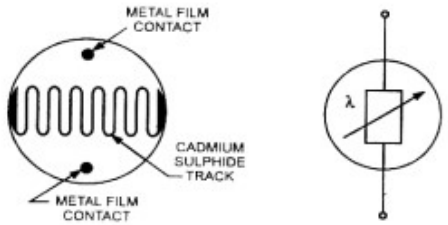


PHOTO CONDUCTIVE CELL (OR) LIGHT DEPENDENT RESISTOR



(a) Basic Structure *(b) Symbol*

LDR

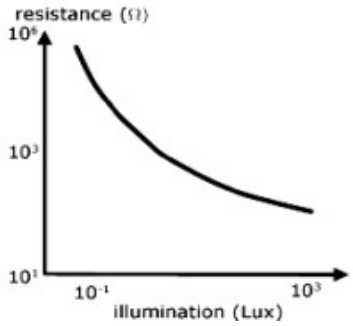
Construction

It is generally made up of cadmium compounds such as cadmium sulphide (cds), cadmium selenide (cdse). The device is in the form of either a slab of a semiconductor in bulk form (or) a thin film deposited on an insulating substrate. The ohmic contacts are made at the opposite ends. The material is arranged in the form of a long strip, zigzagged across a disc. A glass (or) plastic cover may be included for protection.

Operation:

When the device is exposed to light, the conductivity increases. The radiation supplied to the semiconductor ionizes the covalent bonds. Hence new e^{-ns} -whole pairs are produced. Due to this the resistance decreases and the conductivity is increased. Hence it is called photo resistor (or) photo conductor.

Characteristics



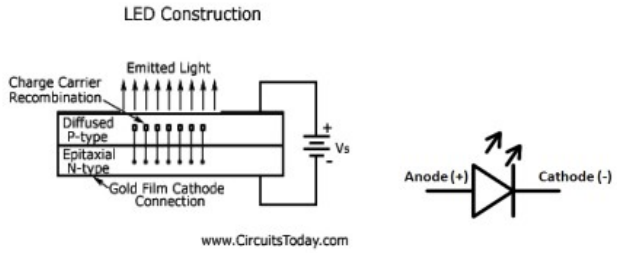
With the increase in illumination, the resistance decreases.

Applications:
LDRs are used
1. As switches
2. In counting application
3. In burglar alarms
4. In relay controls
5. As smoke detector
6. To measure intensity of light.

LIGHT EMITTING DIODE (LED):

A p-n junction which emits light when forward biased is known as LED. The amount of light output is proportional to the forward current.

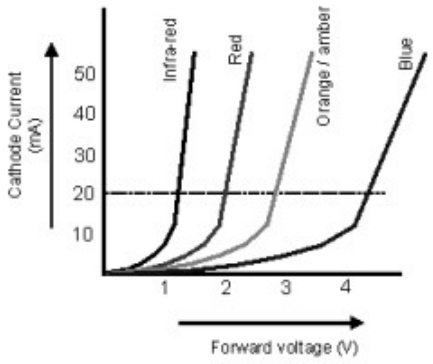
Construction



An n-type epitaxial layer is grown upon a substrate. The p- region is created by diffusion. The recombination occurs in the p- region. So this region is kept uppermost. The metal film anode is made such that most of the light is emitted from the p-region. A gold film is applied to the bottom of the device.
It provides cathode connection. The colours of light depend on the LED materials.
Ga As – infrared (invisible)
Ga P – red or green
Ga As P – red or yellow

Operation:

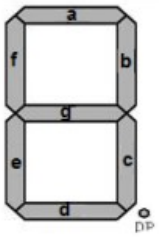
When the LED is forward biased, the *e-ns* and holes move towards the junction. Then the charge carrier recombination takes place. So, it releases energy in the form of light. The brightness of the emitted light is directly proportional to the forward bias current. The characteristics are similar to that of a p-n junction diode.



Application:
LEDs are used
1. In numeric displays
2. In multimeters
3. In digital displays
4. In calculator
5. In panels
6. In digital watches
7. In video displays
8. In optical communication systems

Seven Segment Display

Seven Segment Display is an LED based display screen that can display information in the form of decimal numbers. The seven segment display is a used in place of the more complex dot matrix displays. It is called so because it consists of seven segments of light emitting diodes (LEDs) that are assembled like decimal 8 as shown in the following figure.



Seven segments LED display can be used in applications where an electronic display device is required for showing decimal numbers from 0 to 9, sometimes, basic characters as well. Since, it uses LEDs; therefore it is an energy efficient display device. Therefore, it is most widely used in those devices that are powered by a small battery or a cell.

Working of Seven Segment LED Display

A seven segment display consists of seven LED segments arranged like a decimal 8. These LED segments are illuminated to form a pattern that represents a decimal number from 0 to 9. Now, let us understand, how the seven segment LED display work to display different numbers.

- When electrical energy is supplied to all the segments, then the seven segment LED display shows the decimal number 8.

- When power is given to all the segments and if we disconnect power from the segment ‘g’, then it displays the decimal number 0.
- When the power is given to segments "b" and "c" only, then it displays the number 1.
- When the power is given to the segments "a", "b", "g", "e", "d", then it displays the number 2.
- When the power is given to segments "a", "b", "g", "c", "d", then it displays the number 3.
- When the power is given to segments "b", "c", "f", "g", then it displays the number 4.
- When the power is given to segments "a", "c", "d", "f", "g", then it displays the number 5.
- When the power is given to segments "a", "c", "d", "e", "f", "g", then it displays the number 6.
- When the power is given to segments "a", "b", "c", then it displays the number 7.
- When the power is given to segments "a", "b", "c", "d", "f", "g", then it displays the number 9.

In this way, we can display any decimal number from 0 to 9 by illuminating a set of LED segments of the seven segment LED display.

Truth Table of Seven Segment LED Display

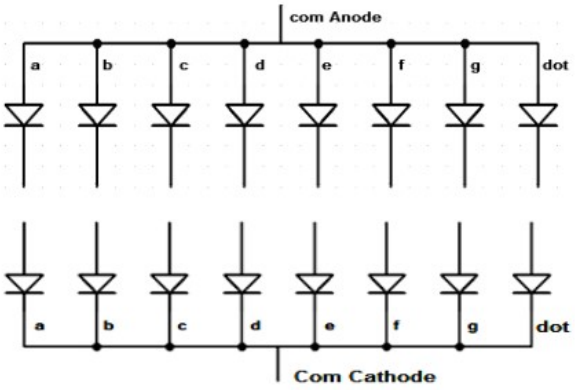
The following table shows the truth table of a seven segment LED display to display the decimal numbers from 0 to 9.

Seven Segment Display output	LED Segments Input						
	a	**b**	**c**	**d**	**e**	**f**	**g**
0	1	1	1	1	1	1	0
1	0	1	1	0	0	0	0
2	1	1	0	1	1	0	1
3	1	1	1	1	0	0	1
4	0	1	1	0	0	1	1
5	1	0	1	1	0	1	1
6	1	0	1	1	1	1	1
7	1	1	1	0	0	0	0
8	1	1	1	1	1	1	1
9	1	1	1	1	0	1	1

Types of Seven Segment LED Displays

There are two types of seven segment displays available −

- **Common Cathode Seven Segment Display** − In this type of seven segment display, the cathode terminal of all LED segments are connected together to logic 0 (lower voltage level). The logic 1 (higher voltage level) is applied through a current limiting resistor to forward bias the individual LED segments at their anode terminals.
- **Common Anode Seven Segment Display** − In this type of seven segment LED display, the anode terminals of all the LED segments are connected together to the logic 1 (higher voltage level), and the logic 0 (lower voltage level) is used through a current limiting resistor to the individual cathode terminals of LED segments.

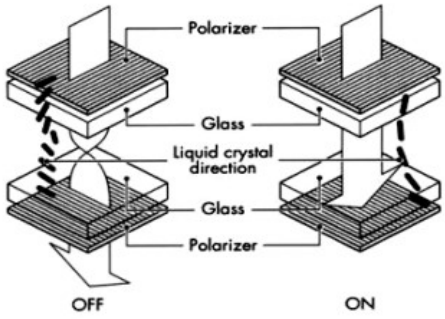


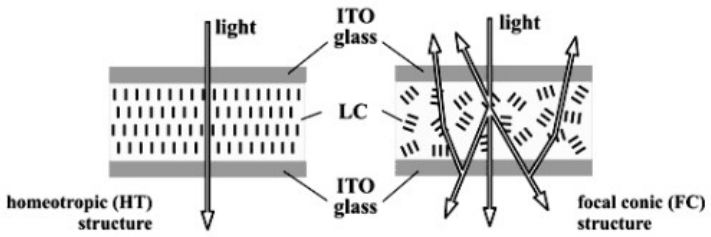
Applications of Seven Segment LED Displays

Seven Segment LED Displays are widely used in the following devices −

- Digital watches and clocks
- Calculators
- Microwaves
- Remote controls
- Speedometers
- Vehicle odometers
- Clock radios, etc.

LIQUID CRYSTAL DISPLAY (LCD)





Liquid crystal is an organic compound containing carbon, hydrogen, oxygen and nitrogen. It will not emit light, it will alter the illumination.

Construction

A liquid crystal cell consists of a layer of liquid crystal sandwiched between glass sheets. The transparent metal film electrodes are deposited inside the glass sheets. When both glass sheets are transparent, it is known as transmissive type. When one plate is transparent and the other has reflective coating, it is called reflective type.

Dynamic scattering mode

when it is not activated light is reflected from the mirror surface. The cell does not appear bright. When activated, the dynamic scattering phenomenon occurs and the cell appears bright.

Field effect mode

here two thin polarizing optical filters are placed at the inside of each glass sheet. The L.C twists the light when the cell is not energized. This allows light to pass through the optical filters and the cell appears bright. When the cell is energized, no twisting of light takes place and the cell appears dark.

Advantages

1. Low power is required
2. Good contrast
3. Low cost.

Disadvantages

1. Slow device
2. When DC is used life reduces
3. Occupy large area

Applications

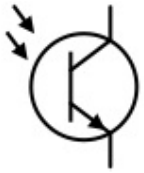
LCDs are used in
1. Displays
2. Image sensing circuits
3. Solid state video display
4. Digital watch.

Comparison between LCD and LED

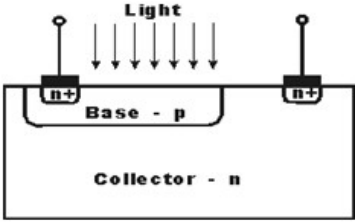
S.No	LED	LCD
1	Consumes more power	Consumes less power
2	Good brightness level	Moderate brightness level
3	Life time is more	Life time is low
4	Emits the light	Will not emit the light

PHOTO TRANSISTOR

Symbol



Construction



Working

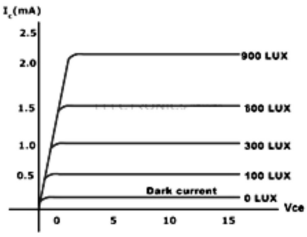
A phototransistor is nothing but an ordinary bi-polar transistor in which the base region is exposed to illumination. It is available in both the P-N-P and N-P-N types having different configurations like common emitter, common collector, and common base but generally, common emitter configuration is used. It can also work while the base is made open. Compared to the conventional transistor it has more base and collector areas.

Ancient phototransistors used single semiconductor materials like silicon and germanium but now a day's modern components use materials like gallium and arsenide for high-efficiency levels. The base is the lead responsible for activating the transistor. It is the gate controller device for the larger electrical supply. The collector is the positive lead and the larger electrical supply. The emitter is the negative lead and the outlet for the larger electrical supply.

With no light falling on the device there will be a small current flow due to thermally generated hole-electron pairs and the output voltage from the circuit will be slightly less than the supply value due to the voltage drop across the load resistor R. With light falling on the collector-base junction the current flow increases. With the base connection open circuit, the collector-base current must flow in the base-emitter circuit, and hence the current flowing is amplified by normal transistor action.

The collector-base junction is very sensitive to light. Its working condition depends upon the intensity of light. The base current from the incident photons is amplified by the gain of the transistor, resulting in current gains that range from hundreds to several thousand. A phototransistor is 50 to 100 times more sensitive than a photodiode with a lower level of noise.

Characteristics:



It is similar to that of CE output characteristics. When the light intensity increases, the collector current increases.

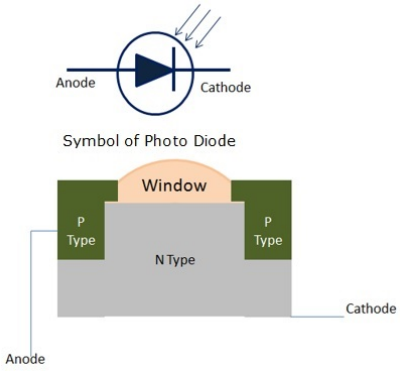
Application:

1. In light operated relays
2. In electro optical shaft encoder.
3. In optical paper tape reader
4. In light detection system
5. As light operated switch
6. In brushless DC motor.

Photodiode

A photodiode is a PN-junction diode that consumes light energy to produce an electric current. They are also called a photo-detector, a light detector, and a photo-sensor. Photodiodes are designed to work in reverse bias condition. Typical photodiode materials are Silicon, Germanium and Indium gallium arsenide.

Symbol



Photodiode Working

A photodiode is subjected to photons in the form of light which affects the generation of electron-hole pairs. If the energy of the falling photons (hv) is greater than the energy gap (E_g) of the semiconductor material, electron-hole pairs are created near the depletion region of the diode. The electron-hole pairs created are separated from each other before recombining due to the electric field of the junction. The direction of the electric field in the diode forces the electrons to move towards the n-side and consequently the holes move towards the p-side. As a result of the increase in the number of electrons on the n-side and holes on the p-side, a rise in the electromotive force is observed. Now when an external load is connected to the system, a current flow is observed through it.

The more the electromotive force created, the greater the current flow. The magnitude of the electromotive force created depends directly upon the intensity of the incident light. This effect of the proportional change in photocurrent with the change in light intensity can be easily observed by applying a reverse bias.

Since photodiodes generate current flow directly depending upon the light intensity received, they can be used as photo detectors to detect optical signals. Built-in lenses and optical filters may be used to enhance the power and productivity of a photodiode.

Advantages of Phototransistor

Phototransistors have several important advantages that separate them from another optical sensor some of them are mentioned below

- Phototransistors produce a higher current than photodiodes.
- Phototransistors are relatively inexpensive, simple, and small enough to fit several of them onto a single integrated computer chip.
- Phototransistors are very fast and are capable of providing nearly instantaneous output.
- Phototransistors produce a voltage, that photo-resistors cannot do so.

Disadvantages of Phototransistor

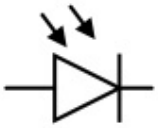
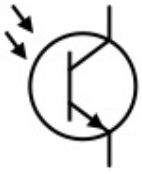
- Phototransistors that are made of silicon are not capable of handling voltages over 1,000 Volts.
- Phototransistors are also more vulnerable to surges and spikes of electricity as well as electromagnetic energy.
- Phototransistors also do not allow electrons to move as freely as other devices do, such as electron tubes.

Applications

- Photodiodes are used in solar cell panels.
- Photodiodes are used in logic circuits.
- Photodiodes are used in the detection circuits.
- Photodiodes are used in character recognition circuits.
- Photodiodes are used for the exact measurement of the intensity of light in science and industry.

Difference between Photodiode and Phototransistor

Both photodiodes and phototransistors are photosensitive semiconductor devices having similar function. However, there are several differences between them that are given in the following table

Basis of Difference	Photodiode	Phototransistor
Definition	A photodiode is a semiconductor PN junction diode which converts the light energy into electrical energy.	A phototransistor is two terminal bipolar junction transistor which converts light energy into electrical energy.
Circuit symbol		
Terminals	A photodiode has two terminals namely anode and cathode.	A phototransistor may have two or three terminals depending on the design which are emitter, base and collector.
Semiconductor regions	A photodiode has two semiconductor regions, i.e. a P-type anode region and N-type cathode region.	A phototransistor has three semiconductor regions namely emitter, base and collector.
Number of PN junctions	There is only one PN junction in the photodiode.	A phototransistor consists of two PN junctions.
Types	There is no further classification of photodiode.	There are two types of phototransistors namely NPN and PNP.
Biasing	Photodiode is always used in reverse biased mode.	Phototransistor is always used in forward biased mode.
Cost	The cost of photodiode is less.	The cost of transistor is comparatively high.