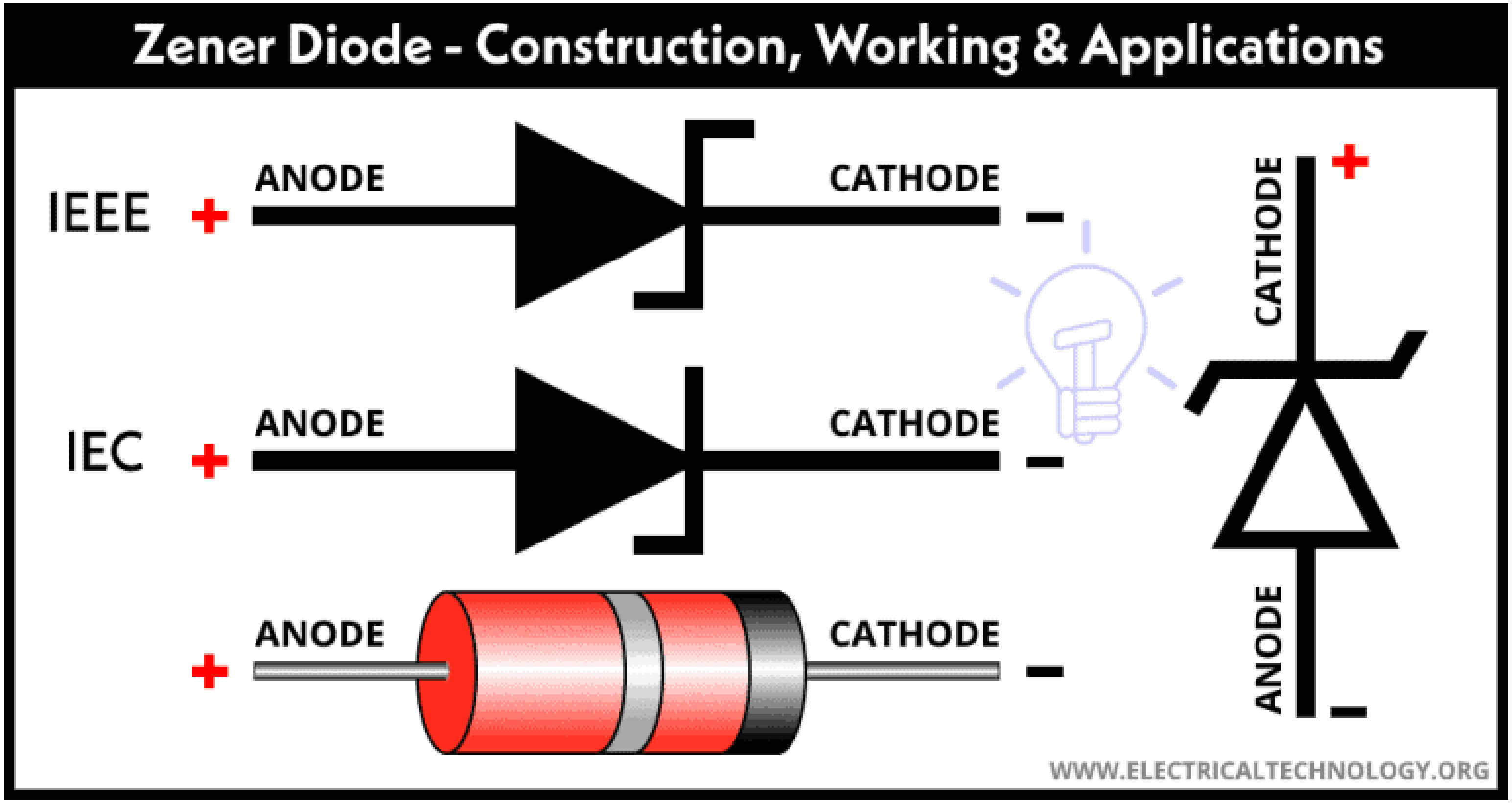
MODULE 4

Zener diode, LED, Photo Diode AND APPLICATIONS

Zener Diode



Zener Diode - Construction, Working & Applications
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A heavily doped p-n junction diode that works in reverse bias conditions is called a Zener Diode.

They are special semiconductor devices that allow the current to flow in both forward and backward directions.

For the Zener diode, the voltage drop across the diode is always constant irrespective of the applied voltage. Thus, Zener diodes are used as a voltage regulator.

A Zener diode can be considered as a highly doped p-n junction diode which is made such that it works in reverse bias condition.

Zener diode that is also known as a breakdown diode is a heavily doped semiconductor device that has been specially designed to operate in the reverse direction.

When the potential reaches the Zener voltage which is also known as Knee voltage and the voltage across the terminal of the Zener diode is reversed, at that point time, the junction breaks down and the current starts flowing in the reverse direction.

This effect is known as the Zener effect.

The diode consists of a very thin depletion region as it is made up of heavily doped semiconductor material.

Zener Diode Working in Reverse Biased

In forward-biased conditions, the Zener Diode works like any normal diode but in the reverse-bias condition, a small leak current flows through the diode.

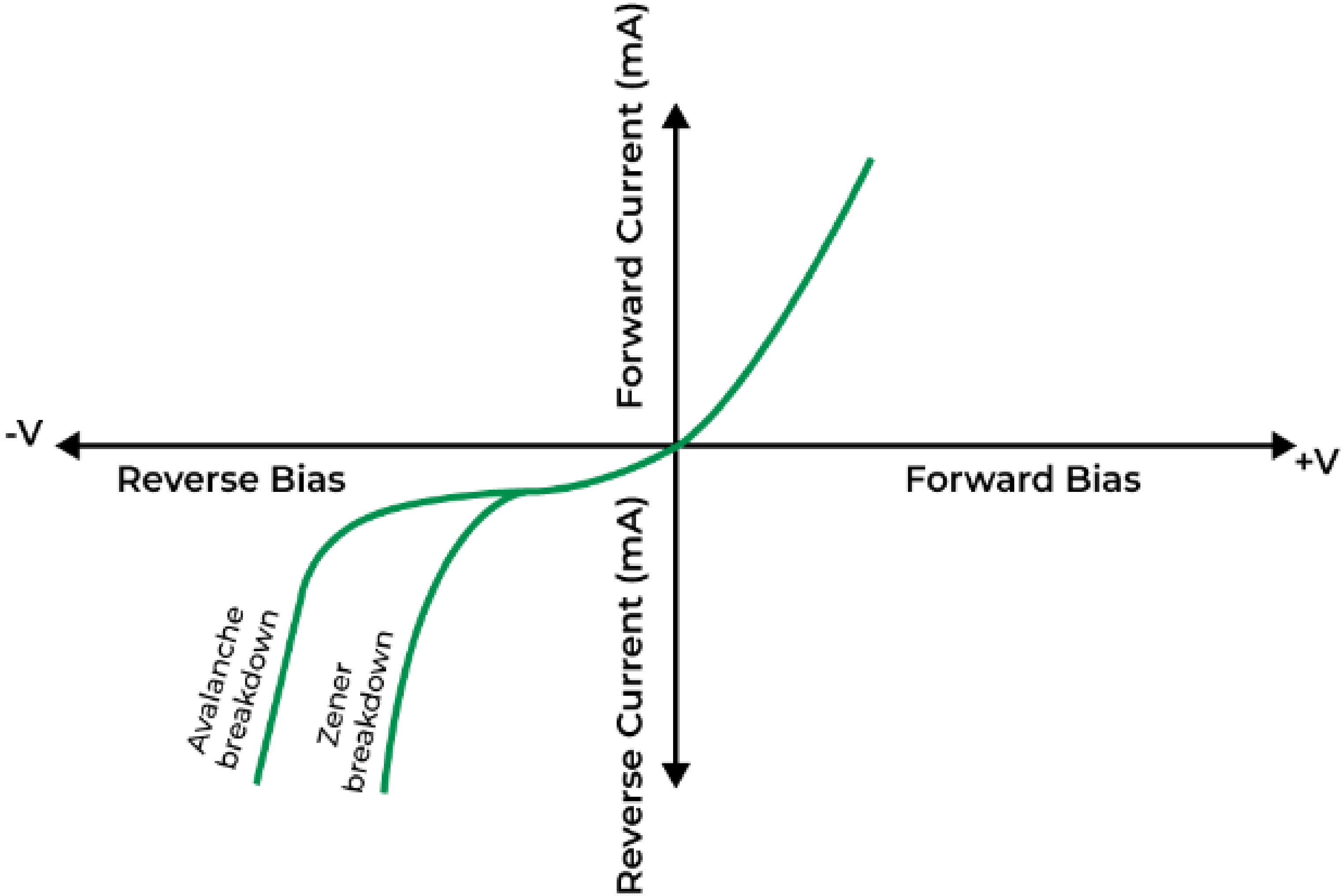
As we keep increasing the reverse voltage it reaches a point where the reverse voltage equals the breakdown voltage.

The breakdown voltage is represented as Vz and in this condition the current start flowing in the diode.

After the breakdown voltage the current increase drastically unit it reaches a stable value.

In reverse bias condition, two kinds of breakdowns occur for Zener Diode which are,
Avalanche Breakdown
Zener Breakdown

VI Characteristics of Zener Diode



Avalanche Breakdown	Zener Breakdown
Avalanche breakdown occurs when the high voltage increase the free electron in the semiconductor and a sudden increase in current is seen.	Zener breakdown happens when electrons from the valance band gain energy and reaches the conduction band which then conducts electricity.
Avalanche breakdown is seen in the diodes having breakdown voltage greater than 8 volts.	Zener breakdown is seen in the diodes having breakdown voltage in the range of 5 to 8 volts.
Avalanche breakdown is observed in diodes that are lightly doped.	Zener breakdown is observed in diodes that are highly doped.
In the Avalanche breakdown, the VI characteristics curve is not as sharp as the VI characteristics curve in the Zener breakdown.	Zener Breakdown has a sharp VI characteristics curve.
For Avalanche breakdown increase in temperature increases the breakdown voltage.	For Zener breakdown increase in temperature decreases the breakdown voltage.

Forward Characteristics of Zener Diode

Forward characteristics of the Zener Diode are similar to the forward characteristics of any normal diode.
It is clearly evident from the above diagram in the first quadrant that the VI forward characteristics are similar to other P-N junction diodes.

Reverse Characteristics of Zener Diode

In reverse voltage conditions a small amount of current flows through the Zener diode. This current is because of the electrons which are thermally generated in the Zener diode.
As we keep increasing the reverse voltage at any particular value of reverse voltage the reverse current increases suddenly at the breakdown point this voltage is called Zener Voltage and is represented as Vz.

Applications of Zener Diode

Zener diode is a very useful diode. Due to its ability to allow current to flow in reverse bias conditions, it is used widely for various purposes. Some of the common uses of Zener Diode are discussed below,

Zener diode as Voltage Regulator

Zener diode is utilized as a Shunt voltage controller for managing voltage across little loads. The breakdown voltage of Zener diodes will be steady for a wide scope of current. The Zener diode is associated with corresponding to the heap to make it switch predisposition and when the Zener diode surpasses knee voltage, the voltage across the heap will become consistent.

Zener Diode in Over-Voltage Protection

At the point when the info voltage is higher than the Zener breakage voltage, the voltage across the resistor drops bringing about a short-out. This can be kept away from by utilizing the Zener diode.

Zener Diode in Clipping Circuits

Zener diode is utilized for adjusting AC waveform cutting circuits by restricting the pieces of it is possible that one or both the half patterns of an AC waveform.

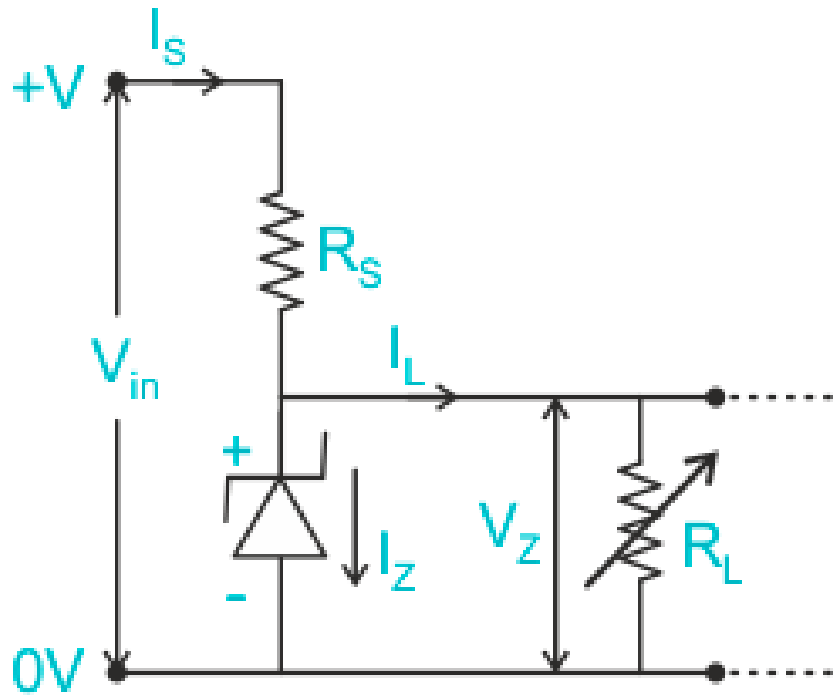
Working of Zener Diode as a Voltage Regulator

The capacity of a Zener diode to keep a constant voltage regardless of changes in source or load current is critical in this application.

A voltage regulation device's general role is to give a constant output voltage to a load connected in parallel to it, regardless of variations in the load's energy drawn (Load current) or fluctuations and instability in the supply voltage.

If the current remains within the limit of the min and max reverse currents, the Zener diode will produce a constant voltage.

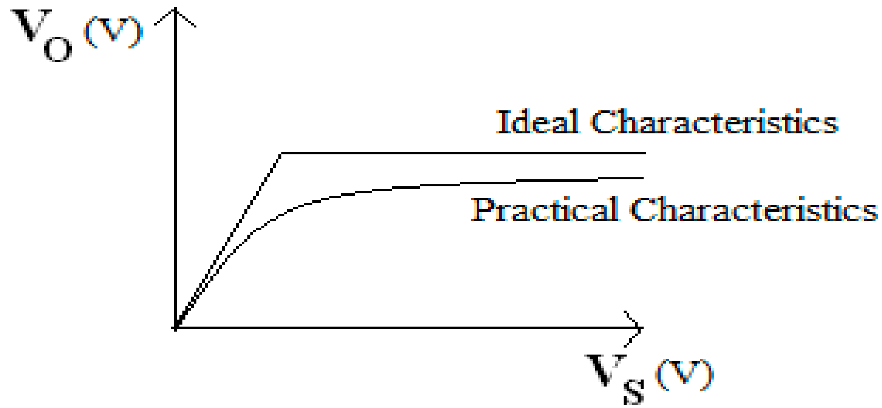
To restrict the current that flows through the Zener diode, a resistor Rs is connected in series with the diode, and also the input voltage Vin is connected across as shown in the image, and the output voltage Vout is chosen to take across the Zener diode with Vout=Vz.



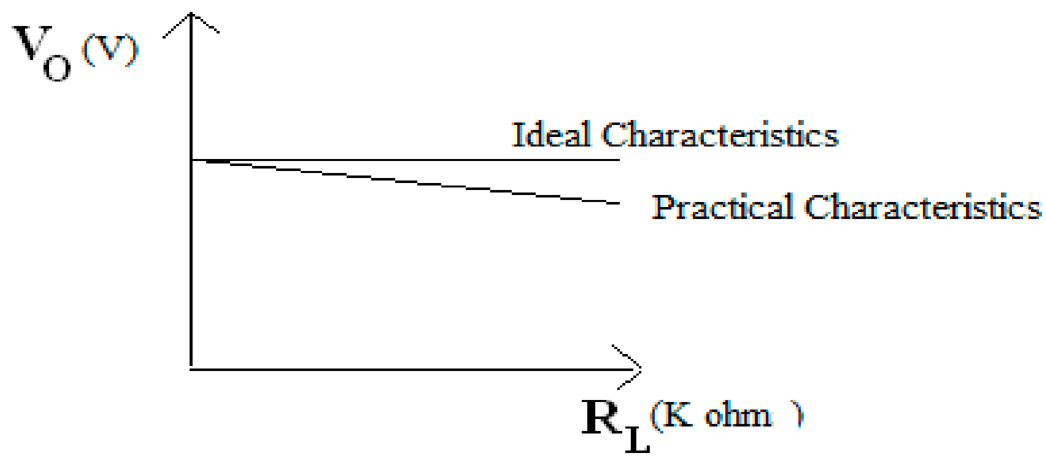
The value of the resistor can be determined by the formula
RS=(Vin−VZ)/Iz
Where, RS is the value of series resistance and Vin is the input voltage and Vz is Zener voltage.

Using this method, it is simple to assure that the resistor value chosen does not result in a current flow greater than the Zener can tolerate.

Line Regulation



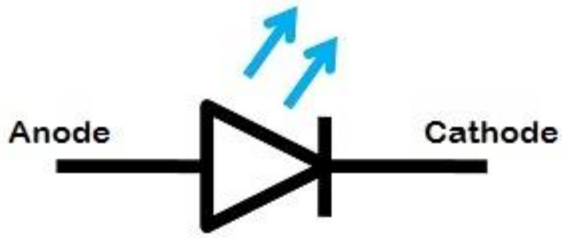
Load Regulation:



Light Emitting Diode : Working & Its Applications

The lighting emitting diode is a p-n junction diode. It is a specially doped diode and made up of a special type of semiconductors. When the light emits in the forward biased, then it is called a light-emitting diode.

The LED symbol is similar to a diode symbol except for two small arrows that specify the emission of light, thus it is called LED (light-emitting diode). The LED includes two terminals namely anode (+) and the cathode (-). The LED symbol is shown below.



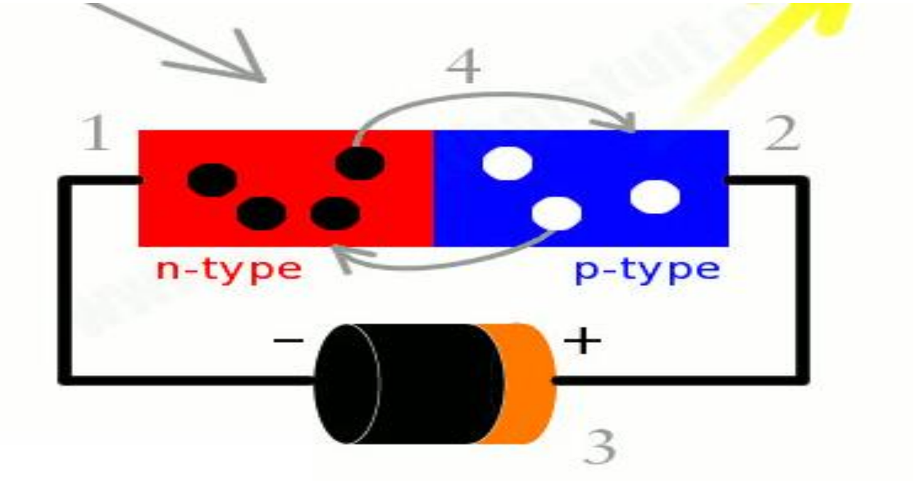
Construction of LED

The construction of LED is very simple because it is designed through the deposition of three semiconductor material layers over a substrate. These three layers are arranged one by one where the top region is a P-type region, the middle region is active and finally, the bottom region is N-type. The three regions of semiconductor material can be observed in the construction. In the construction, the P-type region includes the holes; the N-type region includes elections whereas the active region includes both holes and electrons.

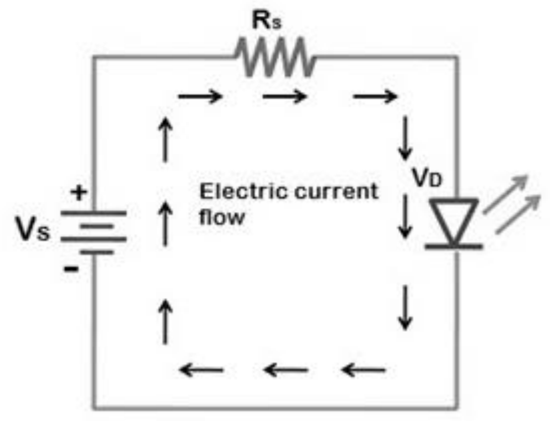
When the voltage is not applied to the LED, then there is no flow of electrons and holes so they are stable. Once the voltage is applied then the LED will forward biased, so the electrons in the N-region and holes from P-region will move to the active region. This region is also known as the depletion region. Because the charge carriers like holes include a positive charge whereas electrons have a negative charge so the light can be generated through the recombination of polarity charges.

How does the Light Emitting Diode Work?

The light-emitting diode simply, we know as a diode. When the diode is forward biased, then the electrons & holes are moving fast across the junction and they are combined constantly, removing one another out. Soon after the electrons are moving from the n-type to the p-type silicon, it combines with the holes, then it disappears. Hence it makes the complete atom & more stable and it gives the little burst of energy in the form of a tiny packet or photon of light.



Light Emitting Diode Circuit for Biasing



Most of the LEDs have voltage ratings from 1 volt-3 volt whereas forward current ratings range from 200 mA-100 mA. If the voltage (1V to 3V) is applied to the LED, then it functions properly due to the flow of current for the applied voltage will be in the operating range. Similarly, if the applied voltage to an LED is high than the operating voltage then the depletion region within the light-emitting diode will break down due to the high flow of current. This unexpected high flow of current will damage the device.

This can be avoided by connecting a resistor in series with the voltage source & an LED. The safe voltage ratings of LEDs will be ranges from 1V to 3 V whereas safe current ratings range from 200 mA to 100 mA.

Here, the resistor which is arranged in between the voltage source and LED is known as the current limiting resistor because this resistor restricts the flow of current otherwise the LED may destroy it. So this resistor plays a key role in protecting the LED.

Mathematically, the flow of current through the LED can be written as
IF = Vs – VD/Rs

Where,
'IF 'is forward current
'Vs' is a voltage source
'VD' is the voltage drop across the light-emitting diode
'Rs' is a current limiting resistor

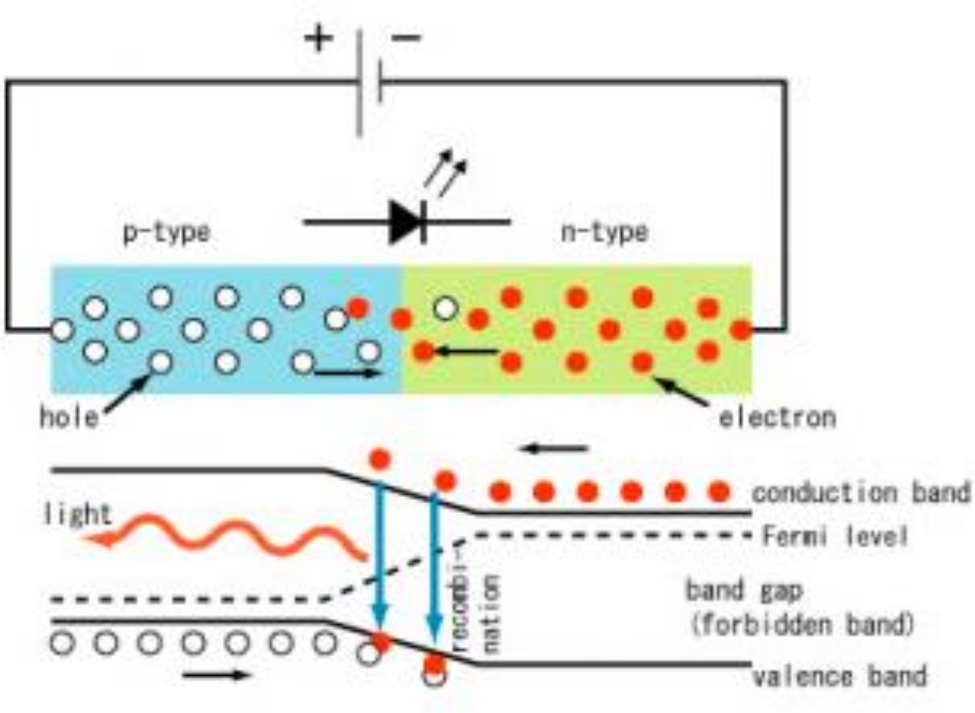
The amount of voltage dropped to defeat the barrier of the depletion region. The LED voltage drop will range from 2V to 3V while Si or Ge diode is 0.3 otherwise 0.7 V.
Thus, the LED can be operated by using high voltage as compared with Si or Ge diodes.
Light-emitting diodes consume more energy than silicon or germanium diodes to operate.

Working Principle of LED

The working principle of the Light-emitting diode is based on the quantum theory.

The quantum theory says that when the electron comes down from the higher energy level to the lower energy level then, the energy emits from the photon.

The photon energy is equal to the energy gap between these two energy levels.



The flow of current in the semiconductors is caused by the flow of holes in the opposite direction of current and the flow of electrons in the direction of the current.

Hence there will be recombination due to the flow of these charge carriers.

The recombination indicates that the electrons in the conduction band jump down to the valence band.

When the electrons jump from one band to another band the electrons will emit the electromagnetic energy in the form of photons and the photon energy is equal to the forbidden energy gap.

Advantages and Disadvantages of LED’s

The advantages of light-emitting diode include the following.

The cost of LED’s is less and they are tiny.
By using the LED’s electricity is controlled.
The intensity of the LED differs with the help of the microcontroller.
Long Lifetime
Energy efficient
No warm-up period
Rugged
Doesn’t affect by cold temperatures
Directional
Color Rendering is Excellent
Environmentally friendly
Controllable

The disadvantages of light-emitting diode include the following.

Temperature sensitivity
Temperature dependence
Light quality
Electrical polarity
Voltage sensitivity
Efficiency droop
Impact on insects

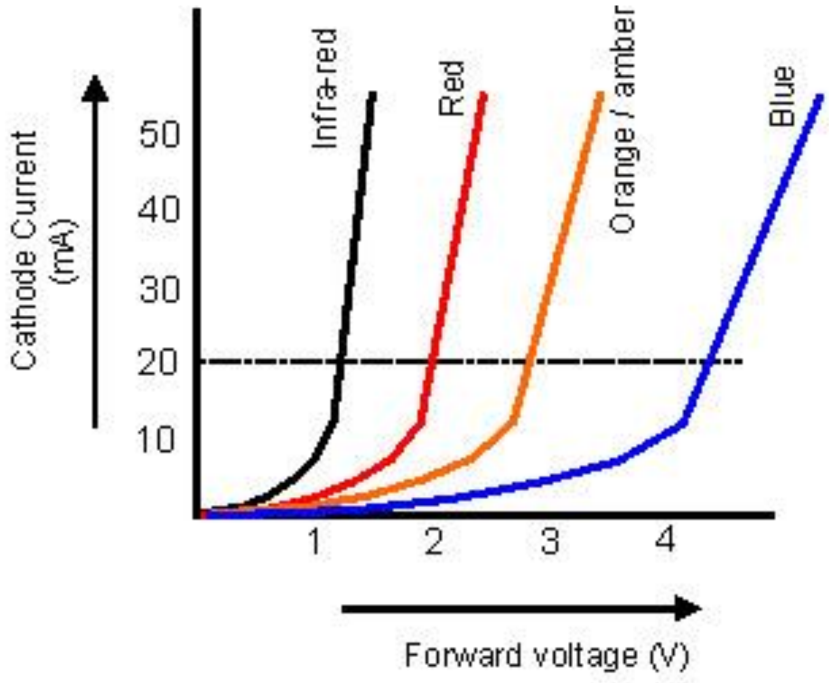
Applications of Light Emitting Diode

There are many applications of LED and some of them are explained below.

LED is used as a bulb in the homes and industries
The light-emitting diodes are used in motorcycles and cars
These are used in mobile phones to display the message
At the traffic light signals led’s are used

I-V Characteristics of LED

There are different types of light-emitting diodes are available in the market and there are different LED characteristics which include the color light, or wavelength radiation, light intensity. The important characteristic of the LED is color. In the starting use of LED, there is the only red color. As the use of LED is increased with the help of the semiconductor process and doing the research on the new metals for LED, the different colors were formed.



The graph shows the approximate curves between the forward voltage and the current. Each curve in the graph indicates a different color. The table shows a summary of the LED characteristics.

WAVELENGTH RANGE (NM)	COLOUR	V_F @ 20MA	MATERIAL
< 400	Ultraviolet	3.1 - 4.4	Aluminium nitride (AlN) Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN)
400 - 450	Violet	2.8 - 4.0	Indium gallium nitride (InGaN)
450 - 500	Blue	2.5 - 3.7	Indium gallium nitride (InGaN) Silicon carbide (SiC)
500 - 570	Green	1.9 - 4.0	Gallium phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
570 - 590	Yellow	2.1 - 2.2	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
590 - 610	Orange / amber	2.0 - 2.1	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaUInP) Gallium phosphide (GaP)
610 - 760	Red	1.6 - 2.0	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
> 760	Infrared	< 1.9	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)

What is a Photodiode?

It is a form of light sensor that converts light energy into electrical energy (voltage or current).

Photodiode is a type of semi conducting device with PN junction. Between the p (positive) and n (negative) layers, an intrinsic layer is present.

The photo diode accepts light energy as input to generate electric current. It is also called as Photodetector, Photo Sensor or Light Detector.

Photodiode operates in reverse bias condition i.e., the p – side of the photodiode is connected with negative terminal of battery (or the power supply) and n – side to the positive terminal of battery.

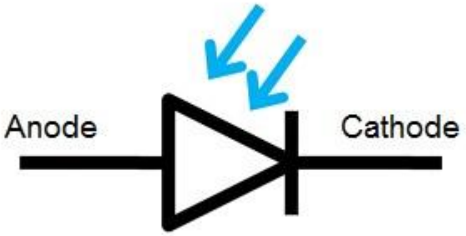
Typical photodiode materials are Silicon, Germanium, Indium Gallium Arsenide Phosphide and Indium gallium arsenide.

Internally, a photodiode has optical filters, built in lens and a surface area. When surface area of photodiode increases, it results in less response time.

Few photo diodes will look like Light Emitting Diode (LED). It has two terminals as shown below.

The smaller terminal acts as cathode and longer terminal acts as anode.

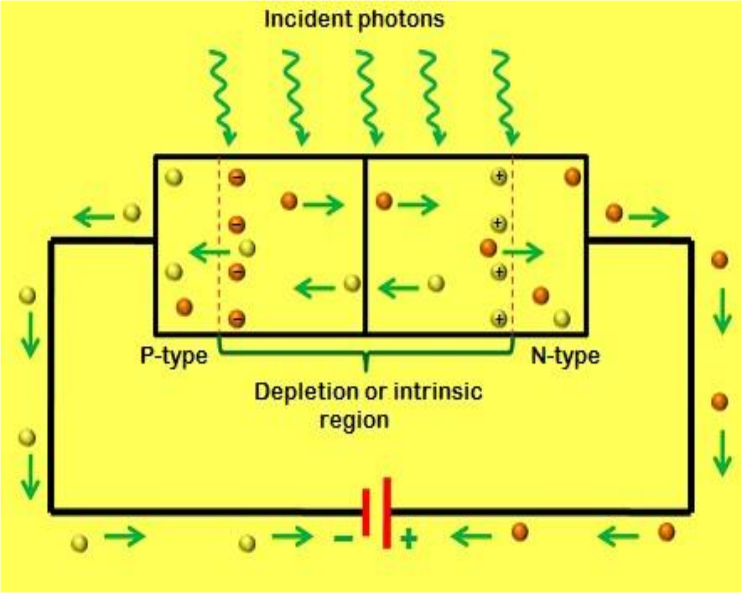
The symbol of the photodiode is similar to that of an LED but the arrows point inwards as opposed to outwards in the LED.



Photodiode symbol

Working of a Photodiode

Generally, when a light is made to illuminate the PN junction, covalent bonds are ionized. This generates hole and electron pairs. Photocurrents are produced due to generation of electron-hole pairs.
Electron hole pairs are formed when photons of energy more than 1.1eV hits the diode. When the photon enters the depletion region of diode, it hits the atom with high energy.
This results in release of electron from atom structure. After the electron release, free electrons and hole are produced.



In general, an electron will have a negative charge and holes will have a positive charge. The depletion energy will have built-in electric field.
Due to that electric field, electron-hole pairs move away from the junction.
Hence, holes move to anode and electrons move to the cathode to produce photocurrent.

The photon absorption intensity and photon energy are indirectly proportional to each other. When energy of photons is less, the absorption will be more. This entire process is known as Inner Photoelectric Effect.

Intrinsic Excitations and Extrinsic Excitations are the two methods via which the photon excitation happens.

Modes of operation of a Photodiode

Photodiode operates in three different modes. They are:

Photovoltaic Mode

Photoconductive Mode

Avalanche Diode Mode

Photovoltaic Mode

This is otherwise called as Zero Bias Mode. When a photodiode operates in low frequency applications and ultra-level light applications, this mode is preferred. When photodiode is irradiated by a flash of light, voltage is produced. The voltage produced will have a very small dynamic range and it has a non-linear characteristic.

Photoconductive Mode

In this mode, photodiode will act in reverse biased condition. Cathode will be positive and anode will be negative. When the reverse voltage increases, the width of the depletion layer also increases. Due to this the response time and junction capacitance will be reduced. Comparatively this mode of operation is fast and produces electronic noise.

Avalanche Diode Mode

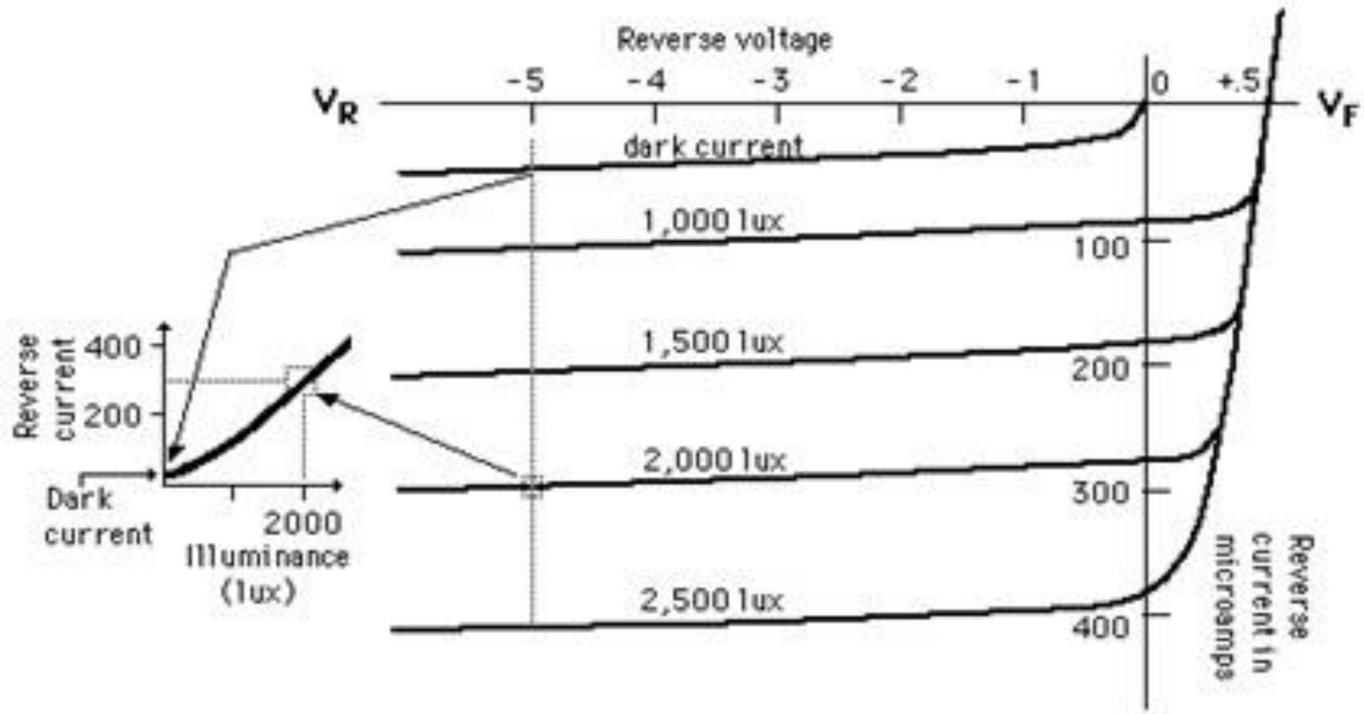
In this mode, Avalanche Diode operates at a high reverse bias condition. It allows multiplication of an Avalanche Breakdown to each photo-produced electron-hole pair. Hence, this produces internal gain within photodiode. The internal gain increases the device response.

V-I Characteristics of Photodiode

Photodiode operates in reverse bias condition. Reverse voltages are plotted along X axis in volts and reverse current are plotted along Y-axis in microampere. Reverse current does not depend on reverse voltage.

When there is no light illumination, reverse current will be almost zero. The minimum amount of current present is called as Dark Current.

Once when the light illumination increases, reverse current also increases linearly.



Applications of Photodiode

Photodiodes are used in many simple day to day applications. The reason for their use is the linear response of photodiode to a light illumination. When more amount of light falls on the sensor, it produces high amount of current. The increase in current will be displayed on a galvanometer connected to the circuit.

Photodiodes help to provide an electric isolation with help of optocouplers.

Photodiodes are also used in safety electronics like fire and smoke detectors. It is also used in TV units.

When utilized in cameras, they act as photo sensors. It is used in scintillators charge-coupled devices, photoconductors, and photomultiplier tubes.

Photodiodes are also widely used in numerous medical applications like instruments to analyze samples, detectors for computed tomography and also used in blood gas monitors.