3

CHAPTER

P-N JUNCTION DIODE

3.1 INTRODUCTION

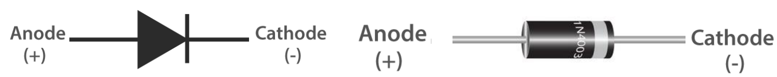
The P-N junction diode is a first semiconductor device which is very useful in the world of electronics. The most common function of a diode is to allow an electric current to pass in one direction (called the diode's forward direction), while blocking current in the opposite direction (the reverse direction). Thus, the diode can be viewed as an electronic switch. In other way this unidirectional behavior is used to convert alternating current to direct current called rectification. Apart from this different variants of diode are used for many applications.

Before the invention of semiconductor diode, vacuum tubes were used. Both diode and vacuum tube devices are similar in operating principle/characteristics but vacuum tubes are bulky in size and also require much power for its operation.

This chapter introduces the construction, working, characteristics and applications of P-N junction diode and other special diodes like Zener diode, photodiode, LED.

3.2 THEORY OF THE P-N JUNCTION DIODE

A P-N junction diode is two-terminal semiconductor device, which allows the electric current in only one direction while blocks the electric current in opposite or reverse direction. If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it allows the electric current to flow. But with negative voltage (reverse bias), it does not allows the electric current to flow. Fig. 3.1 shows a circuit symbol and photographs of commonly used diodes.



(a) (b)

Fig 3.1: (a) symbol (b) photograph of rectifier

A P-N junction Diode is constructed in such a way that a single crystal of semiconductor is doped with acceptor impurity on one side and donor impurity on other side. Fig. 3.2 shows the structure of P-N junction diode. In P-region, acceptor impurities are shown along with its holes and in N-region, donor impurities are shown along with its free electrons. The plane dividing the two halves is called a P-N junction.

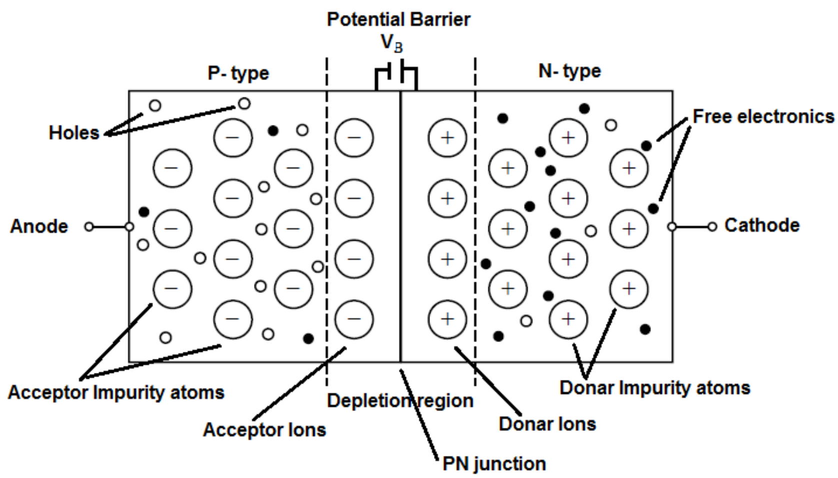


Fig 3.2: Unbiased P-N junction

Since N-type material has high concentration of free electrons, while P-type material has high concentration of holes. Therefore at the junction there is tendency of free electrons to diffuse over to the P-side and holes to the N-side. This process is called diffusion. As the free electrons moves across the junction from N-side to P-side, donor impurity atoms are uncovered. Hence positive charge is built on N-side of the junction. At the same time, holes cross the junction and uncovers negative acceptor impurity atoms. Therefore a negative charge is built on

P-side of the junction. When sufficient numbers of donor and acceptor atoms are uncovered, further diffusion is prevented. This is because positive charge on N-side, repels holes to cross from P-side to N-side and negative charge on P-side, repels electrons to cross from N-side to P-side. Thus the barrier is set up against further movements of charge carriers. This is called as a potential barrier or junction barrier denoted by VB. It is of the order of 0.3V for Ge and 0.7V for Si. The barrier potential is a function of temperature. Barrier potential decreases by 2 mV for every one degree rise in temperature. This region is called as depletion region or space charge region or transition region. It is so called because this region has deficiency of mobile carriers. The physical distance from one side of the barrier to the other side is called width of the barrier which is about 500 0A.

3.3 BIASING METHODS

The process of applying an external voltage to a p-n junction semiconductor diode is called biasing. External voltage to the p-n junction diode can be applied in any of the two methods: forward bias or reverse bias

3.3.1 Forward bias

When external voltage applied to the junction is in such a direction that it overcomes the potential barrier and thus permitting the current flow through the junction. Then that type of biasing is called as a forward biasing. To apply the forward bias, the positive terminal of the battery is connected to the P- region and negative terminal of the battery is connected to the N-region as shown in fig.3.3. If the applied forward voltage is more than 0.3V for germanium diode and more than 0.7V for silicon diode then the holes from P-region are repelled from positive terminal of the battery and are compelled to move towards the junction.

The electrons from N-region are repelled from the negative terminal of the battery and move towards the junction. So some of the holes and electrons penetrate the depletion region and thus reduces the potential barrier. Consequently it decreases the width of the barrier or depletion layer. As a result, more majority carriers diffuse across the junction and thus the large current flows through the junction. When applied voltage is more than barrier potential, then current increases rapidly. The forward biased voltage at which the current through diode increases rapidly is called knee voltage. (knee voltages for Germanium diode = 0.3 V and for Silicon diode = 0.7 V)

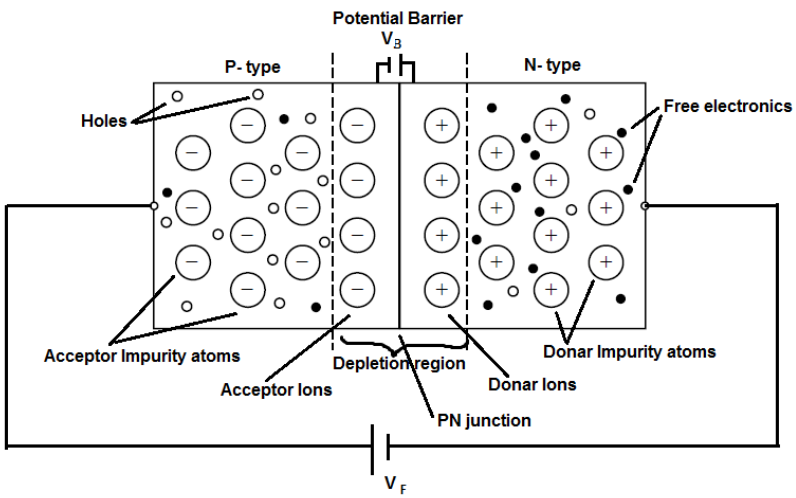


Fig.3.3 Forward biased P-N junction

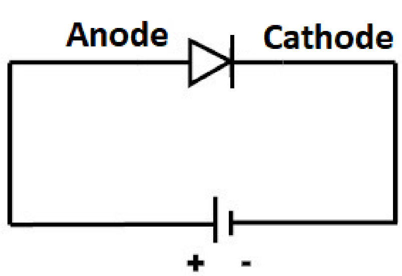


Fig.3.4 circuit diagram of forward biased P-N junction diode

In short, when P-N junction is forward biased then -

1) Potential barrier decreases
2) Depletion layer width decreases
3) Large current flows through the junction

3.3.2 Reverse bias

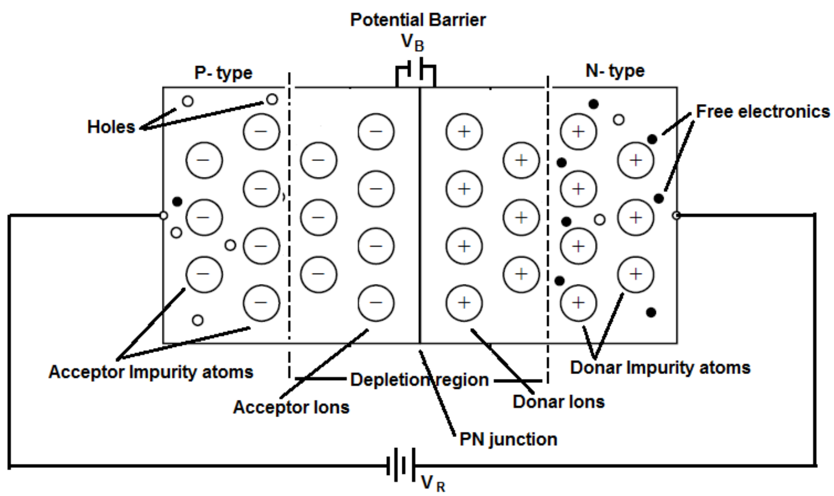


Fig.3.5 Reverse biased P-N junction

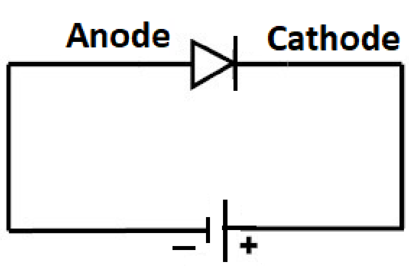


Fig.3.6 circuit diagram of reverse biased P-N junction diode

When the external voltage applied to the junction is in such a direction that it widens the potential barrier and doesn't permit the flow of current through the junction then such type of biasing is called as a reverse biasing.

To apply the reverse bias, the negative terminal of the battery is connected to the P- region and positive terminal of the battery to N-region as shown in fig.3.5. The holes in the P-region are attracted towards the negative terminal of the battery and electrons in the N-region are attracted towards the positive terminal of the battery. Thus the majority carriers are drawn away from the junction. This action widens the depletion region and increases the barrier potential and thus prevents the majority carriers to cross the junction. However this barrier potential is helpful to the minority carriers. Thus the minority carriers constitute a current called as reverse saturation current denoted by Is. This current is very small of the order of few microamperes (μA).

In short, when P-N junction is reverse biased then -

1) The potential barrier increases
2) Depletion layer width increases
3) Only small leakage current flows

3.4 V-I (VOLT - AMPERE) CHARACTERISTICS OF DIODE

The device response will be understood when it is connected in an electrical circuit. The information so collected is plotted by means of a graph known as volt ampere characteristics or V-I characteristics. It is a graph between the voltage applied across the terminals of a diode and the current that flows through it. The typical V-I characteristics of a P-N junction diode is as shown in fig.3.7. This characteristic can be studied in two different modes.

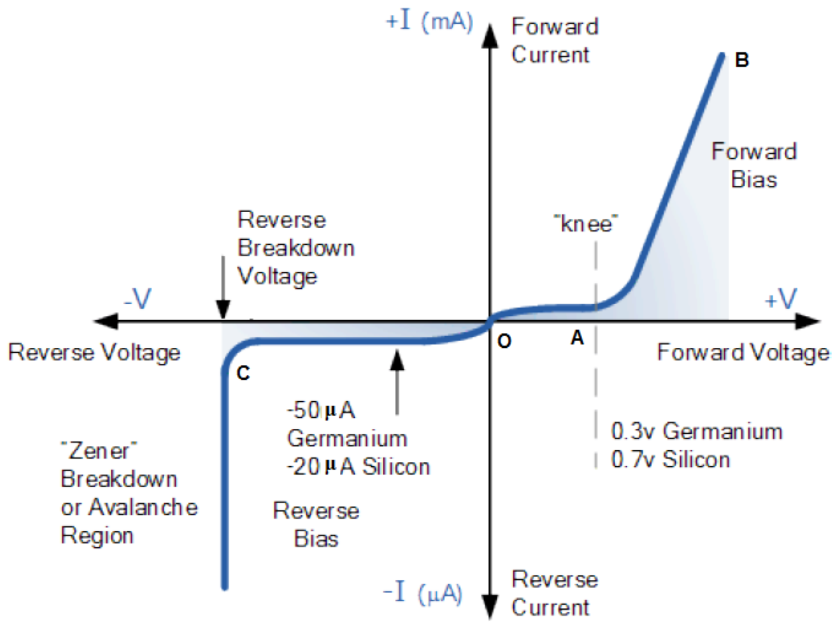


Fig.3.7 V-I characteristics of a P-N junction diode

3.4.1 Forward biased mode

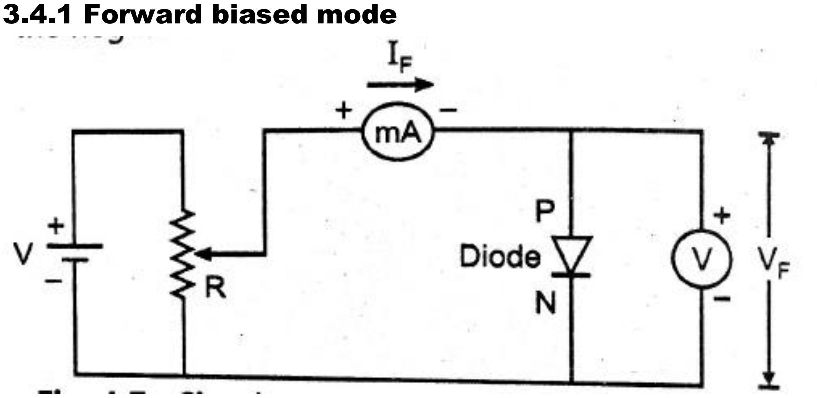


Fig 3.8 : Circuit arrangement of forward bias p-n junction diode

The circuit arrangement for obtaining forward characteristic of a diode is shown in fig.3.8. Here, the positive terminal of the battery is connected to the p-type semiconductor and the negative terminal of the battery is connected to the n-type semiconductor through the potentiometer. The diode is said to be in forward bias. The potentiometer helps in varying the voltage applied across the diode. A voltmeter connected across the diode is used to measure the voltage across it and milli-ammeter (mA) connected in series is used to measure the current through the diode.

In forward biased P-N junction diode, VF represents the forward voltage, whereas IF represents the forward current. If the external voltage applied to the silicon diode is less than 0.7 volts, the silicon diode allows very small electric current and the curve is non-linear as shown by the region OA in the fig 3.7. This is because the external applied voltage is used in overcoming the potential barrier. This small electric current is considered as negligible.

When the external voltage applied to the silicon diode reaches 0.7 volts, the p-n junction diode starts allowing large electric current through it. At this point, a small increase in voltage increases the electric current rapidly as shown by the region AB. The forward voltage at which the silicon diode starts allowing large electric current is called **forward cut-in voltage** or **knee voltage**. The cut-in voltage for silicon diode is approximately 0.7V and is 0.3V for Germanium diode. Thus forward biased diode has very low resistance and acts as short circuit.

3.4.2 Reverse biased mode

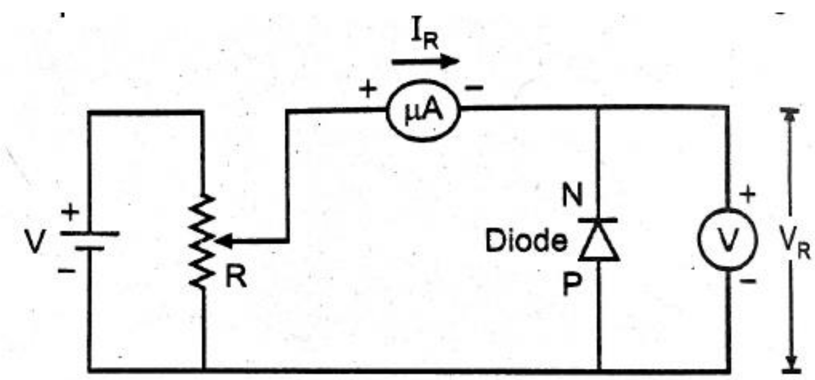


Fig 3.9 : Circuit arrangement of Reverse bias p-n junction diode

If the negative terminal of the battery is connected to the p-type semiconductor and the positive terminal of the battery is connected to the n-type semiconductor, the diode is said to be in reverse bias and this is shown in fig.3.9. In reverse biased P-N junction diode, VR represents the reverse voltage whereas IR represents the reverse current.

With the reverse bias to the diode, the depletion region as well as potential barrier at the junction goes on increasing. The wide depletion region completely blocks the majority charge carrier to cross the junction and thus no current flows through the junction because of majority carriers. However, it allows the minority charge carrier to cross the junction. The free electrons (minority carriers) in the p-type semiconductor and the holes (minority carriers) in the n-type semiconductor can cross the junction and constitute small electric current as shown by the region OC. This electric current is called as reverse leakage current IR. Thus reverse biased diode has very high resistance and acts as open circuit.

If the reverse voltage is increased further continuously, then at a particular reverse voltage, the number of carrier crossing the junction increases, giving rise to sudden increase in current. The corresponding reverse voltage at which break down of junction occurs is called break down voltage of a diode.

3.4.3 Reverse Saturation Current

In n-type and p-type semiconductors, very small numbers of minority charge carriers are present. When a small reverse voltage applied to the diode, it pushes all the minority carriers towards the junction and constitute small electric current called as reverse leakage current IR. The further increase in the external reverse voltage does not increase the electric current. This electric current is called as reverse saturation current (IS). In other words, a point at which the electric current reaches its maximum level and further increase in voltage does not increase the electric current is called reverse saturation current.

The reverse saturation current depends on the temperature. With increase in temperature, the generation of minority charge carriers increases. Hence, the reverse current increases with the increase in temperature. Practically, it is found that the value of reverse saturation current (Is) is doubles in magnitude for every 10oC rise in temperature for Silicon. However, the reverse saturation current is independent of the external reverse voltage. Hence, the reverse saturation current remains constant with the increase in voltage.

However, if the voltage applied on the diode is increased continuously, the P-N junction diode reaches to a state where junction breakdown occurs and reverse current increases rapidly.

In germanium diodes, a small increase in temperature generates large number of minority charge carriers. The number of minority charge carriers generated in the germanium diodes is greater than the silicon diodes. Hence, the reverse saturation current in the germanium diodes is greater than the silicon diodes.

3.4.4 Diode Equation

The volt-ampere characteristic can also be explained with the help of diode equation given by

$$I = Is\,(e^{\frac{qV}{nKT}} - 1) \quad \ldots\ldots\ldots (1)$$

Where, I= current through the diode

IS = reverse saturation current

V=applied voltage

q= electronic charge = 1.602 x 10-19 C

K= Boltzmann's constant = 1.38 x 10-23 J/K

T= absolute temperature in 0 Kelvin

n=1 for Ge, 2 for Si

Under Forward bias condition as applied voltage V increases then

Under Forward bias, $e^{\frac{qV}{nKT}} >> 1$

Therefore, **Forward current =** $I_F = Is.\,e^{\frac{qV}{nKT}} \quad \ldots\ldots\ldots\ldots (2)$

This equation shows that forward current (IF) increases exponentially with voltage.

Under Reverse bias condition as applied voltage (-V) increases then

$$e^{\frac{qV}{nKT}} << 1$$

Therefore, Reverse **current** = $I_R = -I_S$ …….. (3)

This equation shows that Reverse current (IR) is constant and independent of applied voltage.

3.4.5 Diode Resistance

When a diode is connected in a DC circuit it offers a resistance. This resistance is called as DC or static resistance. It is the ratio of DC voltage across the diode to the DC current flowing through it.

$$R = \frac{V}{I}$$

Note that DC resistance changes with the operating point. It decreases as current increases.

When a diode is connected to a small AC signal it offers a resistance. This resistance is called as AC or dynamic resistance. It is the ratio of change in voltage across the diode to the change in current flowing through it.

$$rf = \frac{\Delta V}{\Delta I}$$

AC or dynamic resistance is a combination of bulk resistance (r_B) and junction resistance (r_j).

The bulk resistance of a diode is the sum of ohmic resistance of P and N regions. The bulk resistance is given by,

$$r_B = \frac{V_F - V_\gamma}{I_F}$$

where, V_F= voltage across diode

V_γ = cut in voltage

IF = current through diode

The junction resistance $r_j = \frac{\eta V_T}{I_F}$

At room temperature and $\eta = 1$,

$$r_j = \frac{0.026}{IF}$$

The junction resistance varies inversely with current. Thus the total ac resistance of the diode is given by,

$$rf = rB + rj$$

Diode specifications:-

1) Maximum forward current (IFmax):- It is the highest forward current that the diode can conduct without damage.

2) Maximum power rating (Pmax):- It is maximum power that can be dissipated at the junction without damage.

$$P_{max} = V_{Fmax} \times I_{Fmax}$$

3) Peak Inverse Voltage (PIV):- It is maximum reverse voltage that can be applied to the diode without damage.

3.5 BREAKDOWNS IN DIODES

Consider the I-V characteristics of a pn junction in reverse bias, as shown in figure 3.10. There is initially a small reverse saturation current due to thermally generated electron and holes in the depletion region. This current is called drift current, since this is due to movement of the thermally generated carriers under the applied electric field. With increase in voltage there is a particular value, called the breakdown voltage, beyond which the current increases rapidly. This is called junction breakdown. There are two main mechanisms of junction breakdown, depending on the dopant concentration levels.

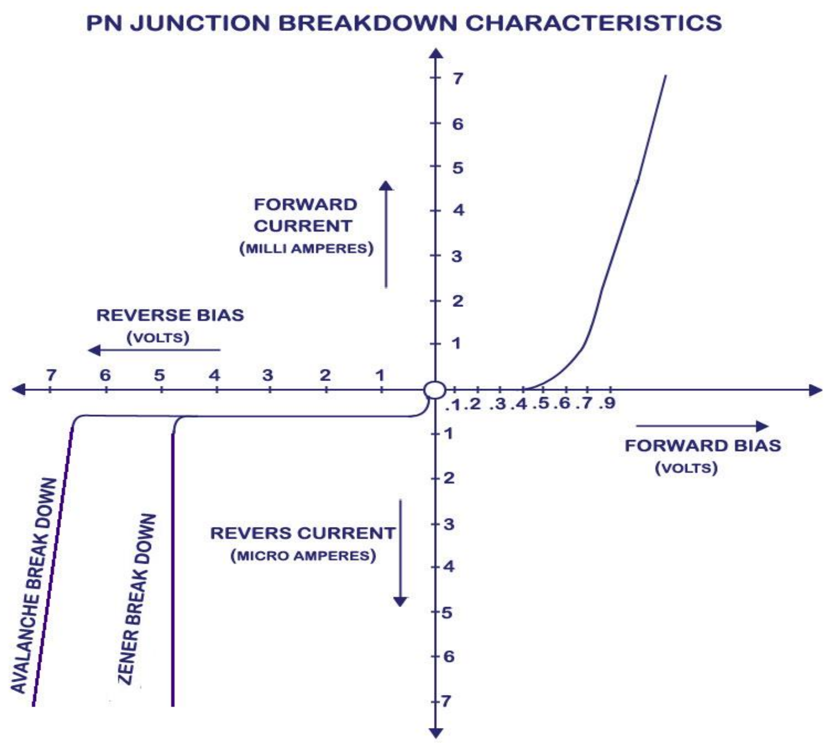


Fig.3.10 Breakdown characteristics in Diodes

Avalanche breakdown:

Avalanche breakdown occurs in moderately and lightly doped pn junctions with a wide depletion region. Thermally generated electron-hole pairs in the depletion region are accelerated by the external reverse bias. Electrons are accelerated towards the n side and holes towards the p side. These electrons can interact with other Si atoms and if they have sufficient energy can knock off electrons from these Si atoms. This process is called **impact ionization** and leads to production of a large number of electrons. This causes the rapid rise in current. The breakdown voltage decreases with increase in dopant concentration

Zener breakdown:

Zener breakdown occurs in heavily doped P-N junctions with a narrow depletion region.

With heavy doping the depletion region is very thin i.e. about 100 ^{0}A. Thus a very high electric field about 0.7x10^{8} V/m is produced near the junction at breakdown voltage. This high electric field takes off electrons out of co-valent bonds directly. Thus large numbers of carriers are available for current conduction. So that at breakdown voltage V_Z , current increases very rapidly. This type of breakdown is called as zener breakdown.

3.5.1 Comparison between Avalanche breakdown and Zener breakdown:

	Avalanche breakdown	Zener breakdown
1	When both sides of the PN junction are lightly doped and the depletion layer becomes large, Avalanche breakdown takes place.	When both sides of the PN junction are heavily doped, consequently the depletion layer is narrow and zener breakdown takes place.
2	The electric field across the depletion layer is not so strong.	When a small reverse bias is applied, a very strong electric field is produced.
3	Thermally generated carriers collide with valence electrons, so covalent bonds are broken and new electron hole are generated.	The strong electric field breaks the covalent bonds. So extremely large number of electrons and holes are produced.
4	These newly generated charge	The electrons and holes thus give

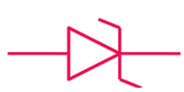
	carriers acquire energy from the applied potential and in turn produces more and more carriers. This cumulative process is called avalanche multiplication and the breakdown is called **avalanche breakdown**	rise to the reverse saturation current called the Zener current. Zener current is independent of applied voltage.

Table 3.1: Comparison between Avalanche breakdown and Zener breakdown

P-N Junction Diode Applications:

1. Diodes are used in rectification process for converting AC signal into DC signal.
2. Diodes are used in clipping and clamping circuits for wave shaping.
3. Diodes are used in voltage multipliers.
4. Diodes are used as switch in digital logic circuits.
5. Diodes are used in demodulation circuits.
6. Diodes are used in voltage regulators.

3.6 ZENER DIODE



(a)

(b)

Fig 3.11: (a) symbol (b) photograph of Zener Diode

A properly doped P-N junction diode which has a sharp breakdown voltage is known as a zener diode. The zener diodes are designed to operate in the breakdown region without damage.

In zener diodes doping is very high so that depletion region is very thin i.e. about 100 ^{0}A. Thus a very high electric field about 0.7×10^8 V/m is produced near the junction at breakdown voltage. This high electric field takes off electrons out of co-valent bonds directly. Thus large numbers of carriers are available for current conduction. So that at breakdown voltage V_Z , current increases very rapidly. This type of breakdown is called as zener breakdown.

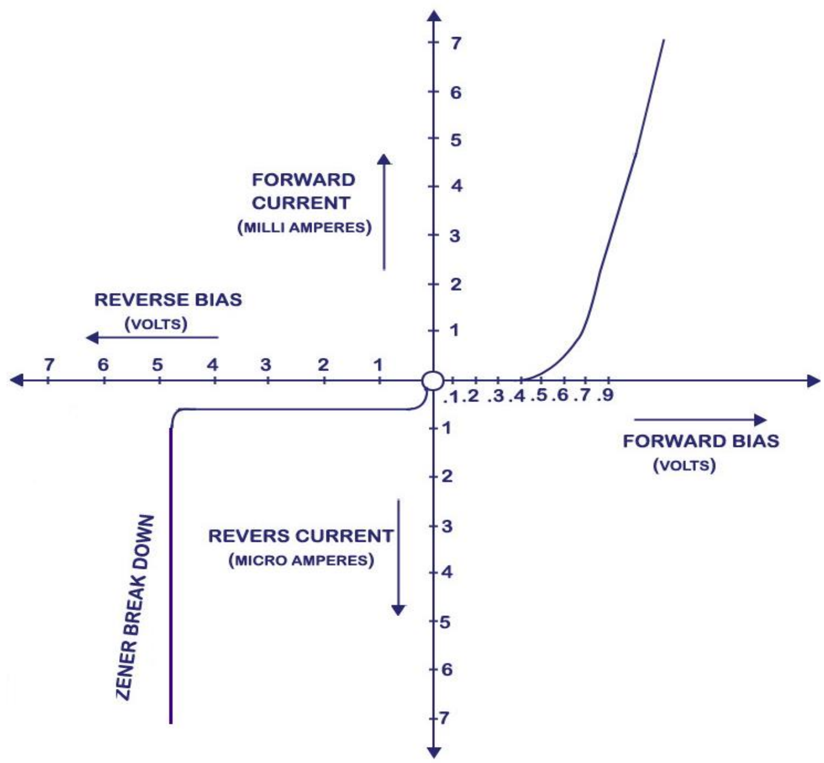


Fig.3.12: V-I characteristics of zener diode

The zener voltage depends upon the amount of doping. As the amount of doping increases, the value of VZ decreases.

From V-I characteristics of zener diode (Fig.3.12), it is seen that the curve is almost linear at breakdown i.e. the voltage across the diode is constant even the current through it changes. Thus the zener diode can be used as a voltage regulator to provide constant voltage from source.

3.6.1 Zener specifications

1. Zener voltage (V_Z): This is the value of breakdown voltage provided by the manufacturer. The zener diodes are available with different values of V_Z rising from 3V to 300V.
2. Power dissipation: it is the product of V_Z & reverse current I_Z.
3. Dynamic impedance:

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

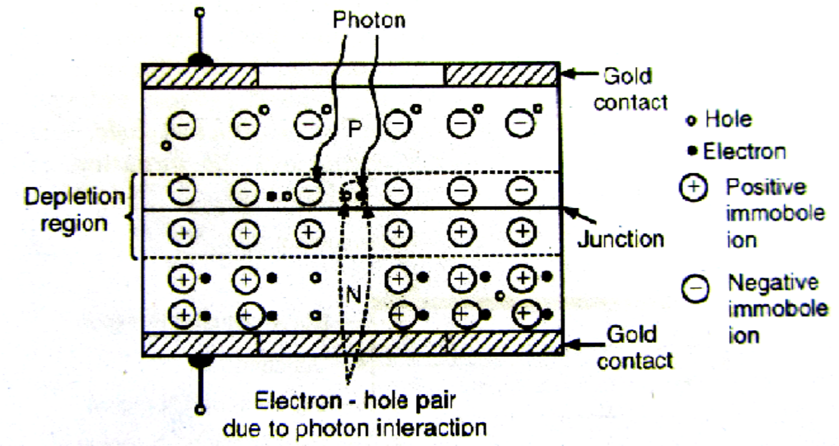
This specification helps to describe how vertical is the reverse characteristics. Ideally Z_Z=0, for perfectly vertical break down curve but in actual practice Z_Z varies from few ohms to 100 ohms.

Applications of Zener diode

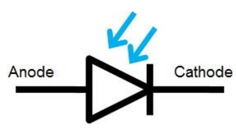
1. Zener diodes are used in voltage regulators.
2. Zener diodes are used in clipping and clamping circuits.
3. Zener diodes are used in various protection circuits.

3.7 PHOTODIODE

The photodiode is a special type of diode that generates current when exposed to light. The amount of current generated is directly proportional to the intensity of light. It is also called as Photo detector, photo sensor or light detector. Photodiodes are operated always in reverse bias mode. Typical photodiode materials are Silicon, Germanium, Indium Gallium Arsenide Phosphate and Indium gallium arsenide.



(a)



(b) (c)

Fig:3.13: (a) construction of Photo Diode (b) Symbol (c) photograph

Working:

Photo Diode works on the principle of Photoelectric effect. It has a P and N junction and is connected in reverse bias that results in a very wide depletion region at the P-N Junction. The glass window is provided for the incidence of light on the junction. When there is no illumination or light on photodiode, a very small amount of current flows through it, called as dark current. But when light is incident through glass window on the P-N junction, photons in the light bombarding the p-n junction and some energy is imparted to the valence electrons. Due to this, valence electrons are dislodged from the covalent bonds and become free electrons. This causes the generation of electron-hole pair. This phenomena occurs when photon energy (h_ν) is greater than the band gap energy (E_g) of the semiconductor (i.e $h_\nu > E_g$). When reverse bias is applied, the generated hole-electron pairs constitute a current called as photo current. The photo current increases almost linearly with the incident light intensity.

Photodiode applications

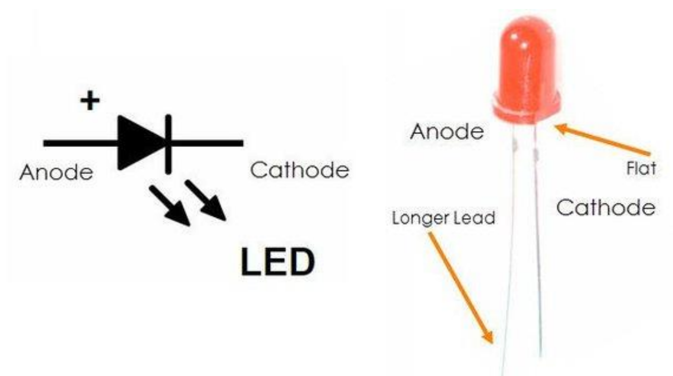
The various applications of photodiodes are

1. Photodiode can be used as a light sensor/ light detector in following instruments.
    a) Light Meter to measure light intensity
    b) Smoke detectors to detect smoke due to fire because of short circuit
    c) Automatic street lighting systems to switch ON/OFF lights
    d) Surrounding light measurement in cameras
2. Photodiodes are coupled with LED to make opto-isolators / opto-couplers. Such device is used to couple two digital or analog circuits
3. Photodiodes are used in barcode scanner, character recognition equipment
4. Used in receivers for infrared remote control devices used to control equipment from televisions to air conditioners
5. It is also used in optical encoders and decoders in Compact disc players

3.8 LIGHT EMITTING DIODE (LED)

LEDs (light-emitting diodes) are opto-semiconductors that convert electrical energy into light energy. LEDs are nothing but p-n junction diodes which emit light when forward biased. When current passes through the LED, the electrons recombine with holes and this recombination results in emission of light. Based on the semiconductor material used and the amount of doping, an LED will emit a different colored light when forward biased. LEDs offer the advantages of low cost and a long service life.

The circuit symbol and actual LED device are shown in fig.3.14.



(a) (b)

Fig: 3.14:(a) Symbol (b) photograph of LED

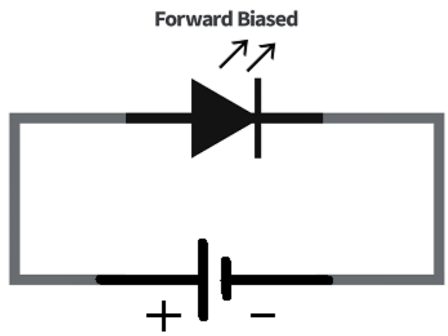


Fig.3.15: Working of LED under forward bias

When LED is forward biased, electrons are injected into the n-region and holes into the p-region. Electrons cross the P-N junction from the n-type material and recombine with holes in the p-type material. The free electrons are in the conduction band and holes in the valence band. The electron–hole recombination takes place and during this process the energy is released. In ordinary diodes, the release of energy is in the form of heat, but in case of LED, the release of energy is in the form of photons. The entire process is known as electroluminescence, and the diodes are known as a light-emitting diode.

Materials used for LED:

The material used for constructing LED determines its color. In other words, the wavelength or color of the emitted light depends on the forbidden gap or energy gap of the material. Light emitting diodes are available in a wide range of colors with the most common being red, amber, yellow and green and are thus widely used as indicators. The actual color of a light emitted by LED is determined by the actual semiconductor compound used for fabrication. Table 3.2 shows the used semiconductor material to produce particular color.

Color	Wavelength Range (nm)	Forward Voltage (V)	Material
Ultraviolet	< 400	3.1 - 4.4	Aluminium nitride (AlN) Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN)
Violet	400 - 450	2.8 - 4.0	Indium gallium nitride (InGaN)
Blue	450 - 500	2.5 - 3.7	Indium gallium nitride (InGaN) Silicon carbide (SiC)
Green	500 - 570	1.9 - 4.0	Gallium phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
Yellow	570 - 590	2.1 - 2.2	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
Orange / Amber	590 - 610	2.0 - 2.1	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaUInP) Gallium phosphide (GaP)
Red	610 - 760	1.6 - 2.0	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium phosphide (GaP)
Infrared	> 760	> 1.9	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)

Table 3.2: semiconductor materials used for LED

Light Emitting Diode Circuit:

Different LEDs requires different forward voltage for its operation as mentioned in Table 3.2. This forward voltage ranges from 1.6 V to 4.4 V and forward current from 10 to 50 mA for different coloured LEDs. Thus the power output of an LED is in milliwatts. Thus while connecting LED in a circuit; there should be appropriate series resistance (Rs) to account for this drop. The LED circuit is shown in fig.3.16. The Value of resistor (Rs), decides the forward current (I_F) of LED thus by deciding light intensity.

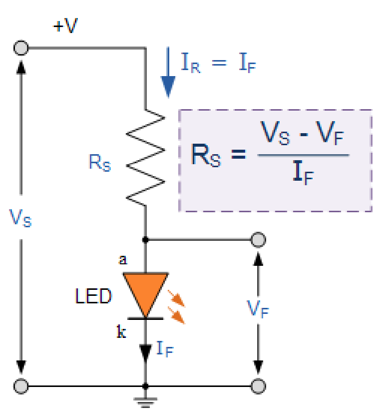


Fig.3.16 : LED circuit

For Example, suppose a LED needs 10 mA and has a voltage drop of 2 volts. Supply voltage used in the circuit is 5 V. What is value of series resistor?

The required series resistance value is,

$$R_S = \frac{V_S - V_F}{I_F} = \frac{5v - 2v}{10mA} = \frac{3}{10x10^{-3}} = 300\Omega$$

Applications of LED:

Following are the important applications of the LED.

1. LEDs are used in 7 segment, 16 segment & dot matrix displays
2. Automotive head lamps
3. In optical switching applications as light source
4. In burglar alarm systems as light source
5. In optical communication as light source
6. As a pilot lamp in many instrument to indicate ON/OFF conditions
7. Output power level indicators in stereo amplifier
8. Camera flashes
9. Traffic signals

3.9 SEVEN SEGMENT DISPLAY

A seven segment display consists of seven LEDs arranged in seven segments as shown in the Fig.3.17. The seven LEDs are arranged in a rectangular fashion and are labeled ‘a’ through ‘g’. Each LED is called a segment because it forms a part of the digit being displayed. An additional LED is used for the indication of a decimal point (DP).

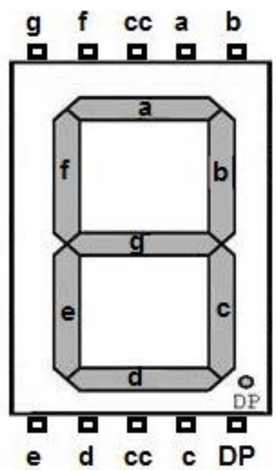


Fig.3.17: Working of Seven Segment Displays

By forward biasing the different LEDs, we can display the digits 0 through 9. For example, to display a zero, the LEDs a, b, c, d, e and f are to be forward biased. To light up a 5, we need to forward bias the segments a, f, g, c, d. Thus in a seven segment display depending upon the digit to be displayed, the particular sets of LEDs are to be forward biased. The various digits from 0 to 9 which can be displayed using seven segment displays are shown in the Fig.3.18.

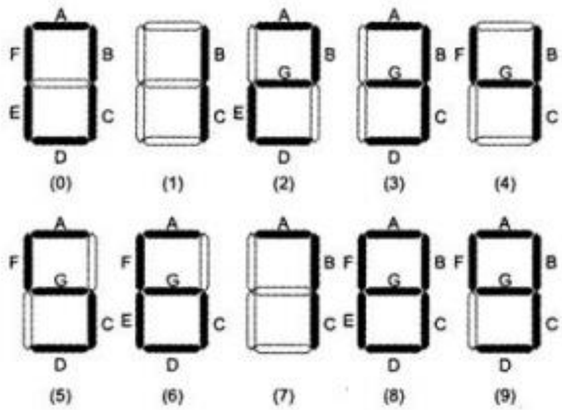


Fig.3.18 : Various digits from 0 to 9 which can be displayed using seven segment display

Decimal Digit	Individual Segments Illuminated						
	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

Table 3.3: Truth table for Common Cathode type display

Types of Seven Segment Display

Seven segment displays are available in two types of configurations:

1) Common anode type

2) Common cathode type

Common Anode Type

In this type, all anodes of LEDs are connected together and common point is connected to +V which is positive supply voltage. A current limiting resistor (R) is required to be connected between each LED and ground.

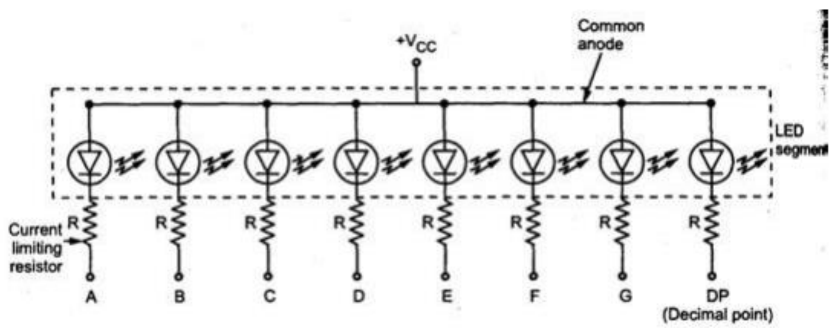


Fig. 3.19 Common Anode Type

Common Cathode Type

In this type, all cathodes of LEDs are connected together and common point is connected to the ground. A current limiting resistor (R) is connected between each LED and the supply + Vcc. The anodes of the respective segments are to be connected to + for the required operation of LEDs.

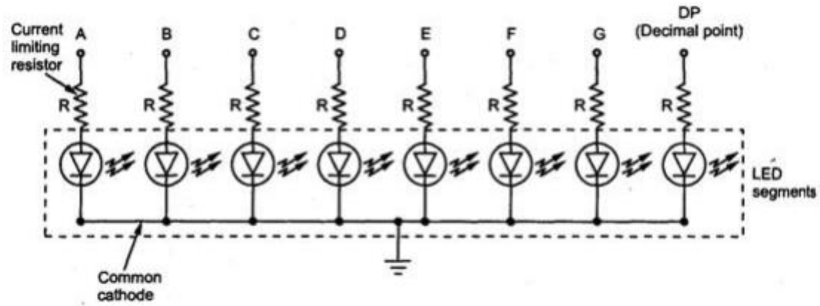


Fig. 3.20 Common Cathode Type

Applications of Seven Segment Displays:

Common applications of seven segment displays are in:

1. Digital clocks
2. Calculators
3. Electronic meters (Voltmeter/ ammeter/speedometers etc.)

EXERCISE

(A) Multiple Choice Questions (MCQs) :

1. If forward bias is applied to the P-N junction diode, then it's barrier width - - - - -

   (a) Increases (b) **Decreases**

   (c) Remain same (d) None of these

2. Reverse biased PN junction acts as a --------- switch.

   (a) Closed (b) **Open**

   (c) Toggle (d) Debounce

3. A reverse biased P-N junction has ....

   (a) very narrow depletion layer

   (b) **almost no current flows**

   (c) acts as closed circuit

   (d) very large current flows

4. The leakage current across a P-N junction is due to ....

   (a) **minority carriers**

   (b) majority carriers

   (c) junction capacitance

   (d) none of the above

5. With forward bias to the P-N junction, the barrier potential ....

   (a) Increases (b) **Decreases**

   (c) Remain same (d) None of these

6. Forward biase P-N junction offers .... resistance.

   (a) Zero (b) **Very low**

   (c) Very high (d) infinite

7. The cut-in voltage of Silicon diode is ....

   (a) 0.2V (b) 0.3V

   (c) 0.7V (d) 1.0V

8. A zener diode ------

   (a) has a high forward voltage rating

   (b) **has a sharp breakdown at low reverse voltage**

   (c) is useful as an amplifier

   (d) has metal-semiconductor junction

9. Zener diode can be used as ---

   (a) an amplifier (b) **voltage regulator**

(c) a rectifier (d) a multivibrator

10. .... device is used to obtain constant output voltage.

(a) **Zener diode** (b) Photodiode

(c) LED diode (d) Rectifier diode

11. Photodiode is normally connected in .... biased.

(a) Forward (b) Reverse

(c) Neither forward nor reverse (d) None of these

12. In a photodiode, when there is no incident light, the reverse current is almost negligible and is called ....

(a) Zener current (b) Dark current

(c) **Photocurrent** (d) PIN current

13. When the intensity of incident light increases in Photodiode, the magnitude of the photocurrent ------

(a) **Increases** (b) Decreases

(c) Remain constant (d) None of these

14. . ...diode that convert electrical energy into light energy.

(a) Zener (b) Photodiode

(c) **LED** (d) None of these

15. LED emits light only under .... conditions.

(a) **Forward biased** (b) Reverse biased

(c) Neither forward nor reverse (d) Zero biased

16. The colour of emitted light from LED depends on.....

(a) Physical dimensions

(b) Number of available carriers

(c) **Type of semiconductor material used**

(d) Number of recombination taking place

(B) Short Answer Questions:

1. What is mean by reverse saturation current in the diode?
2. Write note on diode resistance.
3. Write a note on breakdown phenomenons in Diodes.
4. Compare Avalanche and Zener breakdown phenomenon.
5. Write a note on Zener diode.
6. Write a note on photo Diode.
7. Write a note on LED.
8. Write a note on 7-segment display.
9. Give the applications of LED.

(C) Long Answer Questions:

1. What is P-N junction diode? Explain the phenomena of formation of depletion layer near the junction.
2. Define P-N junction, explain forward and reverse biasing methods for diode.
3. Discuss the behaviour of a P-N junction under forward and reverse bias.
4. Draw and explain V-I characteristic of P-N junction diode.

ΘΘΘ