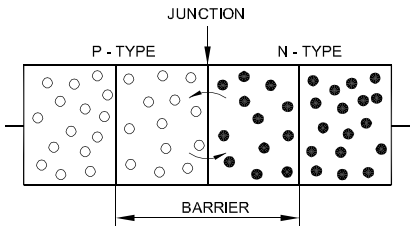
PN Junction - semi conductor diodes

Objectives: At the end of this lesson you shall be able to
- **explain diffusion in PN junction and barrier potential**
- **explain forward and reverse biasing of PN junction and semi conductor diodes and its VI characteristics**
- **state the applications specifications and classification of diodes**
- **state the different industry standards for diode numbering and finding equivalents of diode**
- **state the method of testing diode and identifying the polarity**
- **state special diodes and their functions and PIV.**

PN junction: A diode is made by combining P and N materials. The surface at which these materials meet is the PN junction.

Diffusion occurs when P and N materials are joined together.(Fig 1) some electrons in the N material, near the junction, are attracted to the holes in the P material, thus leaving holes in the N material. The diffusion of electrical charges produces a potential difference in a small area near the junction (Fig 2).As a result, the material will conduct in one direction but not in the opposite direction. For this reason, the area in which this emf exists is called a barrier.

Fig 1



The internal barrier potential (V_b) : Although it is an internal contact potential that cannot be measured directly, the effect can be overcome by 0.3V for a **Ge** junction or 0.7 V for **Si**. The barrier voltage is more for **Si** because its lower atomic number allows more stability in the covalent bonds as already stated.

The PN junction, with the depletion zone magnified, shows the iron that has +ve and -ve charges produce the internal contact potential V_b at the barrier. (Fig 2)

A PN device is knows as a diode. The diode and its symbol are in Fig 3. This type of construction permits the current to flow in one direction but not in the opposite direction.

Biasing the PN junction

Forward Bias : A forward-biased PN junction is in Fig 4 The positive terminal is connected to the P-side and the negative terminal of the DC supply is connected to the N-side of the junction.

Fig 2

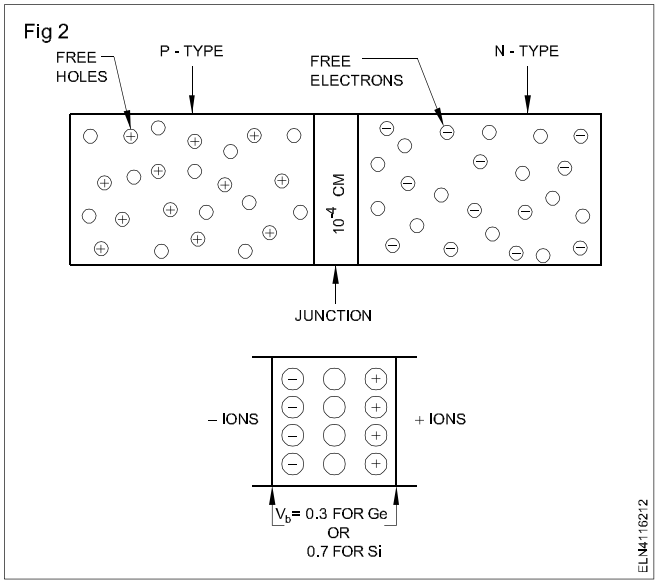
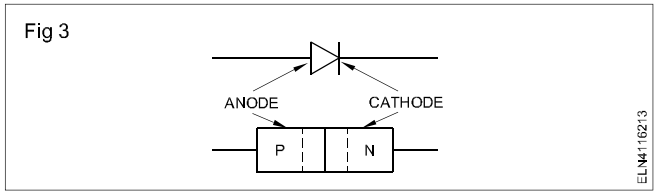


Fig 3



A current will flow through the diode as in the Fig 4. The positive terminal for the battery attracts electrons from P material, leaving an excess of holes. Because electrons are drifting away from the junction, the excess holes tend to accumulate near the junction. At the same instant, electrons from the negative terminal of the battery are attracted to the less negative N material of the diode. This action overcomes the barrier at the junction and allows the electrons to move into the excess holes of the P material, the result is a continuous flow of electrons in one direction. The voltage required to move the charge carries in forward bias conduction called the barrier voltage.

Reverse Bias: If the polarities of the DC supply are as shown in Fig 5, the PN junction is said to be reverse-biased. That is, the P side is connected to the negative and the N-side is connected to the positive terminals of the supply. Fig 5 shows the battery connection reversed (reverse bias). At the same instant, a shift in electrons in the P material causes the positive holes to appear further

away from the junction near the end for the diode, which is connected to the negative terminal of the battery. This action produces a wider barrier at the PN junction through which the electrons cannot flow. (A very small current leakage may however occur).

Fig 4

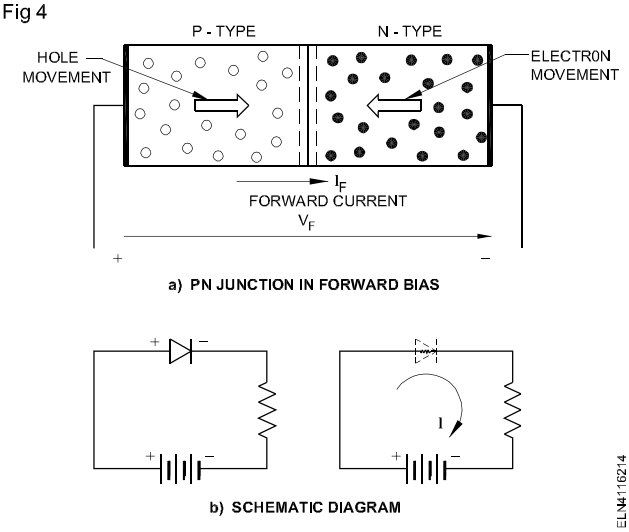
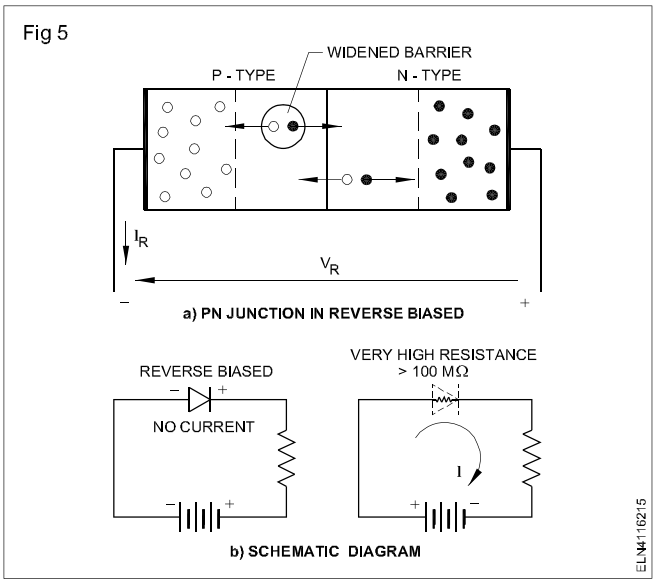
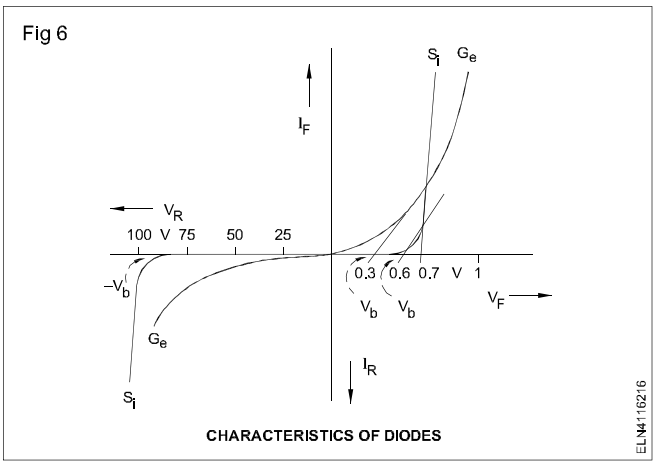


Fig 5



V-I characteristic of PN junction : The static current voltage characteristic is in Fig 6.

Fig 6



The current in the forward direction increases rapidly upon reaching the forward voltage V_b which is known as the barrier potential or the junction potential and the barrier potential for germanium is 0.3 V and for silicon it is 0.7 V.

The behaviour of the PN junction is limited by the maximum forward current, as too much of current may destroy a diode due to the excess heat generation.

The current in the reverse direction of the junction is very small. Upon reaching —V_b in the reverse direction, the reverse current suddenly increases. —V_b in the reverse direction where the current starts increasing is called the knee potential or breakdown voltage. Normally the diode should not be operated in this region. The knee voltage depends on the type of diode which varies from 3V to 20 kV or more.

Application of diodes : Semi conductor diodes are used for various applications. Some of the major areas of application are listed below.

- Modulation and demodulation in communication receivers.
- Switching high speed digital circuits
- Low power and high power rectification
- As surge protectors in EM relay and other circuits.
- For clipping, clamping wave-forms.

For different applications, diodes of different current carrying capacity, different PIV capacity and so on are required. Therefore, manufacturers make diodes to cater to varied applications with different specifications. Before using a diode for a particular application, it is a must to find out whether the voltage, current, and temperature characteristics of the given diode match the requirement or not.

Important specifications of a diodes

The material : The diode is made-of dopped semi-conductor material. This could be Silicon or Germanium or Selenium.This is important because the cut-in voltage depends upon the material the diode is made-of. For example, in Ge diodes the cut-in voltage is around 0.3V, whereas in Si diodes the cut-in voltage is around 0.7V.

Maximum safe reverse voltage : Denoted as V_R or V_r that can be applied across the diode. This is known as peak-inverse-voltage or PIV. If a higher reverse voltage than the rated PIV is applied across the diode, it will become defective permanently.

Maximum average forward current : I_f or I_F that a diode can allow to flow through it without getting damaged.

Forward voltage drop : V_F or V_f that appears across the diode when the maximum average current, I_f flows through it continuously

Maximum reverse current : I_{vr} that flows through the diode when the maximum reverse voltage, PIV is applied.

Maximum forward surge current : I_s that can flow through the diode for a defined short period of time.

The maximum junction temperature: The temperature upto which the diode junction can withstand without mal functioning or getting damaged.

Manufacturer's code of Diodes : The diodes are printed with a type number. When this type number is referred to in the manufacturer's manual, the detailed specifications for a particular type, number of the diode, can be obtained.

To bring standardization for the diodes and other components manufactured by different manufacturers. The Manufacturer and Standards Associations have set certain International Standards for the benefit of users of the components. The principal industry standard numbering systems are dealt with here.

1 **The JEDEC type code:** The EIA in USA maintains a register of 1N, 2N, types familiarly known as JEDEC types, which have world wide acceptance.

1N is used as a prefix for semiconductors with one junction. For example all 1N components refer to diodes because diodes have one junction. Similarly, prefix 2N is used with components with two junctions and so on.

2 **The PRO-ELECTION type code :** The Association International pro-electron in Europe maintains a register of Pro-electron type which have wide acceptance in Europe.

Components in the Pro-electron system have,

- two letter and numeral code for consumer devices (Example, BY127 and so on)
- three letter and numeral code for industrial devices. (Example, ACY17 and so on).

The first letter in the pro-electron type code indicates the type of semiconductor material used in making the device. Example, device numbers starting with A are made of germanium. Refer to diode data book for further details and examples.

The second and third letter indicate the applications of the component. Example, in the type code BY127, the second letter Y indicates that it is a rectifier diode.

The numeral after the second or third letter is the code number of its detailed voltage, current and temperature specification.

3 The JIS type code: In Japan, the JIS, (Japanese Industrial Standards) code is used. This system of component numbering is almost universal. In this system, all component numbers start with 2S, followed by a letter and several numbers. Example. 2SB364.

The letters after the S has the following significance:

A = pnp hf

B = pnp if

C = npn hf

D = npn if

Some components will have a type number which does not match with any of the above said International Standards. Then, these type numbers are particularly known to the individual manufacturer. These codes are generally referred to as manufacturer's house code. However, these type numbers may conform to one or more of the International Standards. Almost all standard diode data books lists popular manufacturers house codes.

Diode equivalent: There are several occasions, especially while servicing electronic circuits, it may not be possible to get a replacement for a diode of a particular type number. In such cases one can obtain a diode having specification closest to the one to be replaced. Such diodes are referred to as equivalents.

Example: In a circuit, diode 1N 4007 is found to be defective, and if 1N4007 is not available in stock, then instead of 1N4007, BY 127 can be used as it is the equivalent for 1N4007.

Some data books give these lists of equivalents.

Classification of Diode

1 Based on their current carrying capacity/power handling capacity, diodes can be classified as

- **low power diode**

  It can handle power of the order of several milliwatts only

- **medium power diode**

  It can handle power of the order of several watts only

- **high power diode**

  It can handle power of the order of several 100's of watts.

2 Based on their principal application, diodes can be classified as,

- **Signal diode**

  Low power diodes are used in communication circuits such as radio receivers etc. for signal detection and mixing

- **Switching diode**

  Low power diodes are used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits

- **Rectifier diode**

  Medium to high power is used in power supplies for electronic circuits for converting AC to DC voltage.

3. Based on the manufacturing techniques used, diodes can be classified as,

- **point contact diode**

  A metal needle is connected with pressure on to a small germanium (Ge) or silicon (Si)

- **Junction diode**

  They are made by alloying or growling or diffusing P and N materials on a semiconductor substrate.

Types of diode packaging : The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal can packaging. High power diodes will invariably have either metal can or ceramic packaging. High power diodes are generally of stud-mounting type.

Testing diodes using ohmmeter: A simple ohmmeter can be used to quickly test the condition of diodes. In this testing method, the resistance of the diode in forward and reverse bias condition is checked to confirm its condition.

Recall that there will be a battery inside an ohmmeter or a multimeter in the resistance range. This battery voltage comes in series with the leads of the meter terminals as in Fig 7.In Fig 7 the lead A is positive, lead B negative.

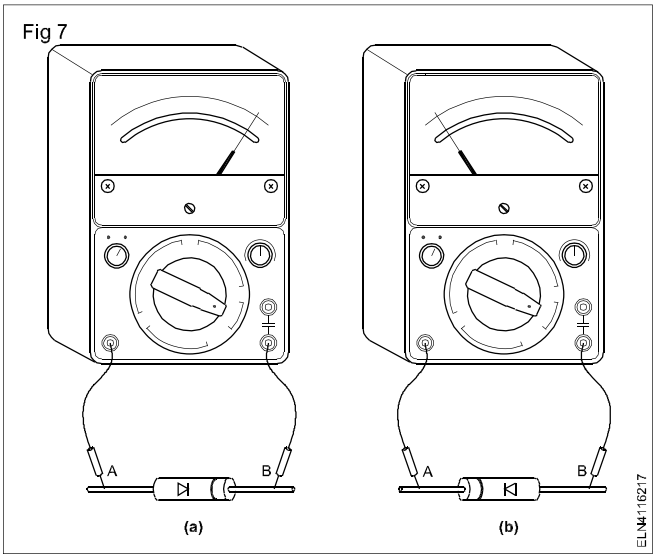
If the polarity of the meter leads are not known at first, the polarity of the meter leads can be determined by using a voltmeter across the ohm meter terminals.

If the positive lead of the ohmmeter, lead A in the Fig 7 is connected to the anode of a diode, and the negative (lead B) to the cathode, the diode will be forward-biased. Current will flow, and the meter will indicate low resistance.

On the other hand, if the meter leads are reversed, the diode will be reverse-biased. Very little current will flow because a good diode will have very high resistance when reverse biased, and the meter will indicate a very high resistance.

While doing the above test, if a diode shows a very low resistance in both the forward and reverse biased conditions,

Fig 7



then, the diode under test must have got damaged or more specifically shorted. On the other hand, a diode is said to be open if the meter shows very high resistance both in the forward and reverse biased conditions.

Polarity marking on the diodes: The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

Special diodes: All diodes are basically PN junction diodes and are made according to the application. There are many special purpose diodes are in use in which zener diodes widely used for voltage regulation.

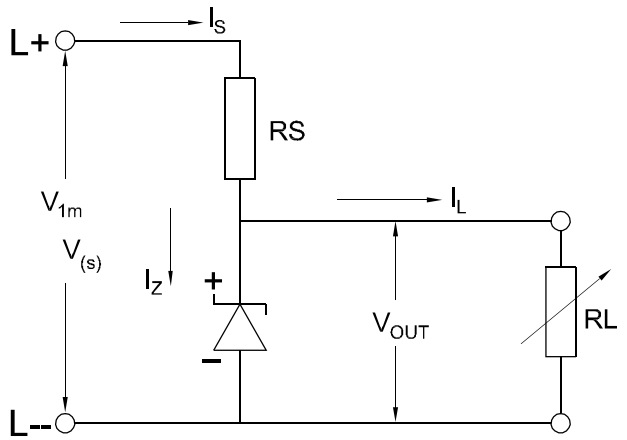
Zener diode: This diode specially designed for voltage regulation. A wide range of voltage regulated zener diodes are available.

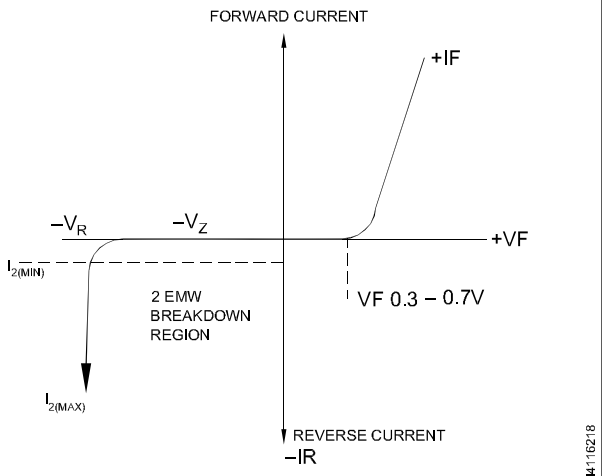
It is a PN junction diode doped heavily for regulation purpose. It has a normal VI characteristic when it is forward biased. But the characteristic are changed abruptly when it is connected in reverse bias.

In the reverse bias condition a leakage current in the order of Microamps will flow. When the reverse voltage reaches to a particular designed voltage a sudden breakdown known as avalanche breakdown happens.

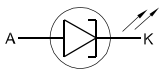
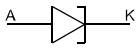
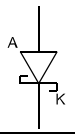
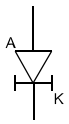
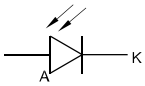
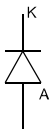
When a heavy current flows at constant voltage, the voltage continue to remain constant. Further increase in voltage, the current suddenly increases. Fig 8 shows the reverse characterises of zener diode.

Fig 8





Few more special diodes listed below in Table 1

Sl.No	Name	Purpose	Symbol
1	LED	Light emitting diode - exhibits light in conduction	
2	TUNEL or ESAKI	Un effected by change in temperature	
3	SCHOTTKY	Fast switching	
4	VARICAP	Varactor -Variable capacitance diode or tuning diode	
5	SCHOKLEY	Constant current diode	
6	PHOTO DIODE	Light dependent diode	
7	IMPATT DIODE	Heavily doped PN layers	
8	PIN DIODE	Low capacitance switching