Junction Field Effect Transistor (JFET)

A JFET is a three terminal semiconductor device in which current conduction is by one type of carrier i.e. electrons or holes. The current conduction is controlled by means of an electric field between the gate and the conducting channel of the device.

Construction Details:

A JFET consists of a p-type or n-type silicon bar containing two PN junctions at the sides as shown in figure.

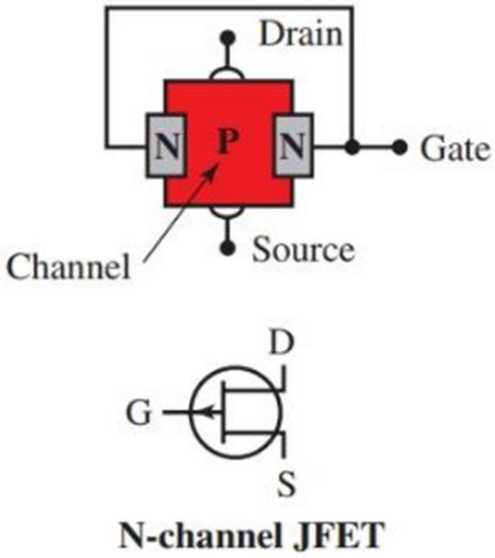


Fig.1(i)

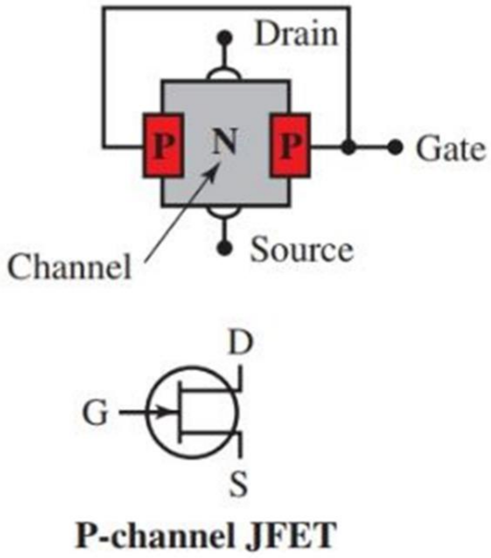


Fig.1 (ii)

The bar forms the conducting channel for the charge carriers.

If the bar is of p-type, it is called p-channel JFET as shown in fig.1(i) and if the bar is of n-type, it is called n-channel JFET as shown in fig.1(ii). The two PN junctions forming diodes are connected internally and a common terminal called gate is taken out. Other terminals are source and drain taken out from the bar as shown in fig.1. Thus a JFET has three terminals such as , gate (G), source (S) and drain (D).

Working of Junction Field Effect Transistor:

- The JFET always works in reverse biasing condition, that is why they have a very high input impedance.
- In the case of the Junction Field Effect Transistor, the gate current is Zero which is denoted by; $I_G=0$
- The input voltage which is represented by V_{GS} is the controlling factor for the output current which is represented by I_D.

Zero Biasing Condition of JFET

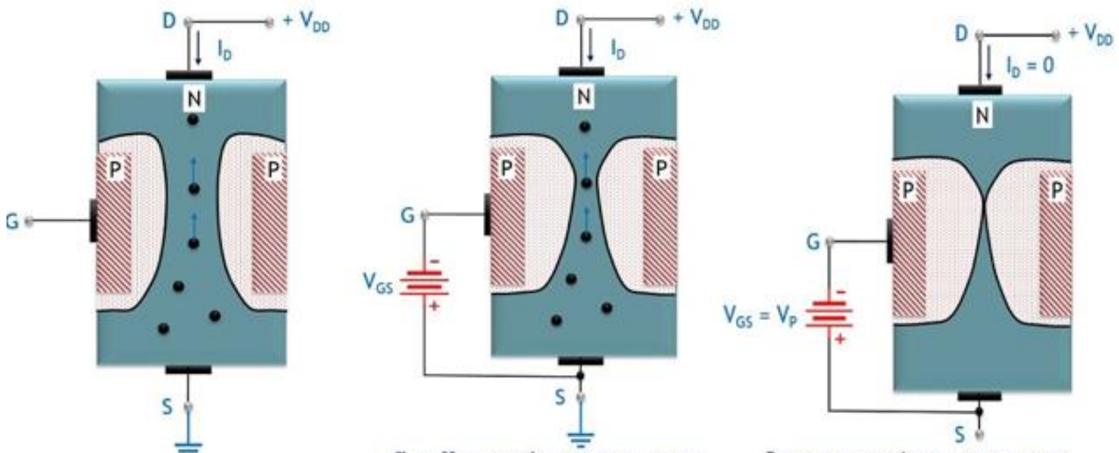
- When no external voltage V_{GS} is applied to the gate the resulting voltage to the drain would be zero which can be written as $V_{GS} = V_{DS} = 0$
- The depletion regions would have the same thickness as they had earlier because the voltage is not being applied yet.
- In this zero biased condition the drain current is produced, The charge carriers in the absence of a potential difference start moving from the source to drain producing a drain current.

Small Reverse Voltage of JFET

- In the presence of a potential or small voltage the gate-source voltage V_{GS} on which the Drain current I_D is dependent, on applying small reverse potential width of the depletion region increases.
- Due to the increase in the width of depletion regions on both sides, the channel finds it difficult to conduct current.
- This difficulty of the channel to conduct current results in voltage drop.
- The width of the depletion region increases more towards the drain terminal and the depletion region increases more towards the drain because the voltage drop is higher at the drain side.
- There is a lesser amount of Drain current I_D because of the shrinkage of the conduction channel.

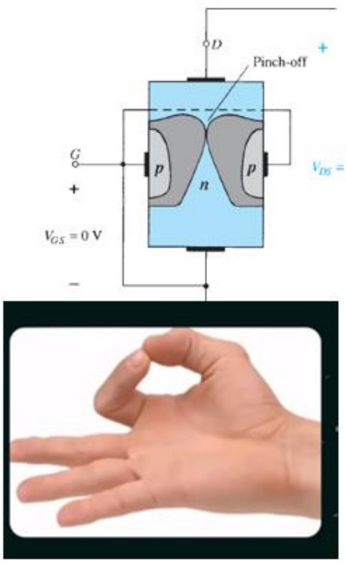
Large reverse voltage of JFET:

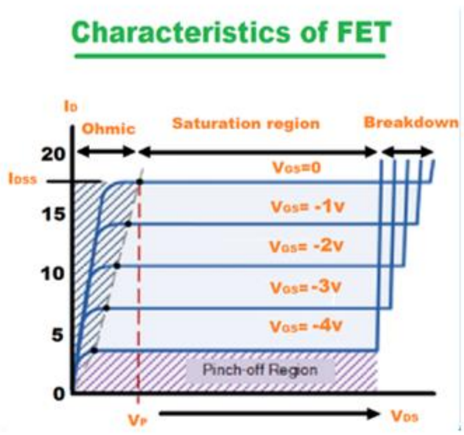
- In this case we apply a higher negative voltage which is our Gate to Source voltage, represented by V_{GS}.
- The depletion regions of both the corresponding PN Junctions, keep on increasing in width.
- Eventually, both the depletion regions meet each other or you can say touch each other.
- The point at which the particular voltage blocks the conduction channel completely is called the cut-off voltage or sometimes pinch-off.



Unbiased condition of JFET | Small negative gate source bias condition of JFET | Large negative gate source bias condition of JFET

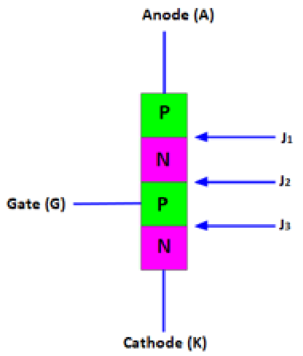
Pinch off Voltage and Characteristics



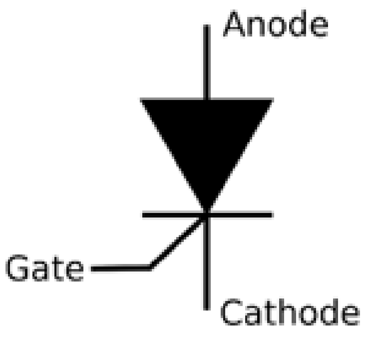


Silicon Controlled Rectifier (SCR)

- A SCR is a 3 terminal and four layer semiconductor current controlling device.
- It is mainly used in the devices for the control of high power.
- SCR is also sometimes referred to as SCR diode, 4-layer diode, 4-layer device, or Thyristor.
- It is made up of a silicon material which controls high power and converts high AC current into DC current (rectification).



SCR Structure



SCR Symbol

Modes of Operation in SCR:

There are three modes of operation for a SCR, depending upon the biasing given to it.

1) Forward Blocking Mode (Off State)

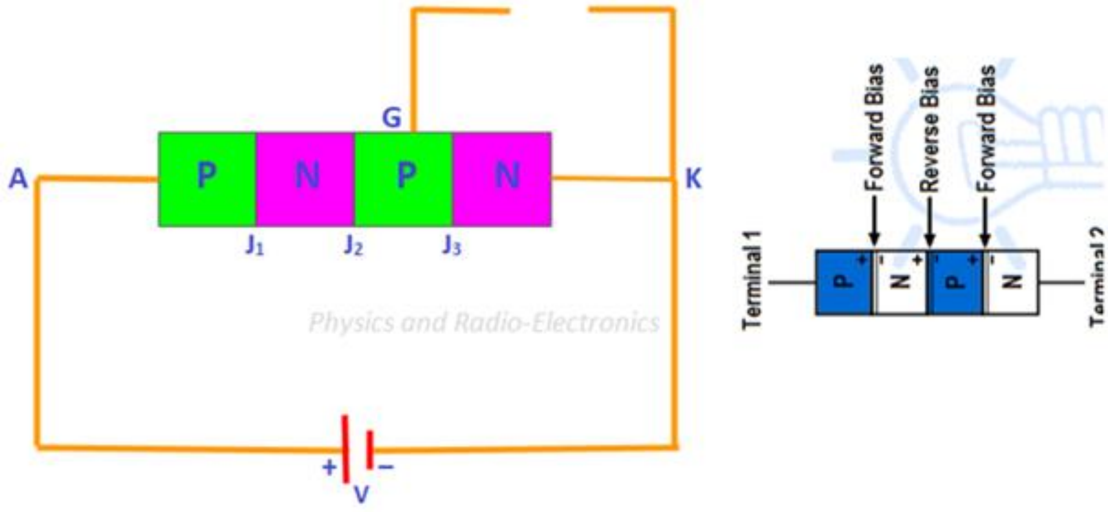
2) Forward Conducting Mode (On State)

3) Reverse Blocking Mode (Off State)

Forward Blocking Mode (Off State)

In this mode of operation, the SCR is connected such that the anode terminal is made positive with respect to cathode while the gate terminal kept open. In this state J1 and J3 are forward biased and the junction J2 reverse biased.

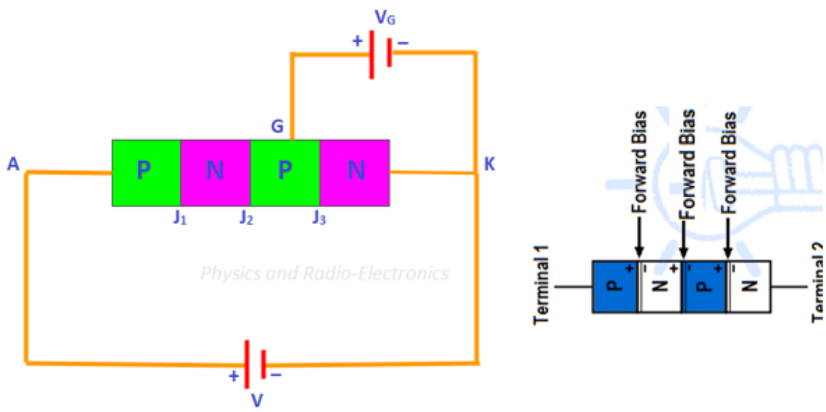
Due to this, a small leakage current flows through the SCR. Until the voltage applied across the SCR is more than the break over voltage of it, SCR offers a very high resistance to the current flow. Therefore, the SCR acts as a open switch in this mode by blocking forward current flowing through the SCR.



Forward Blocking Mode of SCR

Forward Conduction Mode

In this mode, SCR or thyristor comes into the conduction mode from blocking mode. It can be done in two ways as either by applying positive pulse to gate terminal or by increasing the forward voltage (or voltage across the anode and cathode) beyond the break over voltage of the SCR. Once any one of these methods is applied, the avalanche breakdown occurs at junction J2. Therefore the SCR turns into conduction mode and acts as a closed switch thereby current starts flowing through it.



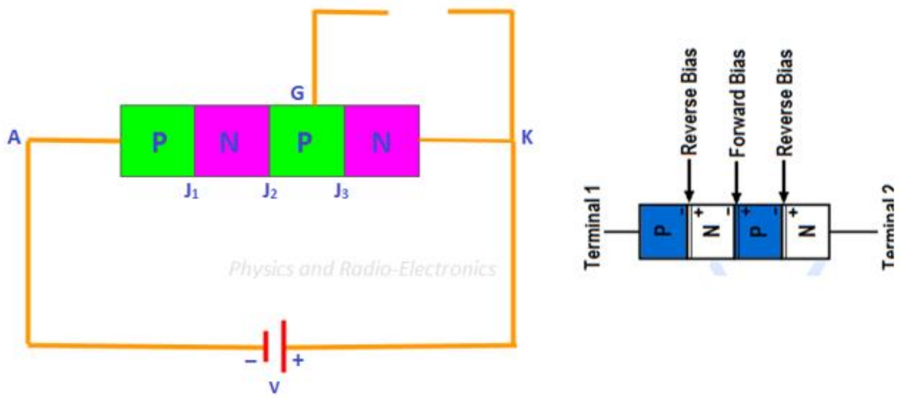
Forward Conducting Mode of SCR

Reverse Blocking Mode

In this mode of operation, cathode is made positive with respect to anode. Then the junctions J1 and J3 are reverse biased and J2 is forward biased. This reverse voltage drives the SCR into reverse blocking region results to flow a small leakage current through it and acts as an open switch as shown in figure.

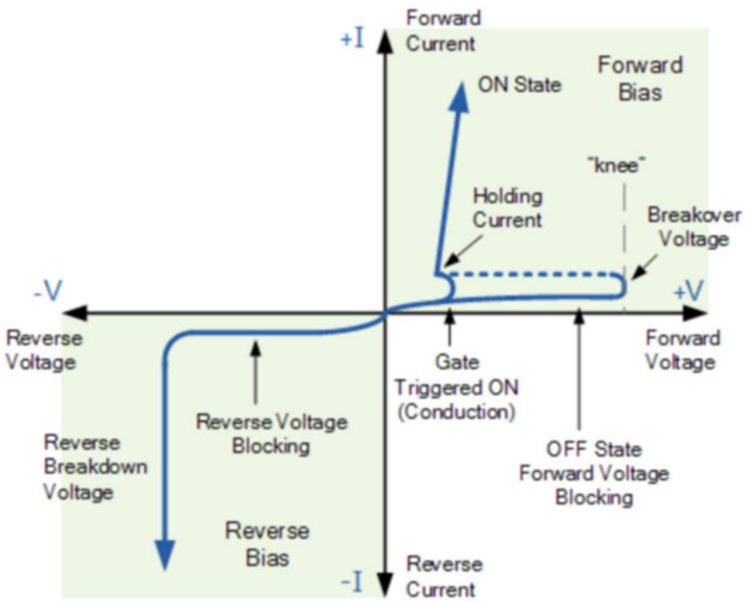
So, the device offers a high impedance in this mode until the voltage applied is less than the reverse breakdown voltage of the SCR. If the reverse applied voltage is increased beyond the VBR, then avalanche breakdown occurs at junctions J1 and J3 which results to increase reverse current flow through the SCR.

This reverse current causes more losses in the SCR and even to increase the heat of it. So there will be a considerable damage to the SCR when the reverse voltage applied more than breakdown voltage.



Reverse Blocking Mode of SCR

Characteristics of SCR:

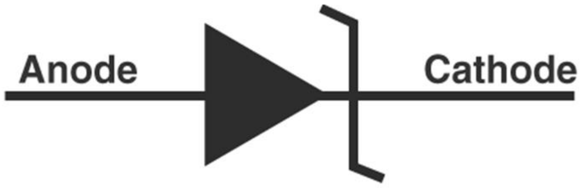


Zener Diode:

A Zener diode is a type of PN junction diode that is designed to conduct in both forward and reverse directions. It has heavily doped regions and is mainly used to conduct current in the reverse direction.

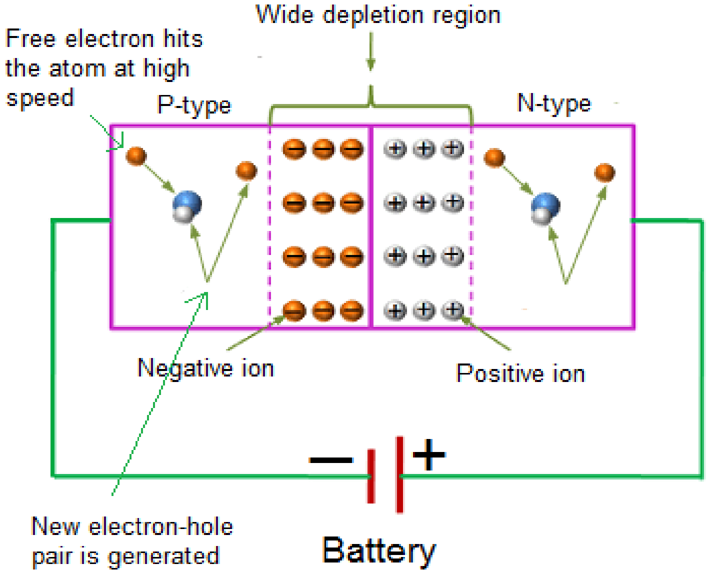
It starts conducting in the reverse direction when the reverse voltage exceeds a certain limit known as the reverse breakdown or Zener breakdown voltage.

Unlike an ordinary diode, a Zener diode can and specially designed to operate in the reverse breakdown region. The voltage across the device remains constant during the breakdown region while the current varies.



Zener diodes are the basic building blocks of electronic circuits. They are widely used in all kinds of electronic equipments. Zener diodes are mainly used to protect electronic circuits from over voltage.

Breakdown in zener diode : There are two types of reverse breakdown regions in a zener diode: avalanche breakdown and zener breakdown.

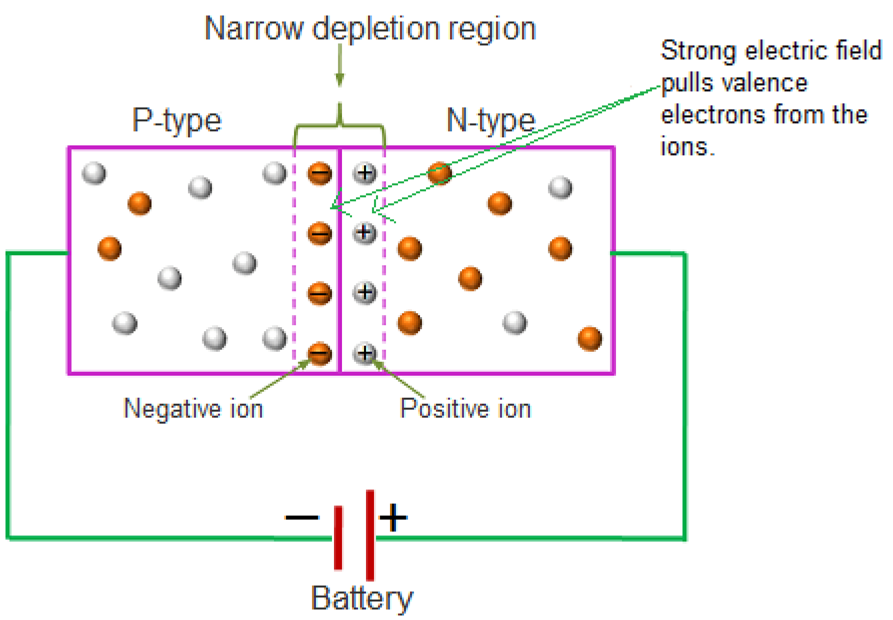


Avalanche breakdown : The avalanche breakdown occurs in both normal diodes and zener diodes at high reverse voltage. When high reverse voltage is applied to the p-n junction diode, the free electrons (minority carriers) gains large amount of energy and accelerated to greater velocities.

The free electrons moving at high speed will collides with the atoms and knock off more electrons. These electrons are again accelerated and collide with other atoms. Because of this continuous collision with the atoms, a large number of free electrons are generated. As a result, electric current in the diode increases rapidly. This sudden increase in electric current may permanently destroys the normal diode. However, avalanche diodes may not be destroyed because they are carefully designed to operate in avalanche breakdown region. Avalanche breakdown occurs in zener diodes with zener voltage (V_z) greater than 6V.

Zener breakdown

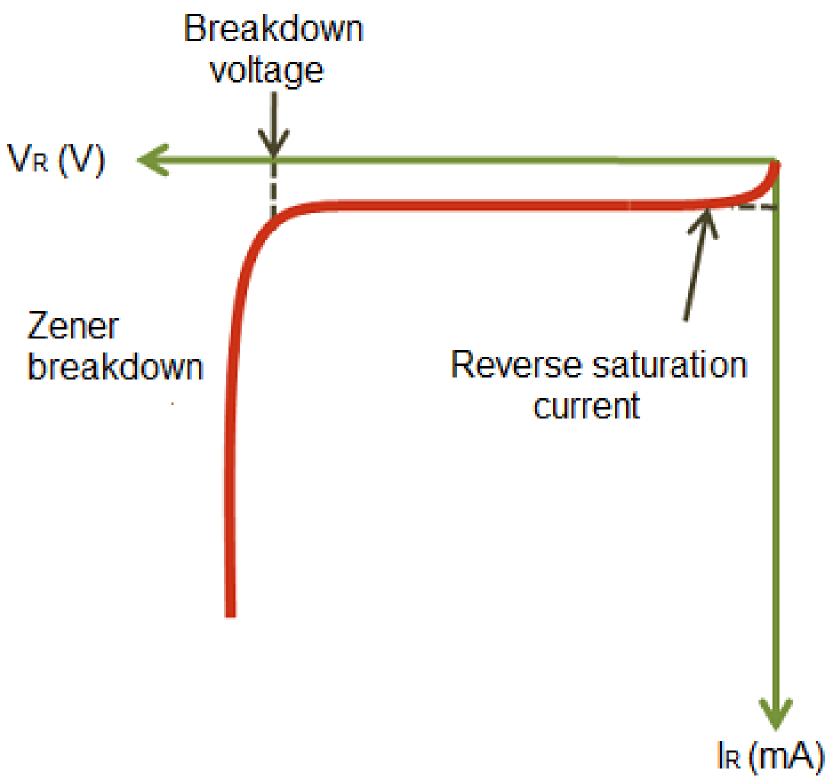
The zener breakdown occurs in heavily doped p-n junction diodes because of their narrow depletion region. When reverse biased voltage applied to the diode is increased, the narrow depletion region generates strong electric field.



When reverse biased voltage applied to the diode reaches close to zener voltage, the electric field in the depletion region is strong enough to pull electrons from their valence band. The valence electrons which gains sufficient energy from the strong electric field of depletion region will breaks bonding with the parent atom. The valance electrons which break bonding with parent atom will become free electrons. This free electrons carry electric current from one place to another place. At zener breakdown region, a small increase in voltage will rapidly increases the electric current.

VI characteristics of zener diode

The VI characteristics of a zener diode is shown in the below figure. When forward biased voltage is applied to the zener diode, it works like a normal diode. However, when reverse biased voltage is applied to the zener diode, it works in different manner.



When reverse biased voltage is applied to a zener diode, it allows only a small amount of leakage current until the voltage is less than zener voltage. When reverse biased voltage applied to the zener diode reaches zener voltage, it starts allowing large amount of electric current. At this point, a small increase in reverse voltage will rapidly increases the electric current. Because of this sudden rise in electric current, breakdown occurs called zener breakdown. However, zener diode exhibits a controlled breakdown that does damage the device.