CLASSIFICATION OF MATERIALS

Materials can be classified based on its conductivity property as

1.Conductor : material through which electric current can pass.

2.Semiconductor

3.Insulator :A material that does not easily transmit energy like electric Current

SEMICONDUCTOR

- Are the materials that partially conduct and partially does not conduct.
- Silicon and Germanium are best examples.
- Electronic devices like p-n diode, zener diode bipolar junction transistor.
- Classification of semiconductors

1. intrinsic semiconductor

2.extrinsic semiconductor

INTRINSIC SEMICONDUCTOR

- They are semi-conducting materials which are pure and no impurity atoms are added to it. Eg: germanium and silicon.
- Properties:

  1. number of electrons is equal to the number of holes. i.e., ne=nh.
  2. electrical conductivity is low.
  3. electrical conductivity of intrinsic semiconductors depends on their temperatures.

EXTRINSIC SEMICONDUCTORS

- Extrinsic semiconductor can be formed by adding impurity to intrinsic semiconductor.
- Properties:

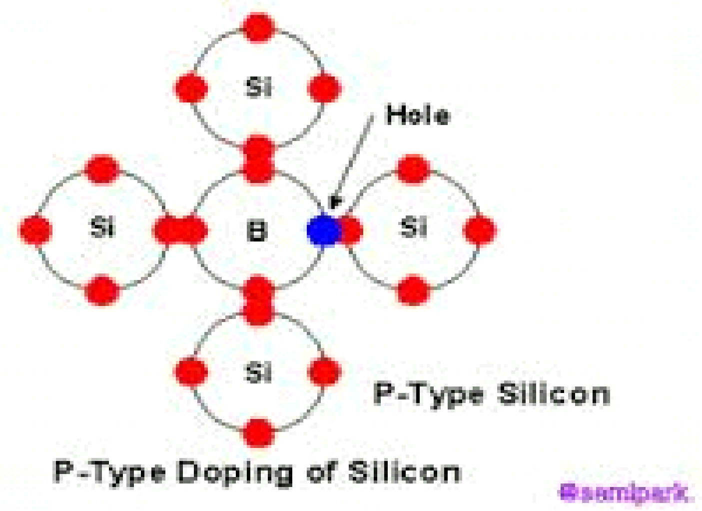
  1. the number of electrons is not equal to the number of holes. i.e., ne is not equal to nh.
  2. The electrical conductivity is high.

3. The electrical conductivity depends on the temperature and the amount of impurity added in them.

Extrinsic semiconductors

Pentavalent (n-type) Trivalent (p-type)

TRIVALENT(p-type)



- When a intrinsic semiconductor is added with Trivalent impurity it becomes a P-Type semiconductors.
- The P stands for Positive, which means the semiconductor is rich in holes or Positive charged ions.
- The total positive charge in a semiconductor is the sum of number of holes and number of donor atoms.

P+Nd------(1)

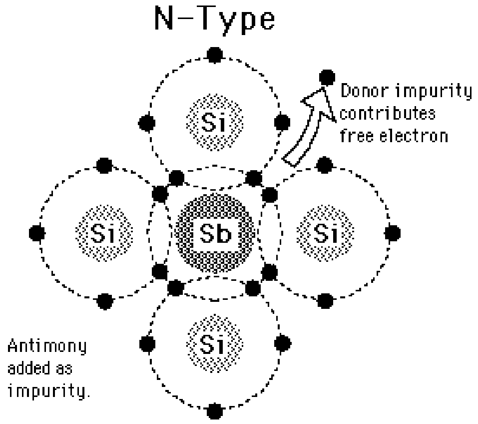
- The total negative charge in a semiconductor is the sum of number of electrons and number of acceptor atoms.

n+Na ------(2)

- At thermal equilibrium, total number of positive charge is equal to negative charge in a semiconductor i.e (1) = (2)

P+Nd= n+Na

N- Type



Formed when a pentavalent impurity is added to intrinsic material.

N-type semiconductors have Negative charged ions or in other words have excess electrons.

Number of free electrons are greater than holes in the n- type semiconductor.

MASS ACTION LAW:

it states that at thermal equilibrium the product of the free electron concentration and the free hole concentration is equal to a constant irrespective of the number of donor atoms or number of acceptor atoms present in the semiconductor.

$$N*p=ni^2$$

(i) n – type

$p+Nd = n + Na$

(a) n> p neglecting p

$Nd=n+Na$

(b) Na=0

$n_n = Nd$

$n_n * p_n = ni^2$

$$p_n = \frac{ni^2}{n_n} = \frac{ni^2}{N_D}$$

(ii) p-type

$$p + N_D = n + N_A$$

Case (i)

- In p-type the number of holes are greater thsn number of electrons so, ‘n’ is neglected

$$p + N_D = N_A$$

Case (ii)

In p-type semiconductor there are no donor atoms hence N_D is neglected

$$p = N_A$$

According to mass action law

$N*p=ni^2$

$$p_n = \frac{ni^2}{n_n} = \frac{ni^2}{N_D}$$

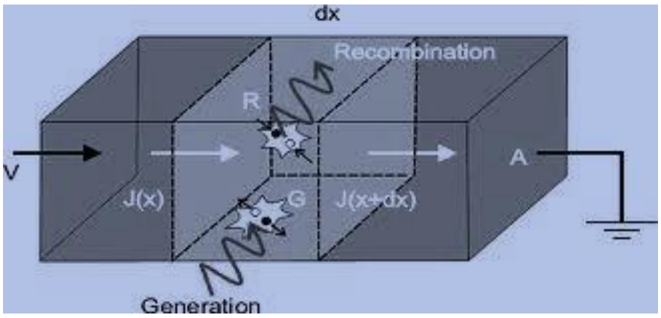
CHARGE DENSITY

- The charge density ρ (C/ m3) in a conductor is defined as the free charge per unit volume.
- The charge density in a metal is related to the density of free electrons, let n be the number of electrons per m^3 , the charge per electron is −q then the free charge per unit volume in the metal is given by

$$\rho = -nq$$

CONTINUITY EQUATION

The continuity equation describes the distribution of electrons and holes with time when they are injected into a semiconductor, there is excess carrier generation recombination and carrier movement. considering the flow of carriers in one-dimension



The above figure is a semiconductor material of cross-sectional area A thickness *dx* at *x.* V is the potential difference across the ends, the total number of electrons within this region at any time is the algebraic sum of the number of electrons flowing into the slice; the number of electrons flowing out of the slice; the number of electrons generated within the volume of the slice by and the number of electron-hole pairs removed by recombination within the volume of the slice. In mathematical terms,

$$\frac{\partial n}{\partial t}Adx = \left|\frac{Jn(x)A}{-q} - \frac{Jn(x+dx)A}{-q}\right| + (G\text{n}-Rn)Adx \qquad (1)$$

To obtain the current relation , taylor series expansion of $Jn(x+dx)A$

$$Jn(x+dx)A = Jn(x) + \frac{\partial Jn}{\partial x}dx + \cdots \qquad (2)$$

To obtain the equation for electrons (2) is sub in (1)

$$\frac{\partial n}{\partial t} = \frac{1}{q}\frac{\partial Jn}{\partial x}dx + (G\text{n}-Rn) \qquad (3)$$

Equation for holes is given by putting negative sign for holes which means generation of carriers

$$\frac{\partial n}{\partial t} = -\frac{1}{q}\frac{\partial Jp}{\partial x}dx + (Gp - Rp) \qquad (4)$$

R_p is the excess number of number of electrons in the excited state and □ n is the *recombination lifetime* , of the order picoseconds. The total current is given by the sum of the drift current and the diffusion current. For electrons:

$$J_n = qJ\mu_n nE + qD_n\frac{d_n}{dx} \qquad (5)$$

$$J_p = qJ\mu_p pE + qD_p\frac{d_p}{dx} \qquad (6)$$

Generation of electron-hole pairs is governed by the absorption. The final term allows for recombination. The continuity equations

$$\frac{\partial n_e}{\partial t} = n\mu_n \frac{\partial E}{dx} + \mu_n E \frac{\partial n}{dx} + D_n \frac{\partial^2 n}{dx^2} + G_n - \frac{n_e}{\tau_n} \qquad (5b)$$

$$\frac{\partial n_p}{\partial t} = n\mu_p \frac{\partial E}{dx} + \mu_p E \frac{\partial p}{dx} + D_p \frac{\partial^2 p}{dx^2} + G_p - \frac{p_e}{\tau_p} \qquad (6b)$$

Drift and Diffusion Current

The total current that flows through a semiconductor has two components

1. Drift Current : is the flow due to the applied voltage across P-N junction. Due to the diffusion of charge carriers. The diffusion current which flows from p – n region is balanced by opposite and equal drift current. The drift current is temperature dependent as the minority carriers are generated thermally. When an electric field is applied across the semiconductor material, the charge carriers attain a certain drift velocity . This combined effect of movement of the charge carriers constitutes a current known as "drift current". Drift current density due to the charge carriers such as free electrons and holes is the current passing through a square centimeter area perpendicular to the direction of flow.

Drift current density J_n , due to free electrons is given by

$$J_n = q\, n\, \mu_n\, E \text{ A / cm}^2$$

Drift current density J_P, due to holes is given by

$$J_P = q\, p\, \mu_p\, E \text{ A / cm}^2$$

Where, n - Number of free electrons per cubic centimeter.

P - Number of holes per cubic centimeter

μ_n – Mobility of electrons in cm^2 / Vs

μ_p – Mobility of holes in cm^2 / Vs

E – Applied Electric filed Intensity in V /cm

q – Charge of an electron = 1.6 x 10^{-19} coulomb.

DIFFUSION CURRENT

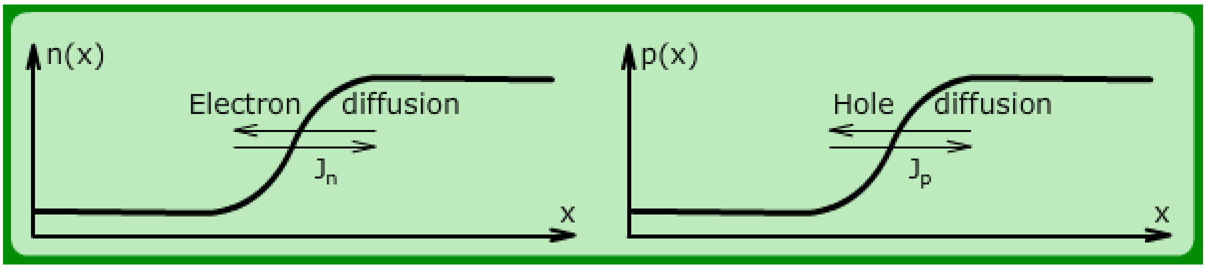
It is the process when a carrier concentration gradient exists in the semiconductor, through random motion, carriers will have a net movement from areas of high carrier concentration to areas of low concentration. This diffusion is dependent on time until hole- electron concentration is uniform without an external force being applied to the device. One-dimensional diffusion equations for electrons (n) and holes (p) can be written as follows:

$$J_{n\,diff} = qD_n \frac{dn_x}{d_x}$$

$$J_{p\,diff} = -qD_p \frac{dp_x}{d_x}$$

where:

J_n and J_p = the diffusion current densities
q = electron charge
D_n and D_p = diffusion coefficients for electrons and holes
n and p = electron and hole concentrations

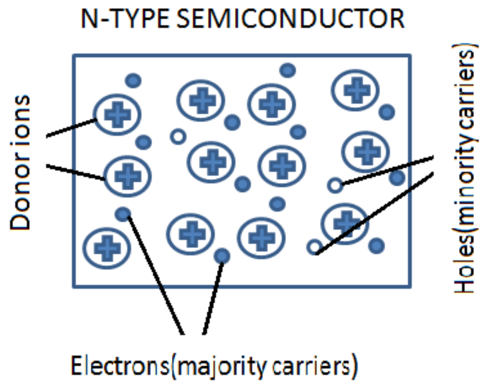


Diffusion currents due to carrier concentration gradient

PN JUNCTION THEORY

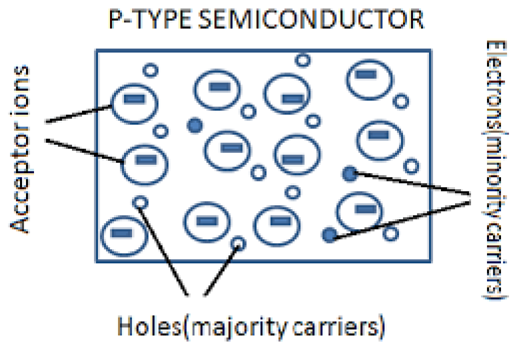
N- Type

In this type of semiconductor majority carriers are electrons and minority carriers are holes. N - type semiconductor is formed by adding pentavalent (five valence electrons) impurity in pure semiconductor crystal, e.g. P. As, Sb.



P-Type

In this type of semiconductor majority carriers are holes and minority carriers are electrons. P- type semiconductor is formed by adding trivalent (three valence electrons) impurity in pure semiconductor crystal, e.g. B, Al Ba.



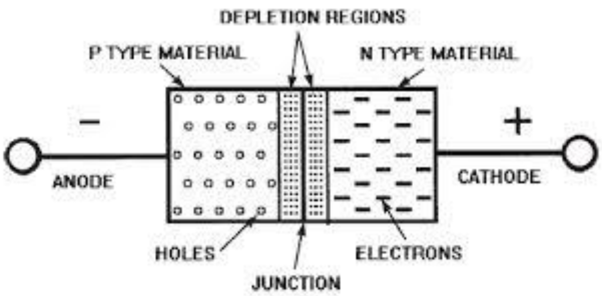
When these two semiconductors are fused then we obtain PN junction diode, when first joined together very large density gradient exists between both sides of the PN junction. Hence some of the free electrons from the donor impurity atoms begin to migrate across this newly formed junction to fill up the holes in the P-type material producing negative ions.

Due to the electrons crossing across the junction they leave behind positively charged donor ions (ND) on the negative side and now the holes from the acceptor impurity migrate across the junction in the opposite direction into the region where there are large numbers of free electrons.

As a result, the charge density of the P-type along the junction is filled with negatively charged acceptor ions (NA), and the charge density of the N-type along the junction becomes positive. This charge transfer of electrons and holes across the PN junction is known as diffusion. The width of these P and N layers depends on how heavily each side is doped with acceptor density NA, and donor density ND, respectively.

This process continues back and forth until the number of electrons which have crossed the junction have a large enough electrical charge to repel or prevent any more charge carriers from crossing over the junction. Eventually a state of equilibrium will occur producing a “potential barrier” zone around the area of the junction as the donor atoms repel the holes and the acceptor atoms repel the electrons.

Since no free charge carriers can rest in a position where there is a potential barrier, the regions on either sides of the junction now become completely depleted of any more free carriers in comparison to the N and P type materials further away from the junction. This area around the **PN Junction** is now called the Depletion Layer.



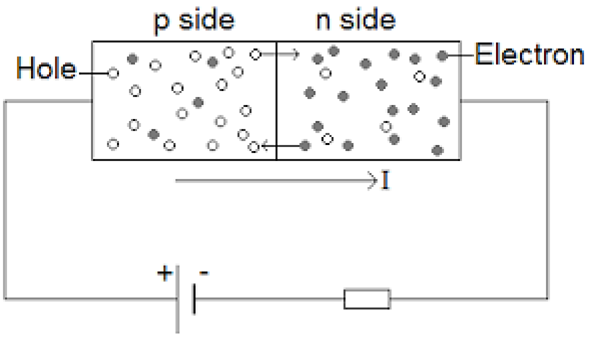
FORWARD BIASED OPERATION

When external voltage is applied then the potential difference is altered between the P and N regions. Positive terminal of the source is connected to the P side and the negative terminal is connected to N side then the junction diode is said to be connected in forward bias condition.

This lowers the potential across the junction. The majority charge carriers in N and P regions are attracted towards the PN junction and the width of the depletion layer decreases with diffusion of the majority charge carriers.

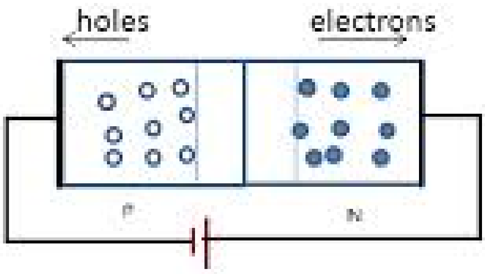
The external biasing causes a departure from the state of equilibrium and a misalignment of Fermi levels in the P and N regions, and also in the depletion layer.

The presence of two different Fermi levels in the depletion layer represents a state of quasi-equilibrium. The amount of charge Q stored in the diode is proportional to the current I flowing in the diode. With the increase in forward bias greater than the built in potential, at a particular value the depletion region becomes very much thinner so that a large number of majority charge carriers can cross the PN junction and conducts an electric current. The current flowing up to built in potential is called as ZERO current or KNEE current.

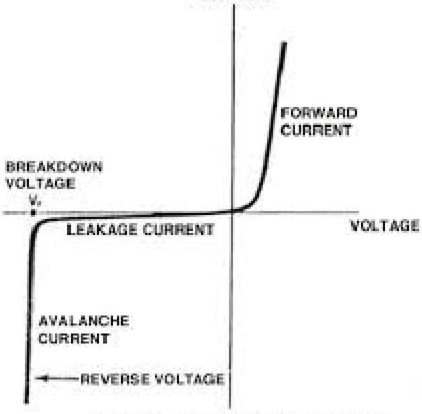


Reverse Bias Operation

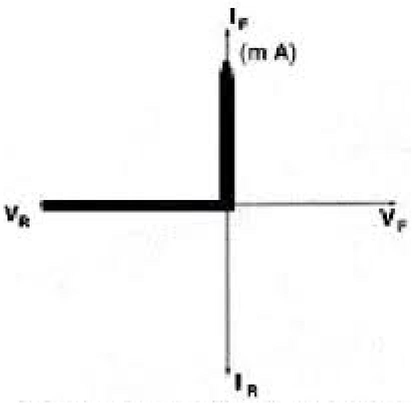
Positive terminal of the source is connected to the N side and the negative terminal is connected to P side. Here majority charge carriers are attracted away from the depletion layer by their respective battery terminals connected to PN junction. The Fermi level on N side is lower than the Fermi level on P side. Positive terminal attracts the electrons away from the junction in N side and negative terminal attracts the holes away from the junction in P side. As a result of it, the width of the potential barrier increases that impedes the flow of majority carriers in N side and P side. The width of the free space charge layer increases, thereby electric field at the PN junction increases and the PN junction diode acts as a resistor. The current that flows in a PN junction diode is the small leakage current, due to minority carriers generated at the depletion layer or minority carriers which drift across the PN junction. The growth in the width of the depletion layer presents a high impedance path which acts as an insulator.



VI characteristics of PN Diode



VI characteristics of diode



VI Characteristics of ideal diode

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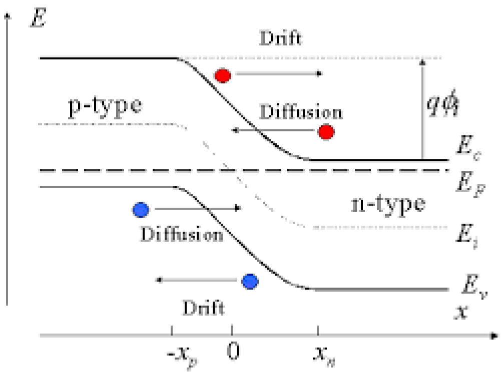
ENERGY BAND STRUCTURE OF OPEN CIRCUITED PN JUNCTION



When the N and P-regions are brought into contact, the electrons would flow from regions of higher Fermi-energy to regions of lower Fermi energy and holes would flow in the opposite direction.

Because of loss of electrons, the N-region would acquire a net positive charge due to the uncovered positively charged donor atoms and P-region would acquire a negative charge due to uncovered negatively charged acceptor atoms.

At equilibrium there is no net flow of either electrons or holes so that the PN junction has a single constant Fermi level.

The transfer of charges will affect only the regions close to the junction so that regions which are far still have the same energy band diagram(i.e. same relative positions of conduction and valence band with respect to Fermi energy)

As we approach the junction from the N-side, the conduction band must bend upwards away from the Fermi energy to indicate the fact that the region is progressively getting depleted of electrons.

The energy band diagram of PN junction is shown above . where the Fermi level Ef is closer to the conduction band edge Ecn in the N-type material while it closer to the valence edge Evp in the P- type material . the conduction band edge Ecp in the P-type material is higher than the conduction band edge in the N-type material.

Similarly the valence band edge Evp in the p type material is higher than valence band edge Evn in the n- tpe material.

E1 and E2 indicate the shifts in the Fermi level from the intrinsic conditions in the P and N materials Respectively . then the total shift in the energy level E0 is given by

$$E_o = E_1 + E_1 = E_{cp} - E_{cn} = E_{vp} - E_{vn}$$

E_0 $-$ is the potential energy of electrons at PN junction $= qV_0$

V_o- contact potential in volts or contact difference of potential or the barrier potential.

Contact Difference of Potential A contact difference of potential exists across an open circuited PN junction.

$$E_f - E_{vp} = \frac{1}{2} E_G - E_1 \qquad (1)$$

$$E_{cn} - E_f = \frac{1}{2} E_G - E_2 \qquad (2)$$

Combining (1) and (2)

$$E_o = E_1 + E_1 = E_G - (E_{cn} - E_F) - (E_F - E_{vp}) \qquad (3)$$

We know

$$np = N_V N_C \, e^{-\frac{E_G}{KT}} \qquad \text{and}$$

$$np = ni^2$$

From the above equation we get

$$E_G = KT \ln \frac{N_C N_V}{ni^2} \qquad (4)$$

We know for N- Type material $E_f = E_c$- $KT \ln \frac{N_C}{N_D}$ therefore from this equation we get

$$E_{cn} - E_f = KT \ln \frac{N_c}{n_n} = KT \ln \frac{N_C}{N_D} \qquad (5)$$

Similarly for P- Type material $E_f = E_c + KT \ln \frac{N_V}{N_A}$ from this equation we get

$$E_f - E_{vp} = KT \ln \frac{N_V}{p_p} = KT \ln \frac{N_V}{N_A} \qquad (6)$$

Sub eq (4) (5) (6) in (3) we get

$$E_o = KT\left[\ln\frac{N_C N_v}{ni^2} - \ln\frac{N_C}{N_D} - \ln\frac{N_V}{N_A}\right]$$

$$= KT\ln\left[\frac{N_C N_v}{ni^2} * \frac{N_C}{N_D} - \frac{N_V}{N_A}\right]$$

$$= KT\ln\frac{N_D N_A}{ni^2} \qquad (7)$$

As $E_o = qV_o$ then the contact difference in the potential barrier is given as

$$V_o = \frac{KT}{q}\ln\frac{N_D N_A}{ni^2}$$

Eo depends up on the equilibrium concentration an alternate equation can be obtained for Eo by

$n_n \approx N_D, p_n = \frac{ni^2}{N_D}, n_n p_p = ni^2, p_p \approx N_A$ and $n_p = \frac{ni^2}{N_A}$ in to eqn (7) then we get

$$E_o = KT\ln\frac{pp_o}{pn_o} = KT\ln\frac{nn_o}{np_o}$$

Where subscript 0 represents the thermal equilibrium condition.

JUNCTION CAPACITANCE

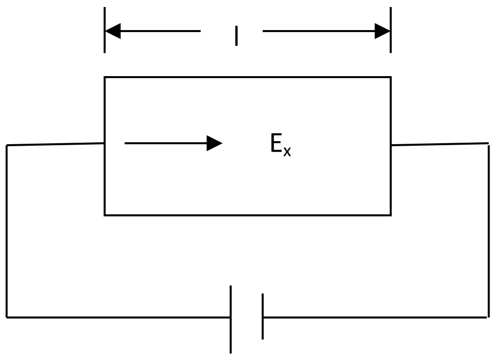
Junction Capacitance Since we have a separation of positive and negative charges in the depletion region, a capacitance is associated with the pn junction. The junction capacitance is given as

$$C' = \frac{dQ'}{dVr} = eN_d\frac{dx_n}{dVr}$$

Junction capacitance is also called as depletion layer capacitance.

MOBILITY AND CONDUCTIVITY

Mobility and conductivity in semiconductor



The ability of an electron to drift under the influence of electric field is called Mobility.

Mobility is the average particle drift velocity per unit electric field

$$\mu_n = -\frac{v_x}{E_x}$$

$$E_x = -\frac{v}{l}$$

The mobility of an intrinsic semiconductor varies as T^{-m} over a temperature range (T) of 100 to 400K. for Si the value of m is 2.5 for electrons and 2.7 for holes. Likewise for Ge m is 1.66 for electrons and 2.33 for holes. The mobility of an intrinsic semiconductor decreases with increase in temperature because of higher temperatures, the number of carriers is more and they are more energetic also. This causes an increase in number of collisions with the atoms and thus mobility decreases.

CONDUCTIVITY

IF an electric field is applied to a metal then due to the electrostatic force, the electrons would be accelerated and the velocity would increase indefinitely if there would have been no collision with the ions. However at each collision with ion the electron loses some energy.

Force experience by electrons due to applied electric field is given by

$$F = q.E$$

Acceleration is given by

$$a = \frac{Force}{mass} = \frac{F}{m} = \frac{q.E}{m}$$

Drift velocity is given by

$$v = a.t = \frac{q.E}{m}.t = \mu.E$$

Consider N number of free electrons distributed uniformly throughout a conductor oflength L and cross sectional area A. the number of electrons passing through any area per second, N/T

Current , I= (N/T)*q

Multiply and divide by L, $I = \frac{N}{T} * q * \frac{L}{L}$

$$I = Nq\frac{V}{T}$$

$$\frac{I}{A} = \frac{NqV}{AL}$$

$$J = \frac{NqV}{AL}$$

$$J = qvn$$

We know that $v = \mu E$

Therefore $\quad J = qn\mu E$

$$\sigma \; is \; the \; conductivity$$

The above relation is for conductor.

For an intrinsic semiconductor, the current flow due to movement of electrons and holes is

$$Jn = qn\mu E$$

$$Jp = qp\mu_p E$$

Total current density is,

$$J = J_p + J_n$$

$$= qn\mu E + \; qp\mu_p E$$

J=σ E

Where, $J = \sigma E$

Therefore

$$\mu = \frac{q.t}{m}$$

Where μ is the mobility of the electron.

$$J = \sigma.E$$

where

$$\sigma = q(n\mu_n + p\mu_p)$$

In an intrinsic semiconductor p=n=n_i

Therefore

$$\sigma = q(\mu_n + \mu_p)n$$

For an N type

$$\sigma = qn\mu_n$$

Since p<<n and μ_p is negligible.

For a P type

$$\sigma = pq\mu_p$$

CLIPPER

An electronic device that is used to evade the output of a circuit to go beyond the preset value (voltage level) without varying the remaining part of the input waveform is called as clipper

WORKING OF CLIPPER CIRCUIT

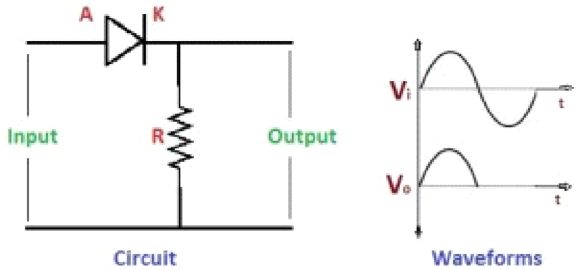
The clipper circuit can be designed by utilizing both the linear and nonlinear elements such as resistors, diodes ortransistors. As these circuits are used only for clipping input waveform as per the requirement and for transmitting the waveform, they do not contain any energy storing element like a capacitor.

In general, clippers are classified into two types: Series Clippers and Shunt Clippers.

1. SERIES CLIPPERS

Series clippers are again classified into series negative clippers and series positive clippers which are as follows:

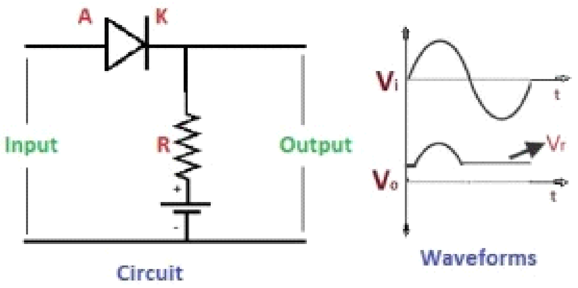
a. SERIES NEGATIVE CLIPPER



Series Negative Clipper

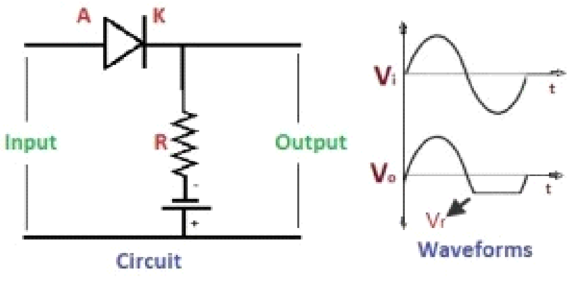
The above figure shows a series negative clipper with its output waveforms. During the positive half cycle the diode (considered as ideal diode) appears in the forward biased and conducts such that the entire positive half half cycle of input appears across the resistor connected in parallel as output waveform. During the negative half cycle the diode is in reverse biased. No output appears across the resistor. Thus, it clips the negative half cycle of the input waveform, and therefore, it is called as a series negative clipper.

Series Negative Clipper With Positive Vr



SERIES NEGATIVE CLIPPER WITH POSITIVE Vr

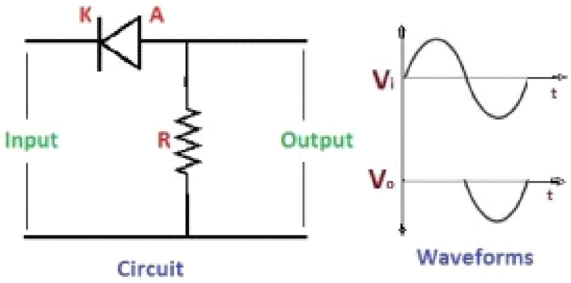
Series negative clipper with positive reference voltage is similar to the series negative clipper, but in this a positive reference voltage is added in series with the resistor. During the positive half cycle, the diode start conducting only after its anode voltage value exceeds the cathode voltage value. Since cathode voltage becomes equal to the reference voltage, the output that appears across the resistor will be as shown in the above figure.



SERIES NEGATIVE CLIPPER WITH NEGATIVE Vr

The series negative clipper with a negative reference voltage is similar to the series negative clipper with positive reference voltage, but instead of positive Vr here a negative Vr is connected in series with the resistor, which makes the cathode voltage of the diode as negative voltage. Thus during the positive half cycle, the entire input appears as output across the resistor, and during the negative half cycle, the input appears as output until the input value will be less than the negative reference voltage, as shown in the figure.

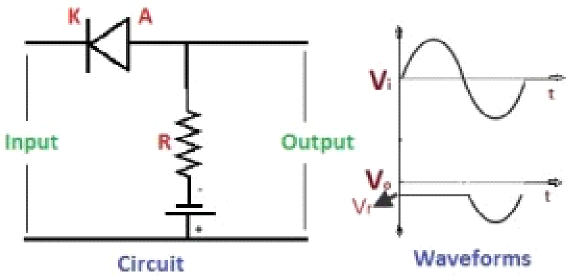
b. SERIES POSITIVE CLIPPER



Series Positive Clipper

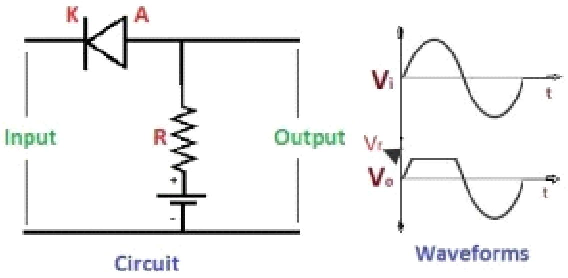
The series positive clipper circuit is connected as shown in the figure. During the positive half cycle, diode becomes reverse biased, and no output is generated across the resistor, and during the negative half cycle, the diode conducts and the entire input appears as output across the resistor.

Series Positive Clipper with Negative Vr



Series Positive Clipper with Negative Vr

It is similar to the series positive clipper in addition to a negative reference voltage in series with a resistor; and here, during the positive half cycle, the output appears across the resistor as a negative reference voltage. During the negative half cycle, the output is generated after reaching a value greater than the negative reference voltage, as shown in the above figure.



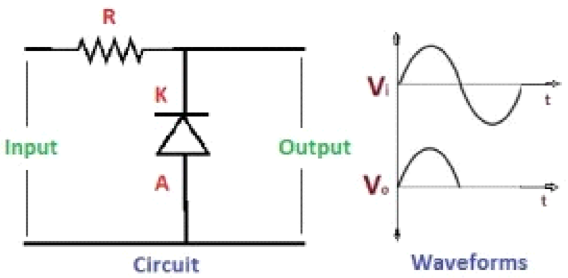
Series Positive Clipper with Positive Vr

Instead of negative reference voltage a positive reference voltage is connected to obtain series positive clipper with a positive reference voltage. During the positive half cycle, the reference voltage appears as an output across the resistor, and during the negative half cycle, the entire input appears as output across the resistor.

2. SHUNT CLIPPERS

Shunt clippers are classified into two types: shunt negative clippers and shunt positive clippers.

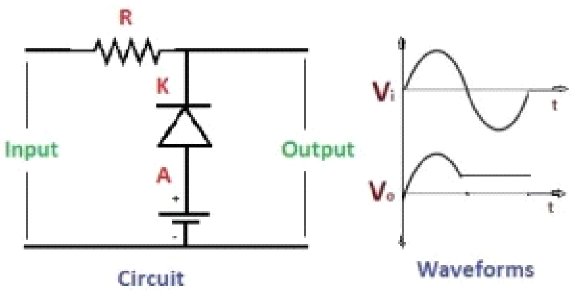
a. SHUNT NEGATIVE CLIPPER



Shunt Negative Clipper

Shunt negative clipper is connected as shown in the above figure. During the positive half cycle, the entire input is the output, and during the negative half cycle, the diode conducts causing no output to be generated from the input.

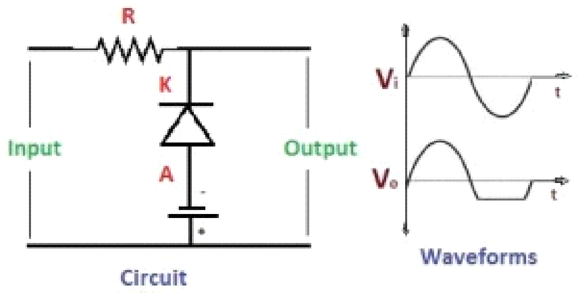
Shunt Negative Clipper with Positive Vr



Shunt Negative Clipper with Positive Vr

A series positive reference voltage is added to the diode as shown in the figure. During the positive half cycle, the input is generated as output, and during the negative half cycle, a positive reference voltage will be the output voltage as shown above.

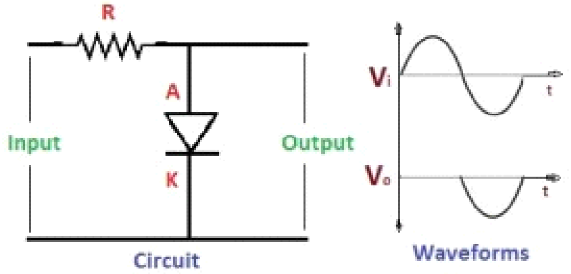
Shunt Negative Clipper with Negative Vr



Shunt Negative Clipper with Negative Vr

Instead of positive reference voltage, a negative reference voltage is connected in series with the diode to form a shunt negative clipper with a negative reference voltage. During the positive half cycle, the entire input appears as output, and during the negative half cycle, a reference voltage appears as output as shown in the above figure.

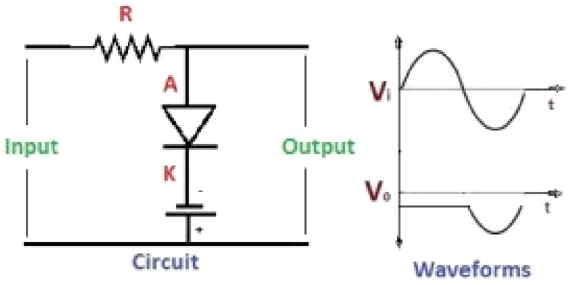
b. SHUNT POSITIVE CLIPPER



Shunt Positive Clipper

During the positive half cycle the diode is in conduction mode and no output is generated; and during the negative half cycle; entire input appears as output as the diode is in reverse bias as shown in the above figure.

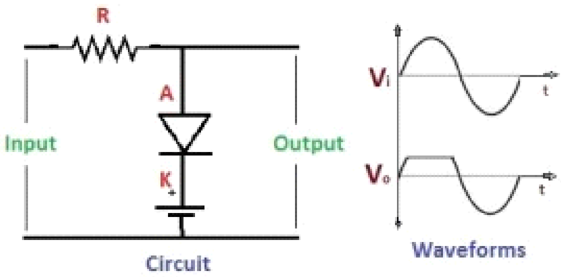
SHUNT POSITIVE CLIPPER WITH NEGATIVE Vr



SHUNT POSITIVE CLIPPER WITH NEGATIVE Vr

During the positive half cycle, the negative reference voltage connected in series with the diode appears as output; and during the negative half cycle, the diode conducts until the input voltage value becomes greater than the negative reference voltage and output will be generated as shown in the figure.

SHUNT POSITIVE CLIPPER WITH POSITIVE Vr

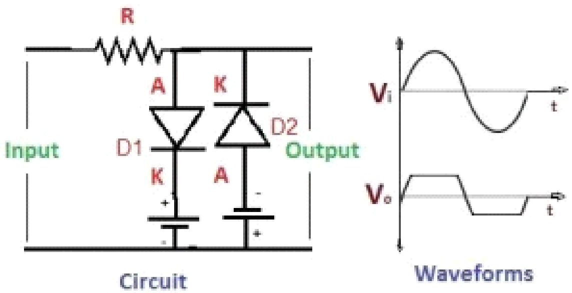


Shunt Positive Clipper with Positive Vr

During the positive half cycle the diode conducts causing the positive reference voltage appear as output voltage; and, during the negative half cycle, the entire input is generated as the output as the diode is in reverse biased.

In addition to the positive and negative clippers, there is a combined clipper which is used for clipping both the positive and negative half cycles as discussed below.

Positive-Negative Clipper with Reference Voltage Vr



Positive-Negative Clipper with Reference Voltage Vr

The circuit is connected as shown in the figure with a reference voltage Vr, diodes D1 & D2. During the positive half cycle, the diode the diode D1 conducts causing the reference voltage connected in series with D1 to appear across the output.

During the negative cycle, the diode D2 conducts causing the negative reference voltage connected across the D2 appear as output, as shown in the above figure.

Clippers find several applications, such as

- They are frequently used for the separation of synchronizing signals from the composite picture signals.
- The excessive noise spikes above a certain level can be limited or clipped in FM transmitters by using the series clippers.
- For the generation of new waveforms or shaping the existing waveform, clippers are used.
- The typical application of diode clipper is for the protection of transistor from transients, as a freewheeling diode connected in parallel across the inductive load.
- Frequently used half wave rectifier in power supply kits is a typical example of a clipper. It clips either positive or negative half wave of the input.
- Clippers can be used as voltage limiters and amplitude selectors.

CLAMPER CIRCUIT.

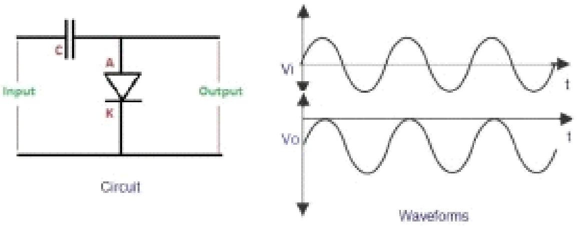
An electronic circuit that is used to alter the positive peak or negative peak of the input signal to a definite value by shifting the entire signal up or down to obtain the output signal peaks at desired level is called as Clamper circuit.

WORKING OF CLAMPER CIRCUIT

The positive or negative peak of a signal can be positioned at the desired level by using the clamping circuits. As we can shift the levels of peaks of the signal by using a clamper, hence, it is also called as level shifter.

The clamper circuit consists of a capacitor and diode connected in parallel across the load. The clamper circuit depends on the change in the time constant of the capacitor. The capacitor must be chosen such that, during the conduction of the diode, the capacitor must be sufficient to charge quickly and during the nonconducting period of diode, the capacitor should not discharge drastically. The clampers are classified as positive and negative clampers based on the clamping method.

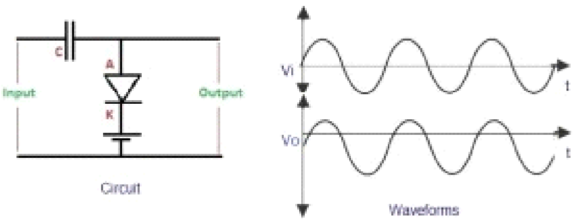
1. NEGATIVE CLAMPER



Negative Clamper

During the positive half cycle, the input diode is in forward bias- and as the diode conducts-capacitor gets charged (up to peak value of input supply). During the negative half cycle, reverse does not conduct and the output voltage become equal to the sum of the input voltage and the voltage stored across the capacitor.

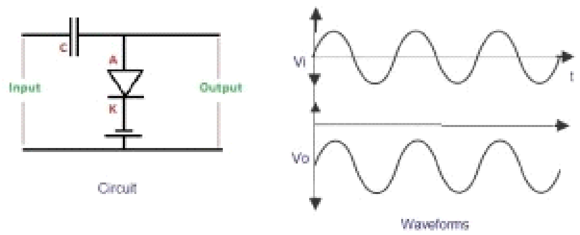
Negative Clamper with Positive Vr



NEGATIVE CLAMPER WITH POSITIVE Vr

It is similar to the negative clamper, but the output waveform is shifted towards the positive direction by a positive reference voltage. As the positive reference voltage is connected in series with the diode, during the positive half cycle, even though the diode conducts, the output voltage becomes equal to the reference voltage; hence, the output is clamped towards the positive direction as shown in the above figure.

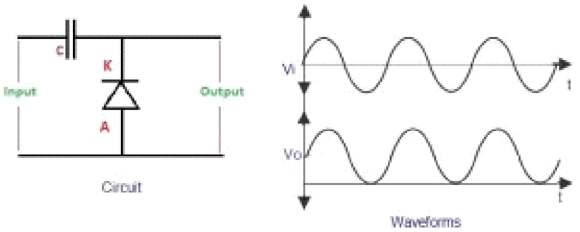
Negative Clamper with Negative Vr



NEGATIVE CLAMPER WITH NEGATIVE Vr

By inverting the reference voltage directions, the negative reference voltage is connected in series with the diode as shown in the above figure. During the positive half cycle, the diode starts conduction before zero, as the cathode has a negative reference voltage, which is less than that of zero and the anode voltage, and thus, the waveform is clamped towards the negative direction by the reference voltage value.

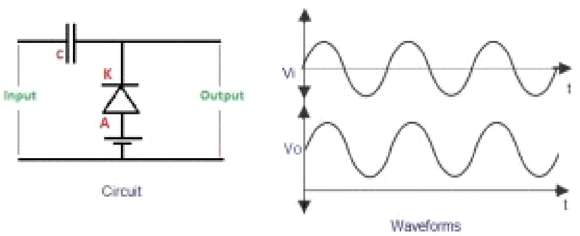
2. POSITIVE CLAMPER



POSITIVE CLAMPER

It is almost similar to the negative clamper circuit, but the diode is connected in the opposite direction. During the positive half cycle, the voltage across the output terminals becomes equal to the sum of the input voltage and capacitor voltage (considering the capacitor as initially fully charged). During the negative half cycle of the input, the diode starts conducting and charges the capacitor rapidly to its peak input value. Thus the waveforms are clamped towards the positive direction as shown above.

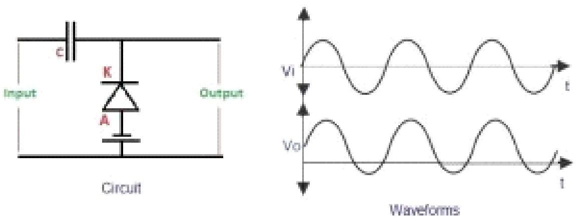
Positive Clamper with Positive Vr



POSITIVE CLAMPER WITH POSITIVE Vr

A positive reference voltage is added in series with the diode of the positive clamper as shown in the circuit. During the positive half cycle of the input, the diode conducts as initially the supply voltage is less than the anode positive reference voltage. If once the cathode voltage is greater than anode voltage then the diode stops conduction. During the negative half cycle, the diode conducts and charges the capacitor. The output is generated as shown in the figure.

POSITIVE CLAMPER WITH NEGATIVE Vr



Positive Clamper with Negative Vr

The direction of the reference voltage is reversed, which is connected in series with the diode making it as a negative reference voltage. During the positive half cycle the diode will be non conducting, such that the output is equal to capacitor voltage and input voltage. During the negative half cycle, the diode starts conduction only after the cathode voltage value becomes less than the anode voltage. Thus, the output waveforms are generated as shown in the above figure.

.**Clampers can be used in applications**

- The complex transmitter and receiver circuitry of television clamper is used as a base line stabilizer to define sections of the luminance signals to preset levels.
- Clampers are also called as direct current restorers as they clamp the wave forms to a fixed DC potential.
- These are frequently used in test equipment, sonar and radar systems.
- For the protection of the amplifiers from large errant signals clampers are used.
- Clampers can be used for removing the distortions
- For improving the overdrive recovery time clampers are used.

- Clampers can be used as voltage doublers or voltage multipliers.

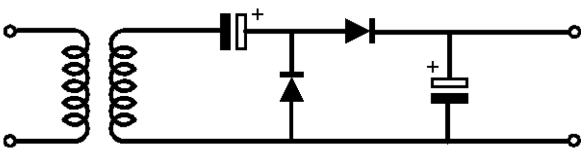
DIODE VOLTAGE MULTIPLIER CIRCUIT

Voltage multiplier is a circuit using simple semiconductor diodes that multiplies the incoming voltage for use in power supply and detector circuits

Within a power supply or other rectifier circuit it is possible to configure the diodes in such a way that they double, triple or more, the level of the incoming voltage. This type of voltage multiplier circuit finds uses in many applications where a low current, high voltage source is required. These circuits may also be used in detector circuits where the detected voltage needs to be increased.

Basic voltage multiplier circuit

Although there are some variations on the basic circuit, these ones shown below use a single winding on the transformer that is required, one side of which can be grounded. Alternatively another AC source can be used. In this configuration the circuit is particularly convenient as the AC source does not need to be isolated from ground.



Diode voltage doubler circuit

In this voltage doubler circuit the first diode rectifies the signal and its output is equal to the peak voltage from the transformer rectified as a half wave rectifier. An AC signal via the capacitor also reaches the second diode, and in view of the DC block provided by the capacitor this causes the output from the second diode to sit on top of the first one. In this way the output from the circuit is twice the peak voltage of the transformer, less the diode drops.

Variations of the basic circuit and concept are available to provide a voltage multiplier function of almost any factor. Applying the same principle of sitting one rectifier on top of another and using capacitive coupling enables a form of ladder network to built up.

The voltage multiplier circuits are very useful. However they are normally suitable only for low current applications. As the voltage multiplication increases the losses increase. The source resistance tends to rise, and loading becomes an issue. For each diode in the chain there is the usual diode drop (normally 0.6 volts for a silicon diode), but the reactance of the capacitors can become significant, especially when mains frequencies of 50 or 60 Hz are used. High voltage high value capacitors can be expensive and large. This may provide physical constraints for making them too large.

ZENER DIODE

A Zener diode is a type of diode that permits current not only in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as "Zener knee voltage" or "Zener voltage". The device was named after Clarence Zener, who discovered this electrical property.

Diode symbol

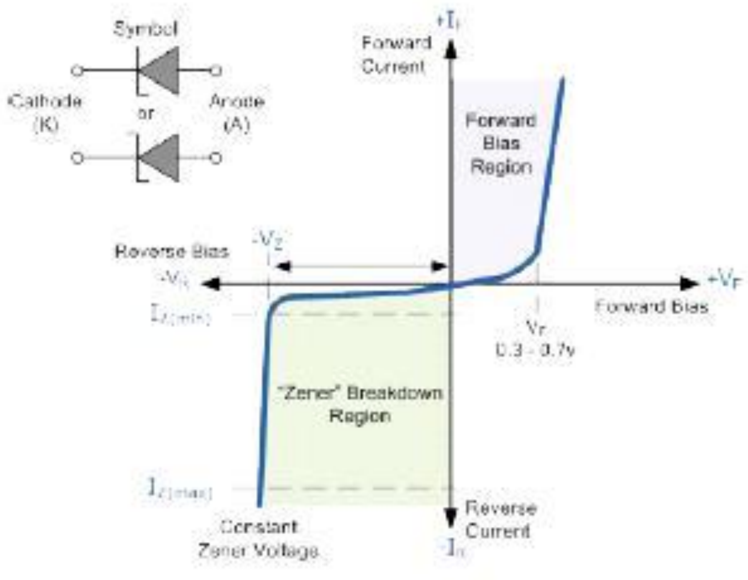
However, the Zener Diode or "Breakdown Diode" as they are sometimes called, are basically the same as the standard PN junction diode but are specially designed to have a low pre-determined Reverse Breakdown Voltage that takes advantage of this high reverse voltage. The point at which a zener diode breaks down or conducts is called the "Zener Voltage" (Vz).

The Zener diode is like a general-purpose signal diode consisting of a silicon PN junction. When biased in the forward direction it behaves just like a normal signal diode passing the rated current, but when a reverse voltage is applied to it the reverse saturation current remains fairly constant over a wide range of voltages. The reverse voltage increases until the diodes breakdown voltage VB is reached at which point a process called Avalanche Breakdown occurs in the depletion layer and the current flowing through the zener diode increases dramatically to the maximum circuit value (which is usually limited by a series resistor). This breakdown voltage point is called the "zener voltage" for zener diodes.

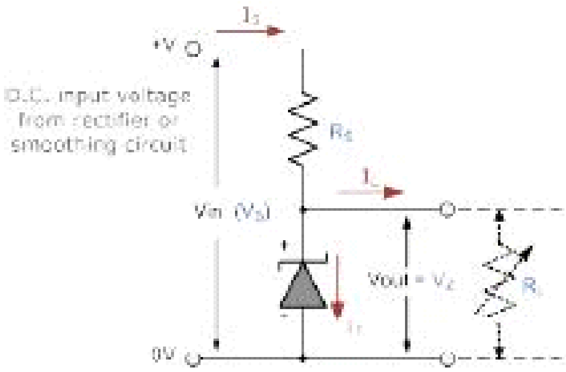
The point at which current flows can be very accurately controlled (to less than 1% tolerance) in the doping stage of the diodes construction giving the diode a specific *zenerbreakdown voltage*, (Vz) ranging from a few volts up to a few hundred volts. This zenerbreakdown voltage on the I-V curve is almost a vertical straight line.

ZENER DIODE CHARACTERISTICS

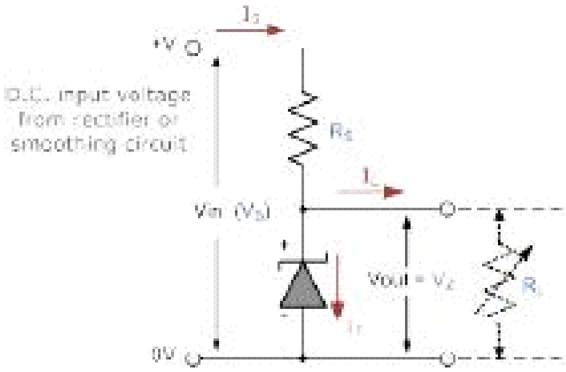
The Zener Diode is used in its "reverse bias" or reverse breakdown mode, i.e. the diodes anode connects to the negative supply. From the I-V characteristics curve above, we can see that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current IZ(min) and the maximum current rating IZ(max).

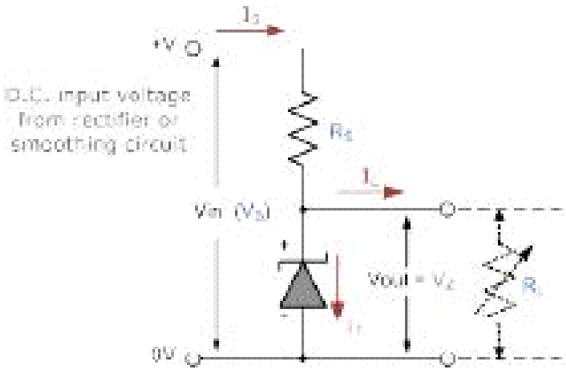


THE ZENER DIODE REGULATOR



Zener Diodes can be used to produce a stabilised voltage output with low ripple under varying load current conditions. By passing a small current through the diode from a voltage source, via a suitable current limiting resistor (RS), the zener diode will conduct sufficient current to maintain a voltage drop of Vout. We remember from the previous tutorials that the DC output voltage from the half or full-wave rectifiers contains ripple superimposed onto the DC voltage and that as the load value changes so to does the average output voltage. By connecting a simple zenerstabiliser circuit as shown below across the output of the rectifier, a more stable output voltage can be produced**.**





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QUESTIONS FOR PRACTICE

explain the drift and diffusion currents in a semiconductor.

State mass action law.

Define conductivity and mobility in a semiconductor.

What is meant by intrinsic semiconductor.

Explain majority and minority carriers in s semiconductor,

Define i.Doping ii. Dopant

Describe the phenomenon of diffusion of charge carriers in semiconductors.

Derive the continuity equation from the first principle.

Describe the action of PN junction diode under forward bias and reverse bias.

Explain V-I characteristic of a PN junction diode.

Mention the applications of PN junction diode.

Explain the difference between intrinsic and extrinsic semiconductors.

Explain the formation of depletion region in a PN junction.

Show that the PN diode works as rectifier.

Explain the following terms in a PN junction diode
a)maximum forward current

b)peak inverse voltage,and

c) maximum power rating

explain how a barrier potential is developed in PN junction diode

write short notes on clippers with necessary diagrams

explain the operation of zener diode

explain clampers.