BASIC ELECTRONICS

UNIT-1 SEMICONDUCTOR JUNCTION DIODES AND ITS APPLICATIONS

- Introduction to Semiconductor
- PN junction Diode
- Construction and operation
- VI Characteristics of PN Junction diode
- Diffusion and Transition Capacitances
- Zener diode
- Tunnel Diode
- Applications: Rectifier - Half Wave Rectifier, Full Wave Rectifier, Bridge Rectifier, Clippers and Clampers- Zener diode as voltage regulator.

- **UNIT-II: SEMICONDUCTOR JUNCTION TRANSISTOR** Bipolar Junction Transistor (BJT): Construction and Operation of NPN and PNP transistors – CE, CB and CC configurations - Input and output characteristics of CE, CB and CC - Transistor biasing – Transistor as an Amplifier - Qualitative explanation of voltage gain, current gain, power gain, input impedance, output impedance, frequency response and bandwidth - Tuned amplifier – Introduction to power amplifier

- **UNIT-III: FIELD EFFECT TRANSISTOR AND OPERATIONAL AMPLIFIERS :** Classification of FETs-JFET, MOSFET, operating principle of JFET. Drain and transfer characteristics of JFET (n-channel and p-channel), CS, CG, CD configurations. Operational Amplifiers (OP-Amp): Ideal OPAMP, Inverting and Non Inverting OPAMP circuits, OPAMP applications: voltage follower, addition, subtraction, integration, differentiation; Numerical examples as applicable.

- **UNIT-IV: ELECTRONIC CIRCUITS: RC differentiator and integrators - Oscillators, RC Phase Shift Oscillator, Wien Bridge Oscillator, Hartley Oscillator and Colpitts Oscillator, Applications - Multivibrators, Types, Operation, Waveforms, Applications**

- **UNIT-V: LOGIC GATES AND ITS APPLICATIONS Logic Gates: Basic gates AND, OR, NOT, NAND, NOR, EX-OR, EX-NOR - Building of AND, OR and NOT Gate with diodes. Applications: Half adder, Full adder, Half Subtractor, Full Subtractor and Binary parallel adder.**

TEXT BOOKS:

1. Millman‘s Electronic Devices and Circuits – J. Millman, C.C.Halkias, and SatyabrataJit, 2 Ed.,1998, TMH.
2. Millman‘s Pulse, Digital and Switching Waveforms –J. Millman, H. Taub and Mothiki S. Prakash Rao, 2 Ed., TMH, 2008.
3. Choudhury B Roy, Sahil B Jain, Linear Integrated Circuits, 3rd Revised edition, NEW AGE Publication ,2010.
4. Floyd T.L, Digital Fundamentals , 10/e, Pearson Education, 2011

REFERENCES:

1. Electronic Devices and Circuits – R.L. Boylestad and Louis Nashelsky, 9 Ed., 2006, PEI/PHI.
2. Electronic Devices and Circuits - K. Lal Kishore, 2 Ed., 2005, BSP.
3. Pulse, Switching and Digital Circuits –David A. Bell, 5th Ed, Oxford, 2015.
4. Electronic Devices and Circuits – S.Salivahanan, N.Suresh Kumar, A.Vallavaraj, 2 Ed., 2008, TMH
5. Mano M.M, Logic and Computer Design Fundamentals, 4/e, , Pearson Education

Principles of Electronics

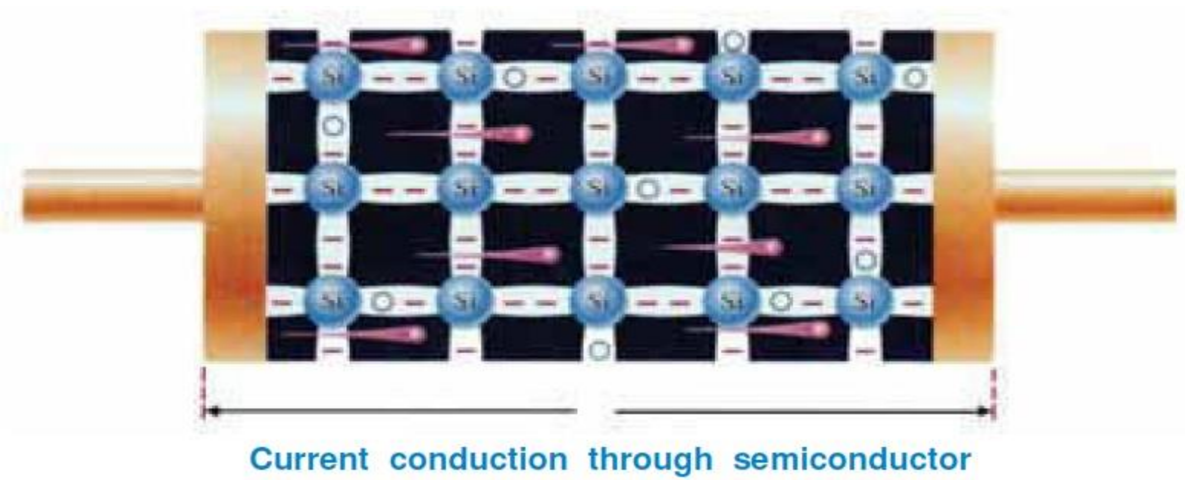
- **Electronics:** The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as ***electronics.**

(OR)

Electronic Means it is Flow Of Negative Charge Particles

(OR)

- **Electronics:** The branch of science that deals with the study of flow and control of electrons and the study of their behavior and effects in vacuums, gases, and semiconductors



ELECTRONIC COMPONENTS

- **Electronic Components are two types**
  - **1) Active components**
  - **2) Passive components**

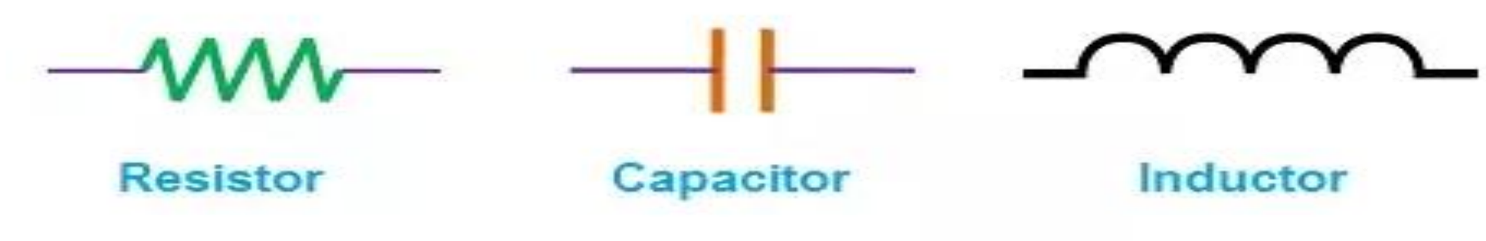
- **Active Components: Those devices or components which required external source to their operation.**

  Examples: Diode, Transistors, SCR, Integrated Circuits, TRIACs, SCRs, LEDs, etc.

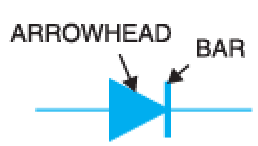
- **Passive Components: Those devices or components which do not required external source to their operation.**

  Examples: Resistor, capacitor and inductor.

- **RESISTOR:** Resistor which opposes the flow of current and drops the voltage. its units is ohms.
- **CAPACITOR:** It Is Used To Stored the voltage it allows ac cuurent and block dc current. its unit is faraday. It does not allow sudden changes in the voltage.
- **INDUCTOR:** it Is Used To Stores the energy in the form of magnetic field. its unit is henry. It doenot allow the sudden changes in the current.



DIODE: it is a flow of current only in one direction



(i) If *arrowhead* of diode symbol is *positive w.r.t. bar* of the symbol, the diode is forward biased

(ii) If the *arrowhead* of diode symbol is *negative w.r.t. bar*, the diode is reverse biased.

- **DC (Direct Current):** The electrons flow in one direction only. Current flow is from negative to positive.

- **AC (Alternating Current):** The electrons flow in both directions in a cyclic manner.

CLASSIFICATION OF SOLID STATE MATERIALS

- **INSULATORS:** Insulators are the materials which are not allowing flow of electric current through them.

  Examples – Glass, Wood, Rubber, Plastic and air.

- **CONDUCTORS:** Conductors are the materials which are easily allowing flow of electric current through them.

  Examples – Copper, Aluminum, Iron and silver

- **SEMICONDUCTORS:** Semiconductors are the materials whose electrical conductivity lies in between insulators and conductors.

  Examples – silicon, Germanium and Gallium

Qualitative Theory of P-N Junction

- **Types of Semiconductor Semiconductors can be classified into two types:**

  1. Intrinsic Semiconductors or Pure of Semiconductors

  2. Extrinsic Semiconductors or Impure of Semiconductors

- **Doping: The process of adding impurities to an intrinsic semiconductor is known as doping.**
- **Intrinsic semiconductors:**

➢ The normal (pure) silicon and Germanium are intrinsic semiconductors.

➢ They posses all essential conducting characteristics of a semiconductor.

➢ The number of electrons present in the outermost orbit of intrinsic semiconductor is four, hence they are termed as tetra valent. So, intrinsic semiconductors are tetra valent in nature.

- **Extrinsic Semiconductors:**

  The process of adding impurities to an intrinsic semiconductor is known as Doping. With respect to the type of impurity added, extrinsic semiconductors are classified into two types.

  1. N- type semiconductors   2. P- type semiconductors

N- type semiconductors:

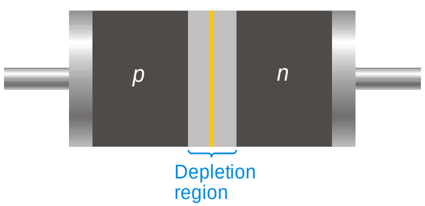
- When a small amount of penta valent impurity (e.g. Antimony, Arsenic) is added to a pure semiconductor, it is known as N - type semiconductor.
- The addition of penta valent gives a large number of free electrons in the semiconductors crystal

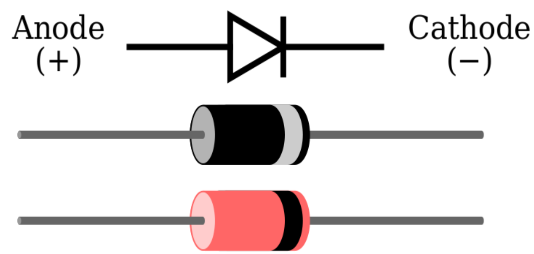
P - type semiconductors :

- When a small amount of trivalent material (e.g. Indium, Gallium) is added to a pure semiconductor, it is called P - type semiconductor.
- The addition of trivalent impurity gives a large number of holes in the semiconductor.

Diodes

- Diode, semiconductor material, such as silicon, in which half is doped as p-region and half is doped as n-region with a pn-junction in between.
- The p region is called **anode** and n type region is called **cathode.**





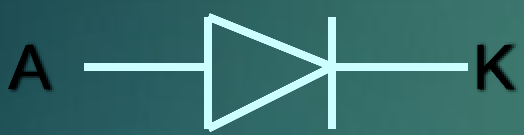
Diode symbol

- It conducts current in one direction and offers high (ideally infinite) resistance in other direction.

Types of Diodes

PN Junction Diodes:

Are used to allow current to flow in one direction while blocking current flow in the opposite direction. The pn junction diode is the typical diode that has been used in the previous circuits.

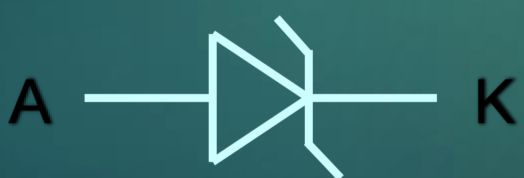


Schematic Symbol for a PN Junction Diode

Representative Structure for a PN Junction Diode

Zener Diodes:

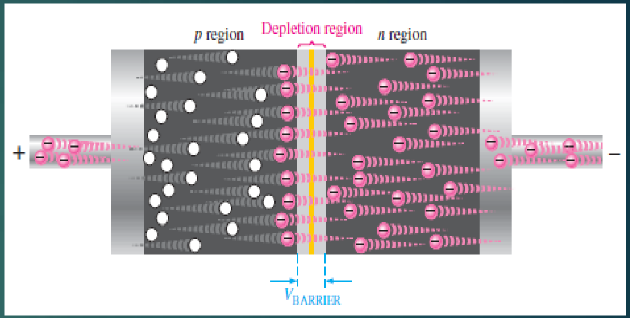
Are specifically designed to operate under reverse breakdown conditions. These diodes have a very accurate and specific reverse breakdown voltage.



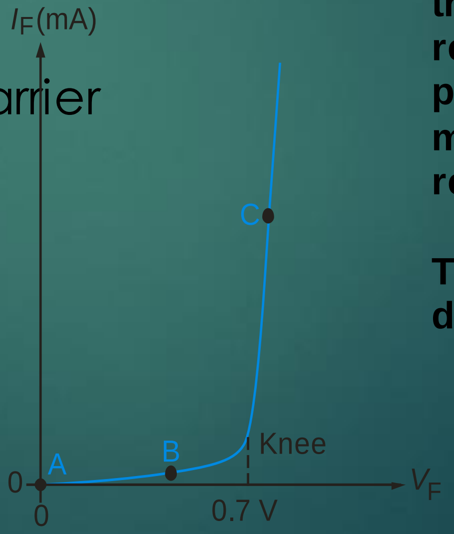
Schematic Symbol for a Zener Diode

Forward Biased

- Forward bias is a condition that allows current through pn junction.



  - A dc voltage (V_{bais}) is applied to bias a diode.
  - Positive side is connected to p-region (anode) and negative side is connected with n-region.
  - V_{bais} must be greater than 'barrier potential'



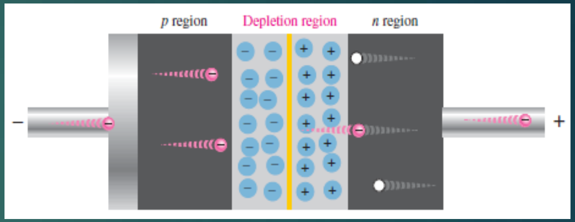
Current limiting resistance

As more electrons flow into the depletion region reducing the number of positive ions and similarly more holes move in reducing the positive ions.

This reduces the width of depletion region.

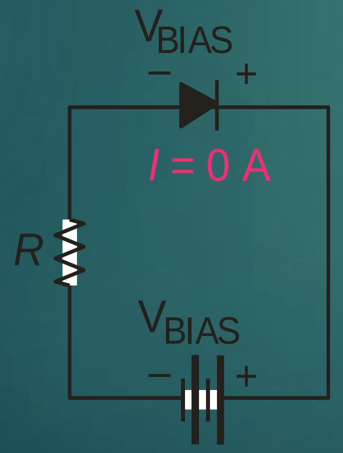
Reverse Biased

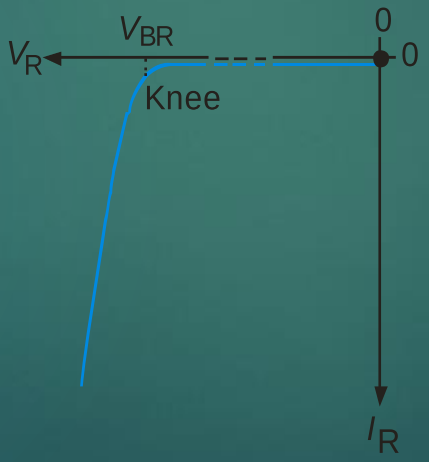
- Reverse bias is a condition that prevents current through junction.
- Positive side of V_{bias} is connected to the n-region whereas the negative side is connected with p-region.
- Depletion region get wider with this configuration.



The positive side of bias voltage attracts the majority carriers of n-type creating more positive ions at the junction.

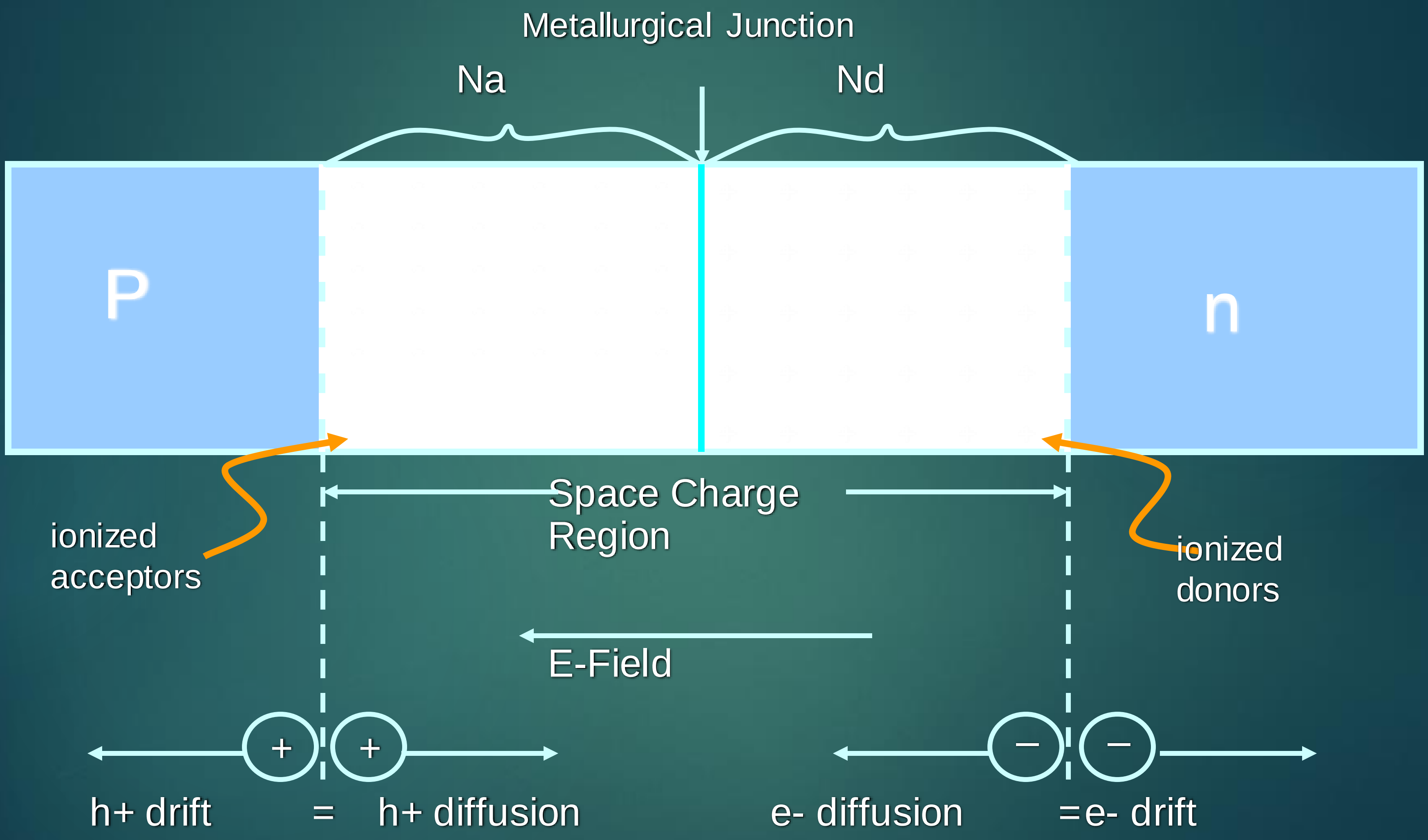
This widens the depletion region.





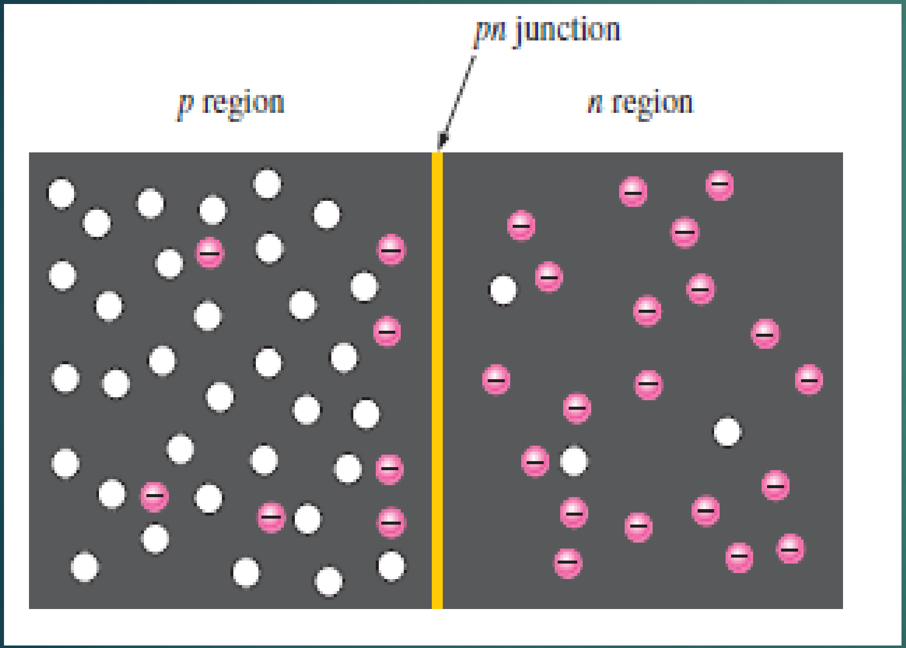
The PN Junction

Steady State[1]



PN Junction

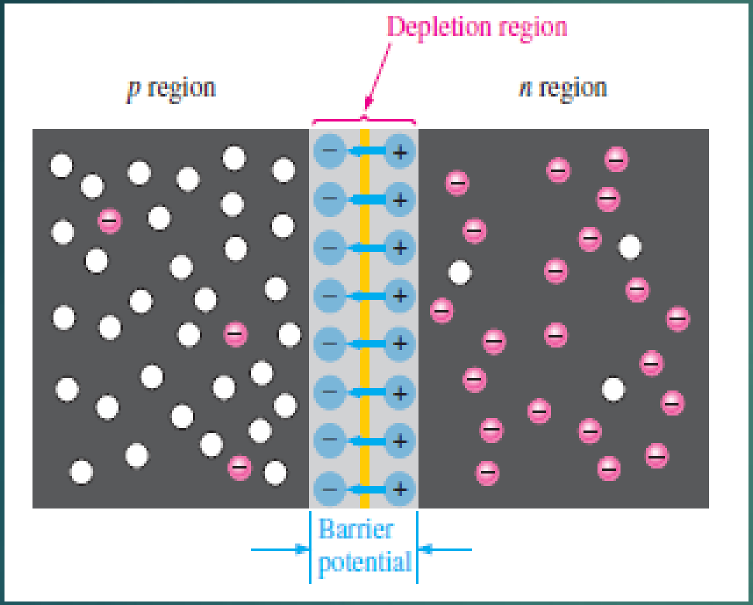
Although P-type material has holes in excess and N-type material has a number of free conduction electron however the net number of proton and electron are equal in each individual material keeping it just neutral.



The basic silicon structure at the instant of junction formation showing only the majority and minority carriers.

Free electrons in the *n region near the pn junction begin to diffuse across the* junction and fall into holes near the junction in the *p region.*

PN Junction

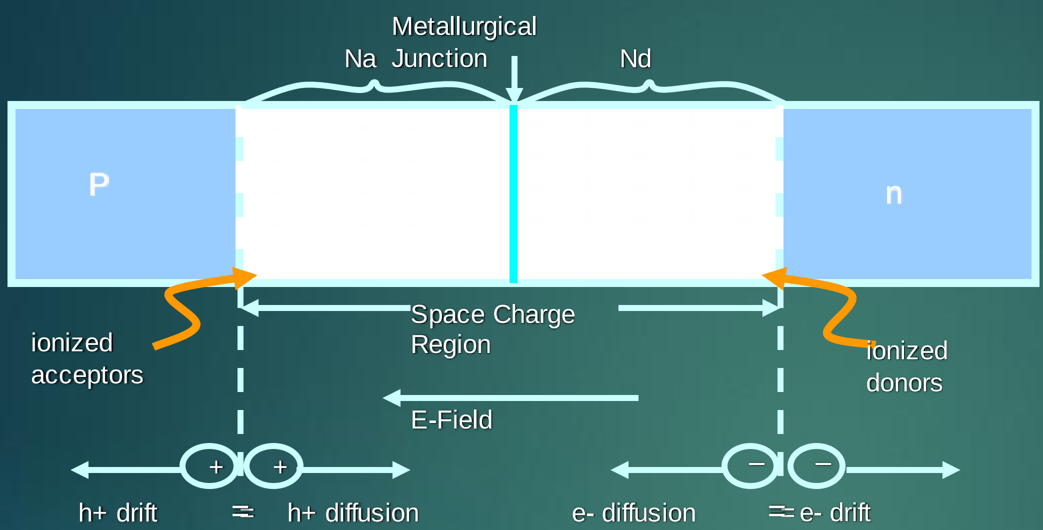


For every electron that diffuses across the junction and combines with a hole, a positive charge is left in the *n region* and a negative charge is created in the *p region, forming a* barrier potential.

This action continues until the voltage of the barrier repels further diffusion.

The blue arrows between the positive and negative charges in the depletion region represent the electric field.

The PN Junction



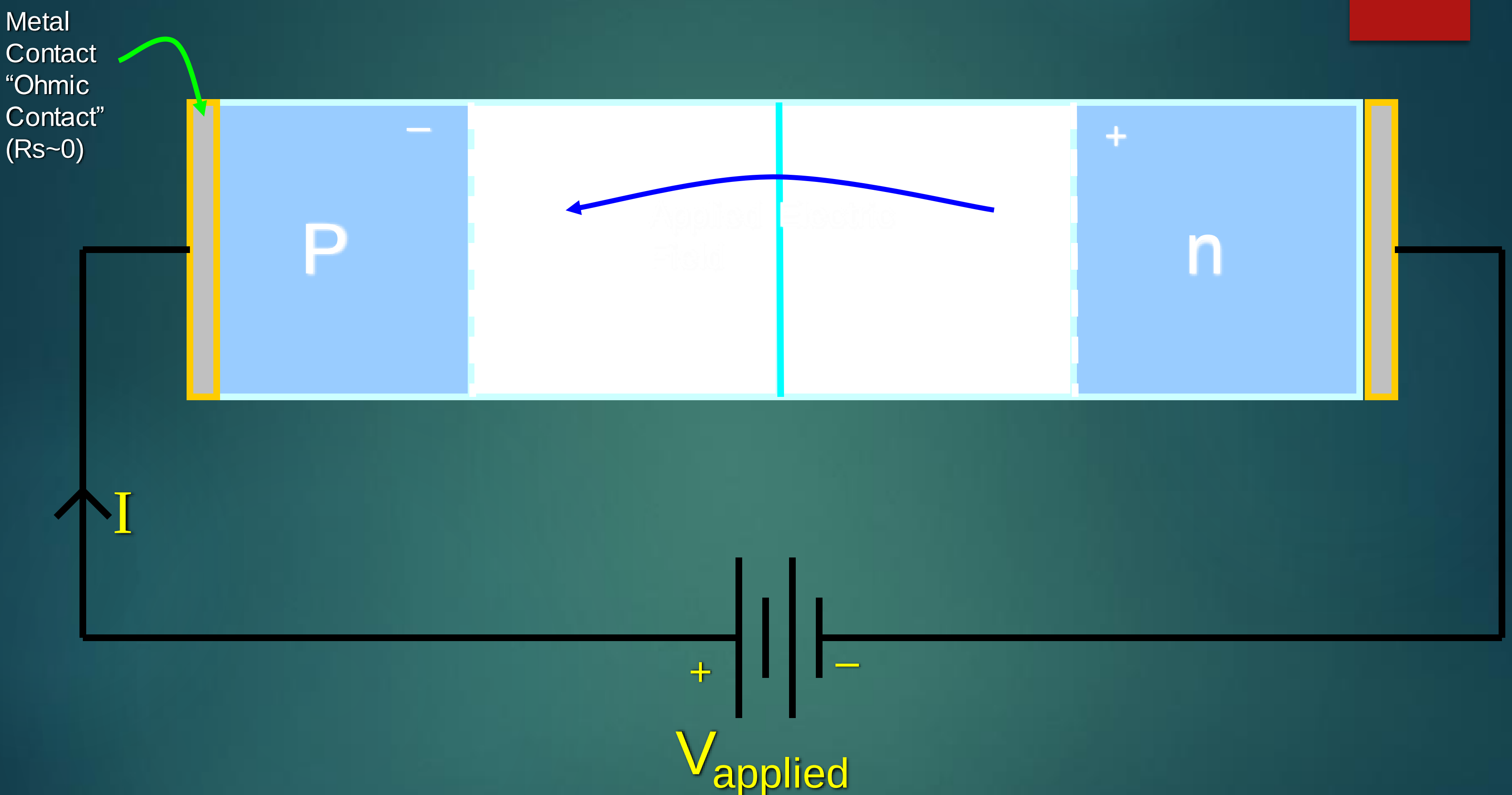
Steady State

When no external source is connected to the pn junction, diffusion and drift balance each other out for both the holes and electrons

Space Charge Region: Also called the depletion region. This region includes the net positively and negatively charged regions. The space charge region does not have any free carriers. The width of the space charge region is denoted by W in pn junction formula's.

Na & Nd: Represent the amount of negative and positive doping in number of carriers per centimeter cubed. Usually in the range of 10^{15} to 10^{20}.

The Biased PN Junction



The pn junction is considered biased when an external voltage is applied. There are two types of biasing: Forward bias and Reverse bias.
These are described on then next slide.

The Biased PN Junction

Forward Bias:

$V_{applied} > 0$

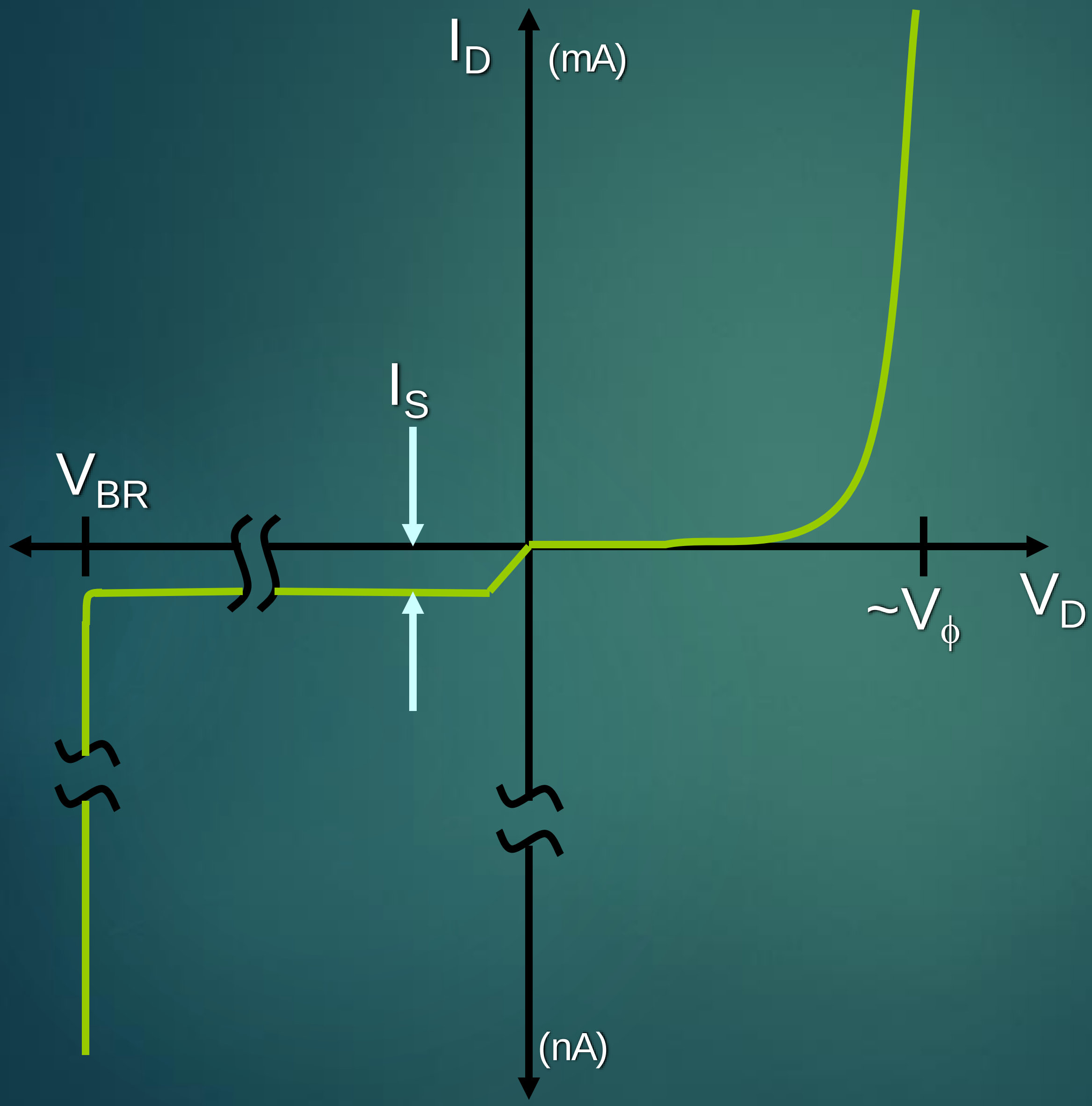
In forward bias the depletion region shrinks slightly in width. With this shrinking the energy required for charge carriers to cross the depletion region decreases exponentially. Therefore, as the applied voltage increases, current starts to flow across the junction. The barrier potential of the diode is the voltage at which appreciable current starts to flow through the diode. The barrier potential varies for different materials.

Reverse Bias:

$V_{applied} < 0$

Under reverse bias the depletion region widens. This causes the electric field produced by the ions to cancel out the applied reverse bias voltage. A small leakage current, Is (saturation current) flows under reverse bias conditions. This saturation current is made up of electron-hole pairs being produced in the depletion region. Saturation current is sometimes referred to as scale current because of it's relationship to junction temperature.

V-I Characterstics of Diode



- V_D = Bias Voltage
- I_D = Current through Diode. I_D is Negative for Reverse Bias and Positive for Forward Bias
- I_S = Saturation Current
- V_{BR} = Breakdown Voltage
- V_ϕ = Barrier Potential Voltage

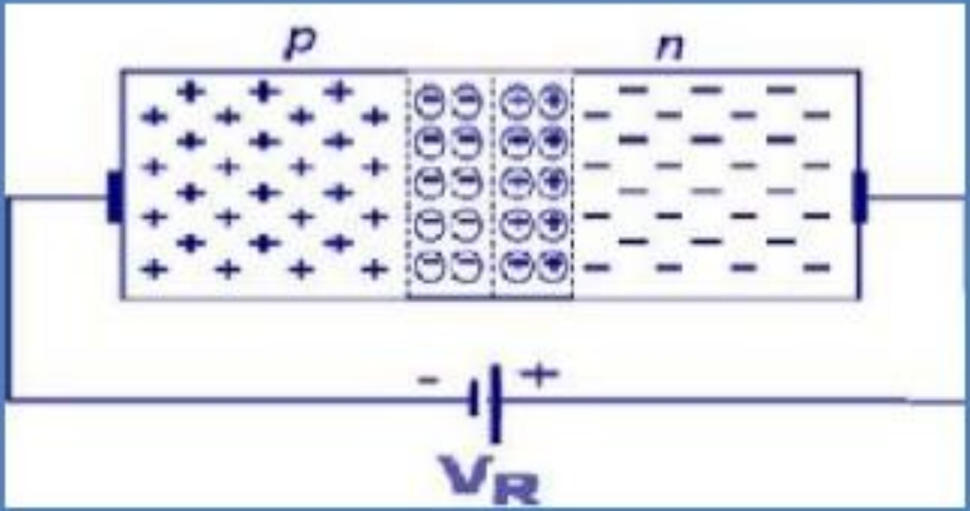
Capacitance Types

Definition: The ability of a system to store an electric charge

1) Transistion capacitance

2) Diffusion capacitance

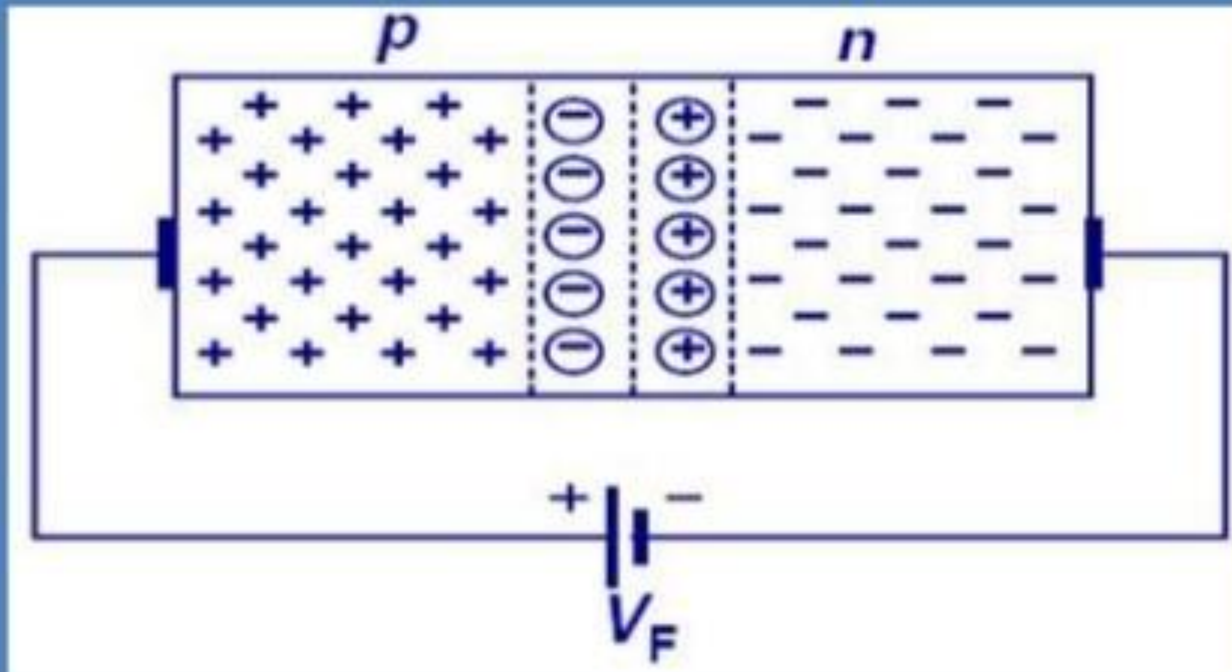
TRANSITION CAPACITANCE



When a p-N junction is reverse biased the depletion region acts like an insulator or dielectric material while the P and N type regions on either side have a low resistance and act as the plates. Thus P-N junction may be considerd as a parrallel plate capacitor.The jumction capacitance is termed as space charge capacitance or transition capacitance and is denoted by C_T.

As mentioned earlier, a reverse bias causes majority carriers to move away from the junction, thereby uncovering more immobile charges. So the thickness W of the depletion layer increases with the increase in reverse bias voltage . This increase in uncovered charge with applied voltage may be considered a capacitative effect . The incremental capacitance may be defined as- C_T = **dQ/dV** where dQ is increase in charge with increase in voltage, dV.

DIFFUSION CAPACITANCE



When a P-N junction is forward biased ,a capacitance which is much larger than the transition capacitance , comes into play . This type of capacitance is called the Diffusion Capacitance and is denoted by C_D.

GRAPH FOR TRANSITION AND DIFFUSION CAPACITANCE

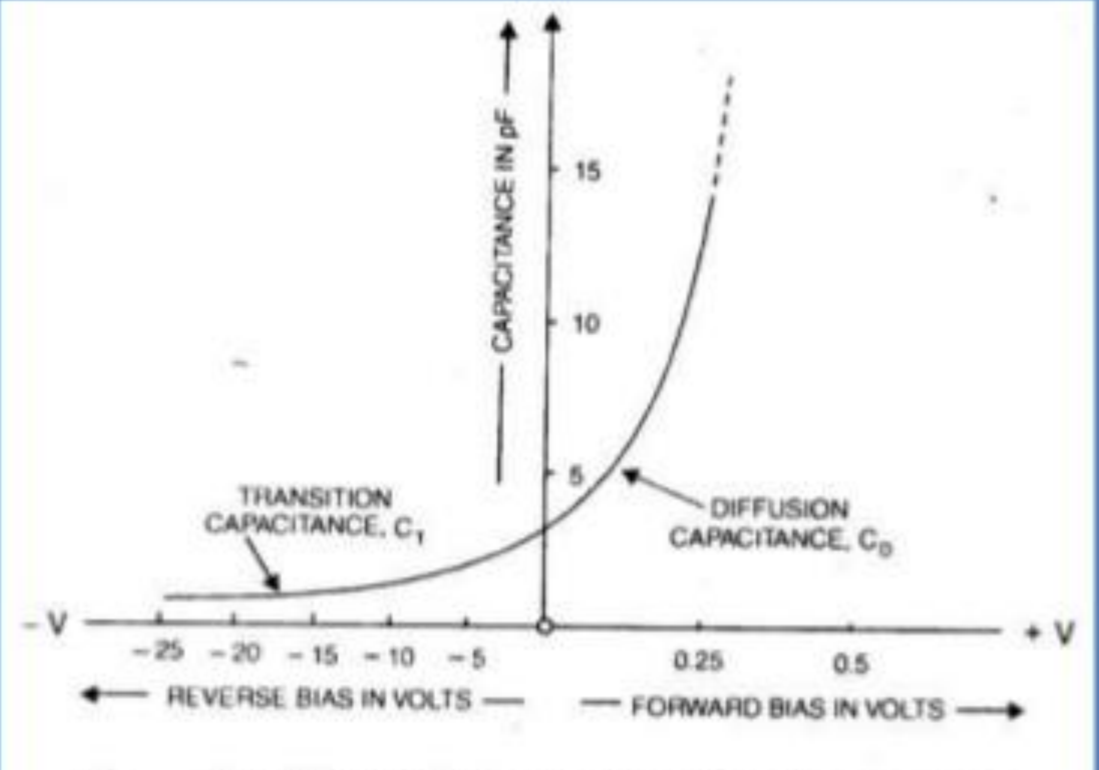
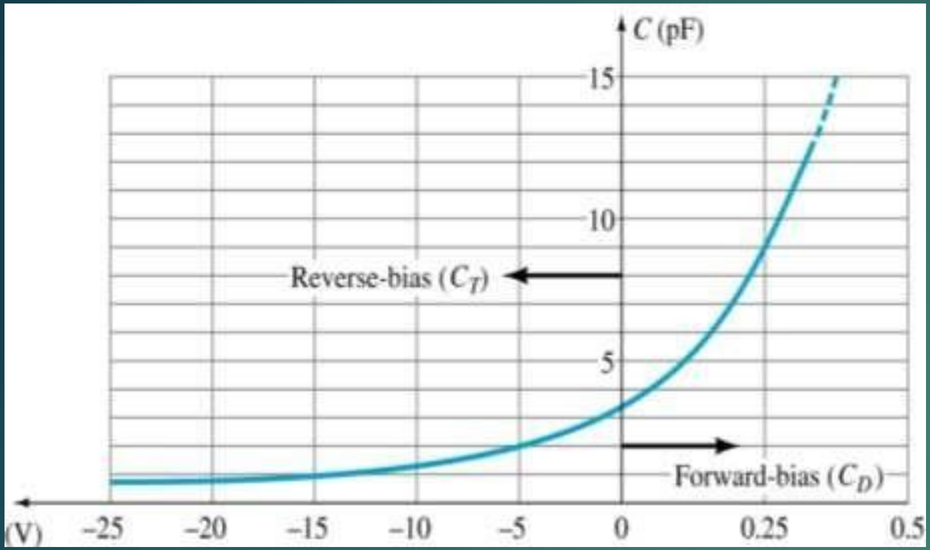


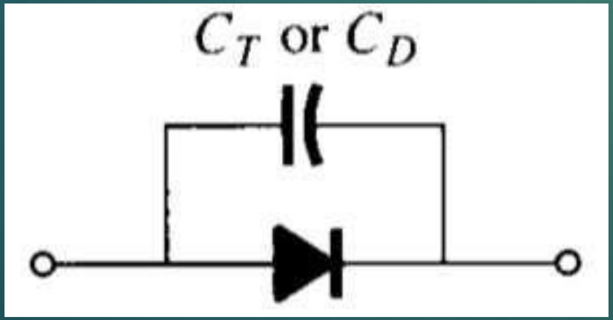
Fig. Transition and Diffusion Capacitance in a *pn* diode

Transition and Diffusion Capacitance



Transition and diffusion capacitance versus applied bias for a silicon diode

In the p-n semiconductor diode, there are two capacitive effects to be considered. Both types of capacitance are present in the forward- and reverse-bias regions, but one so outweighs the other in each region that we consider the effects of only one in each region.



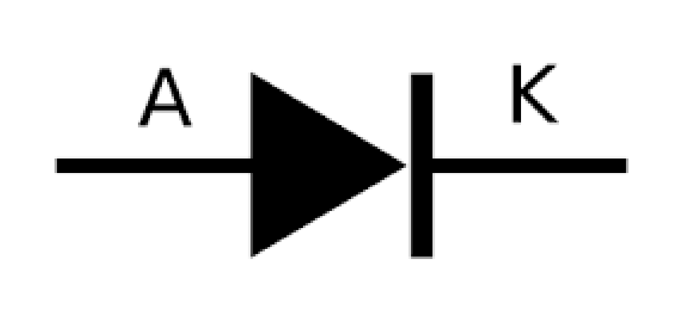
Including the effect of the transition or diffusion capacitance on the diode.

In the reverse-bias region we have the transition- or depletion-region capacitance (CT), while in the forward-bias region we have the diffusion (CD) or storage capacitance.

zener diode

Diode

- A diode is a specialized electronic component with two electrode called the anode and the cathode. Most diodes are made with semiconductor materials such as silicon, germanium, orselenium.

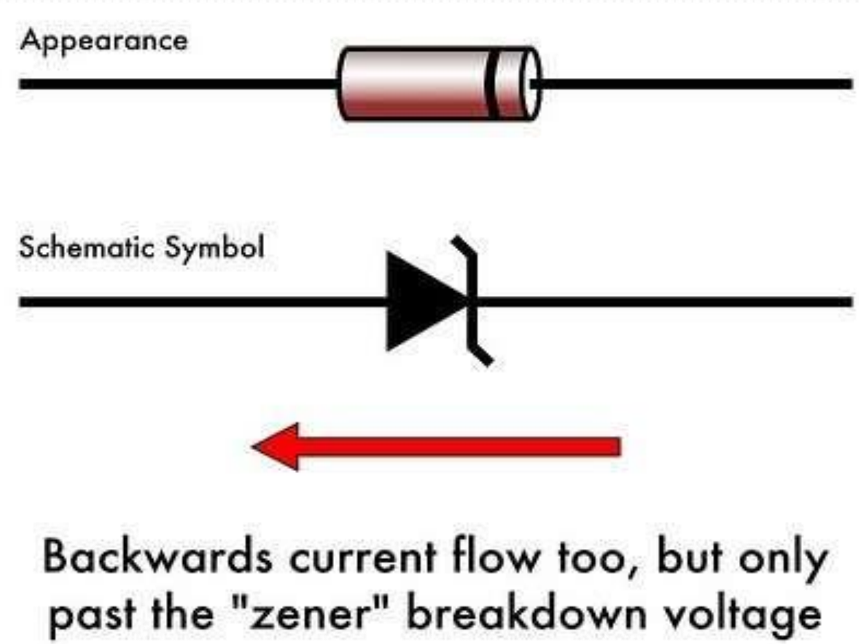


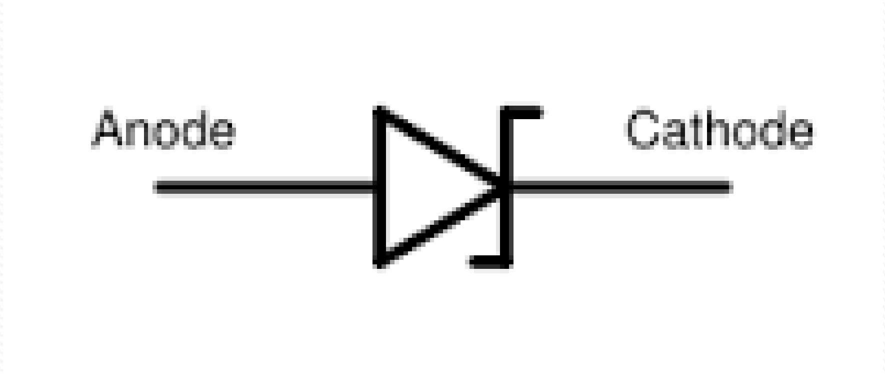
Zener Diode - History

- **Clarence Melvin Zener** (December 1, 1905 – July 2, 1993) was the American physicist who first described the property concerning the breakdown of electrical insulators. These findings were later exploited by Bell Labs in the development of the Zener diode, which was duly named after him

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"

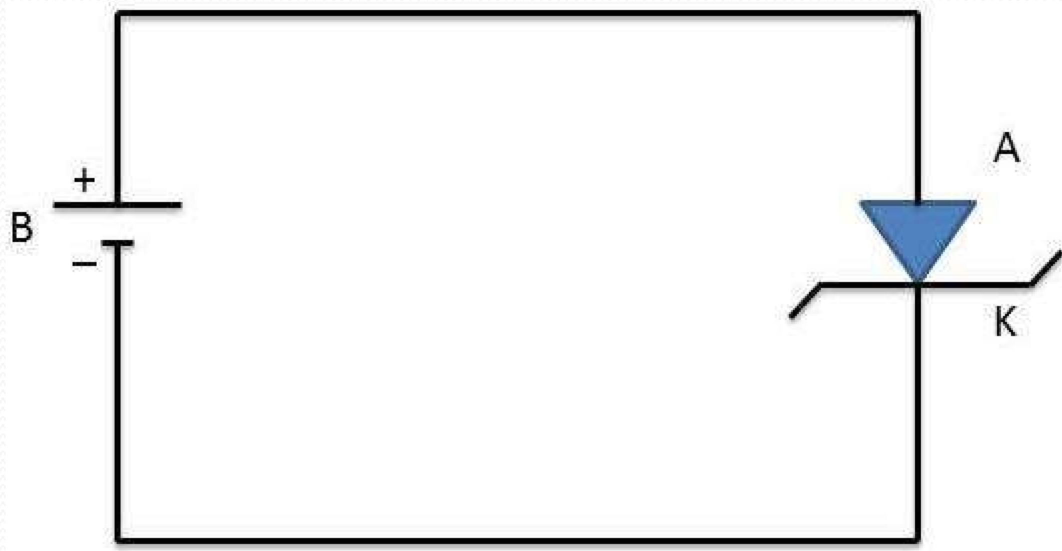




- The arrowhead on a Zener diode symbol points in the direction of forward current when the diode is forward biased.
- The Zener diode is normally operated in reverse breakdown and the current direction is then from anode to cathode

Zener Diode – Forward bias

- When a Zener diode is forward biased, it operates as a normal diode.
- In forward biased P side connected to +ve and N side connected to –ve terminal of battery. In this case the electrons and holes are swept across the junction an large current flow through it.



Forward bias of Zener Diode

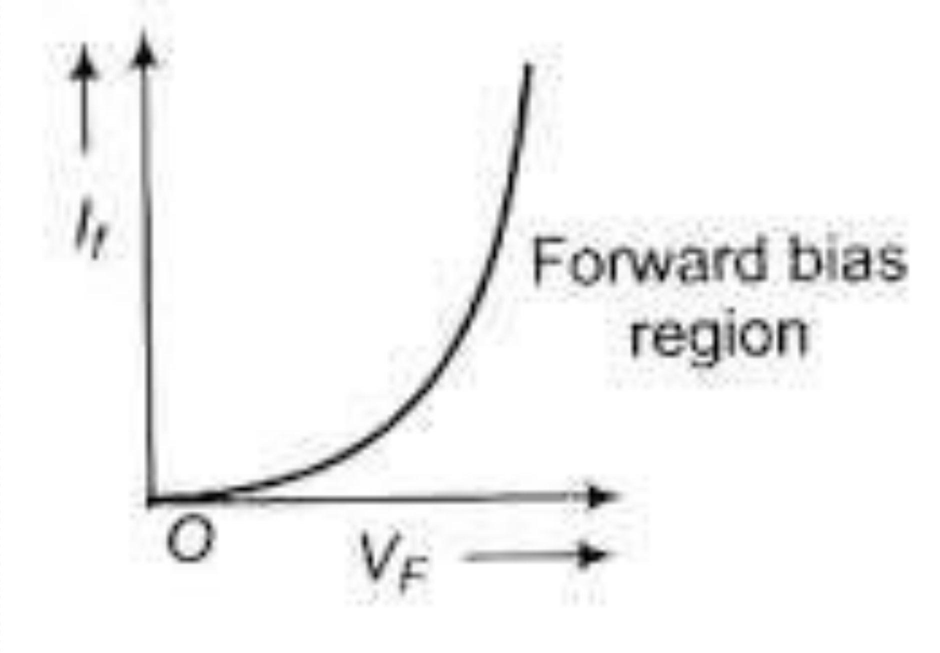
Zener Diode – Reverse biased

- In case of reverse biased current practically zero and at certain voltage which called Zener voltage the current increases sharply.
- Each Zener diode has breakdown rating which specifies the max voltage that can be dropped across it.

Reverse bias of Zener Diode

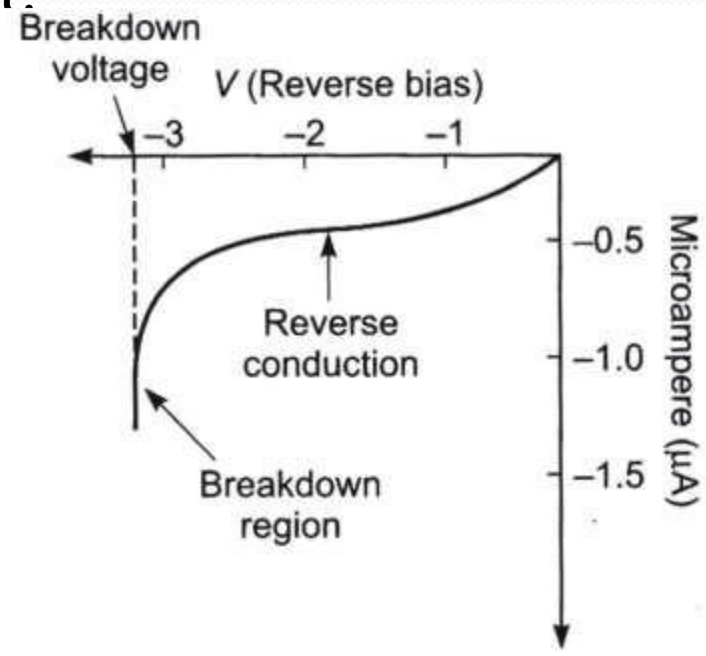
Zener Diode - Characteristics

- The figure shows, the forward characteristics is same as that of ordinary forward biased junction diode.

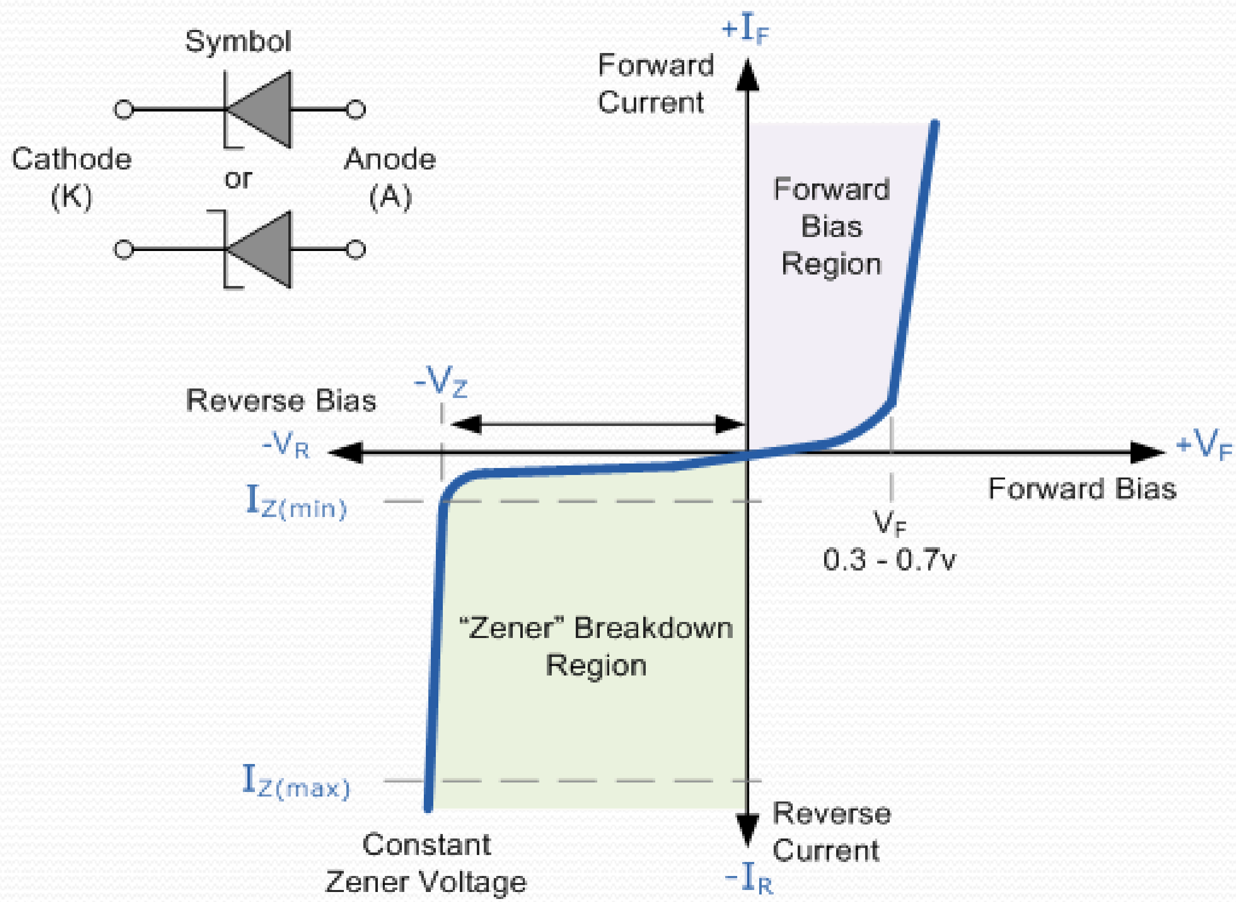


Zener Diode - Characteristics

- In reverse direction however there is a very small leakage current between 0V an the Zener voltage –i.e. tiny amount of current is able to flow.
- Then, when the voltage reaches the breakdown voltage (Vz), suddenly current flow through it.

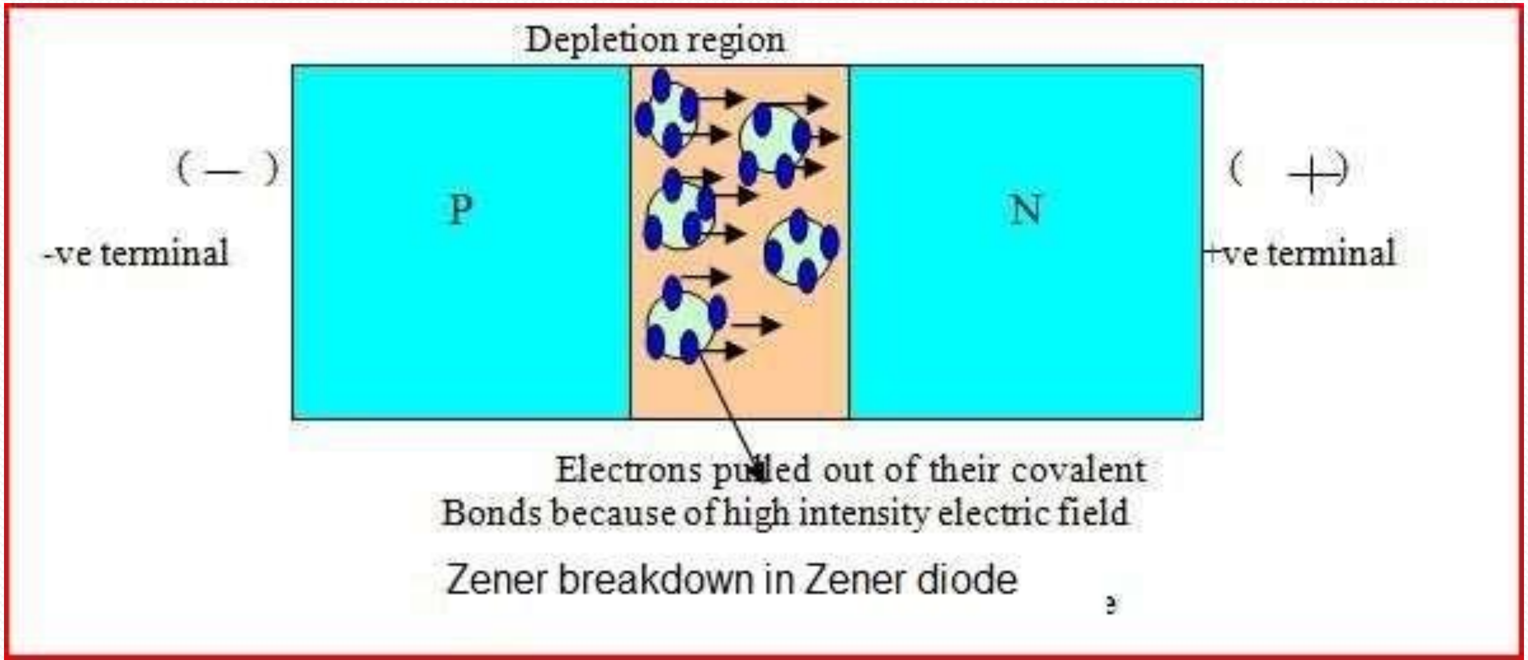


- Notice that as the reverse voltage is increased the leakage current remains essentially constant until the breakdown voltage is reached where the current increasesdramatically.



Zener breakdown

- The Zener effect is a type of electrical breakdown in a reverse biased p-n diode in which the electric field enables tunneling of electrons from the valence to the conduction band of a semiconductor, leading to a large number of free minority carriers, which suddenly increase the reverse current.



The most common application of Zener Diode

1. Zener Regulator

2. Zener Comparator

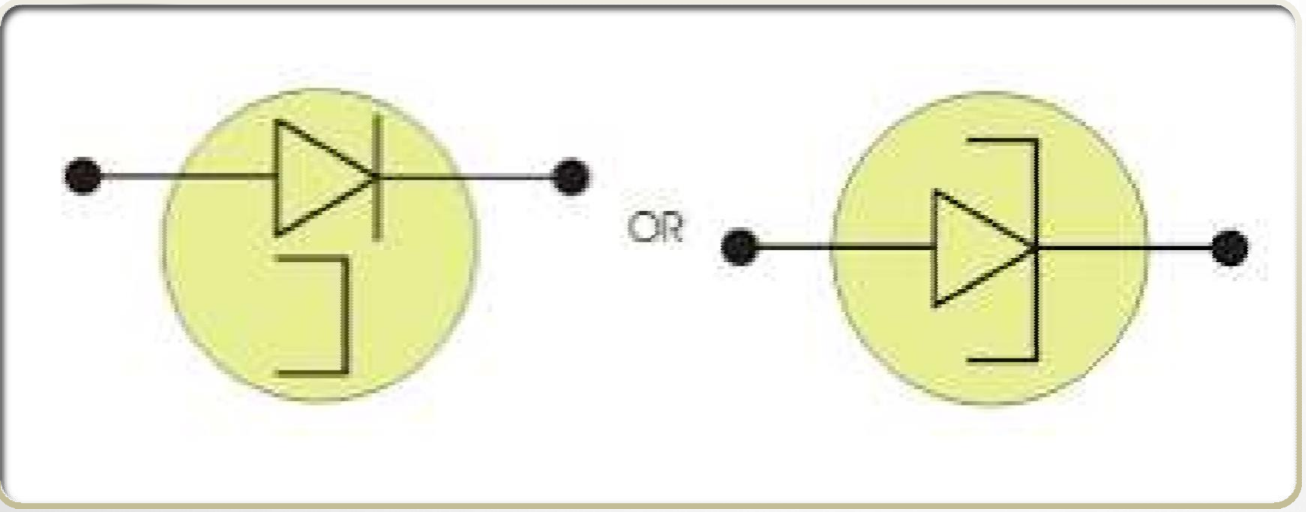
3. Zener Limiters

4. Zener in PowerSupplies

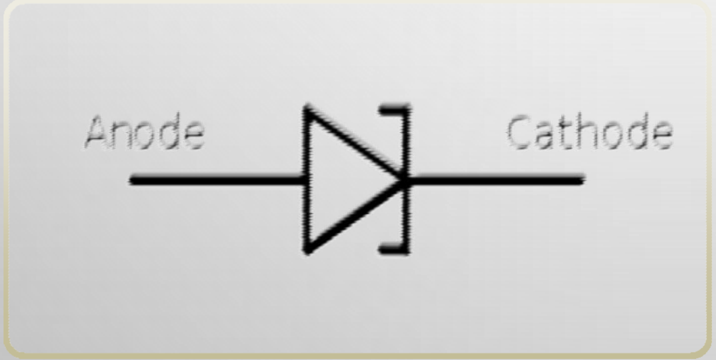
TUNNEL DIODE

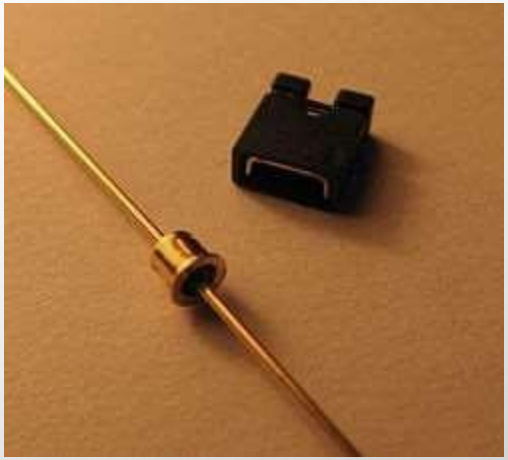
TUNNEL DIODE (ESAKI DIODE)

- IT WAS INTRODUCED BY LEO ESAKI IN 1958.
- HEAVILY-DOPED P-N JUNCTION
  - IMPURITY CONCENTRATION IS 1 PART IN 10^3 AS COMPARED TO 1 PART IN 10^8 IN P-N JUNCTION DIODE
- WIDTH OF THE DEPLETION LAYER IS VERY SMALL (ABOUT 100 A).
- IT IS GENERALLY MADE UP OF GE AND GAAS.
- IT SHOWS TUNNELING PHENOMENON.
- CIRCUIT SYMBOL OF TUNNEL DIODE IS :



Tunnel diode symbol





Physical structure

CHARACTERISTIC OF TUNNEL DIODE

Ip:- Peak Current

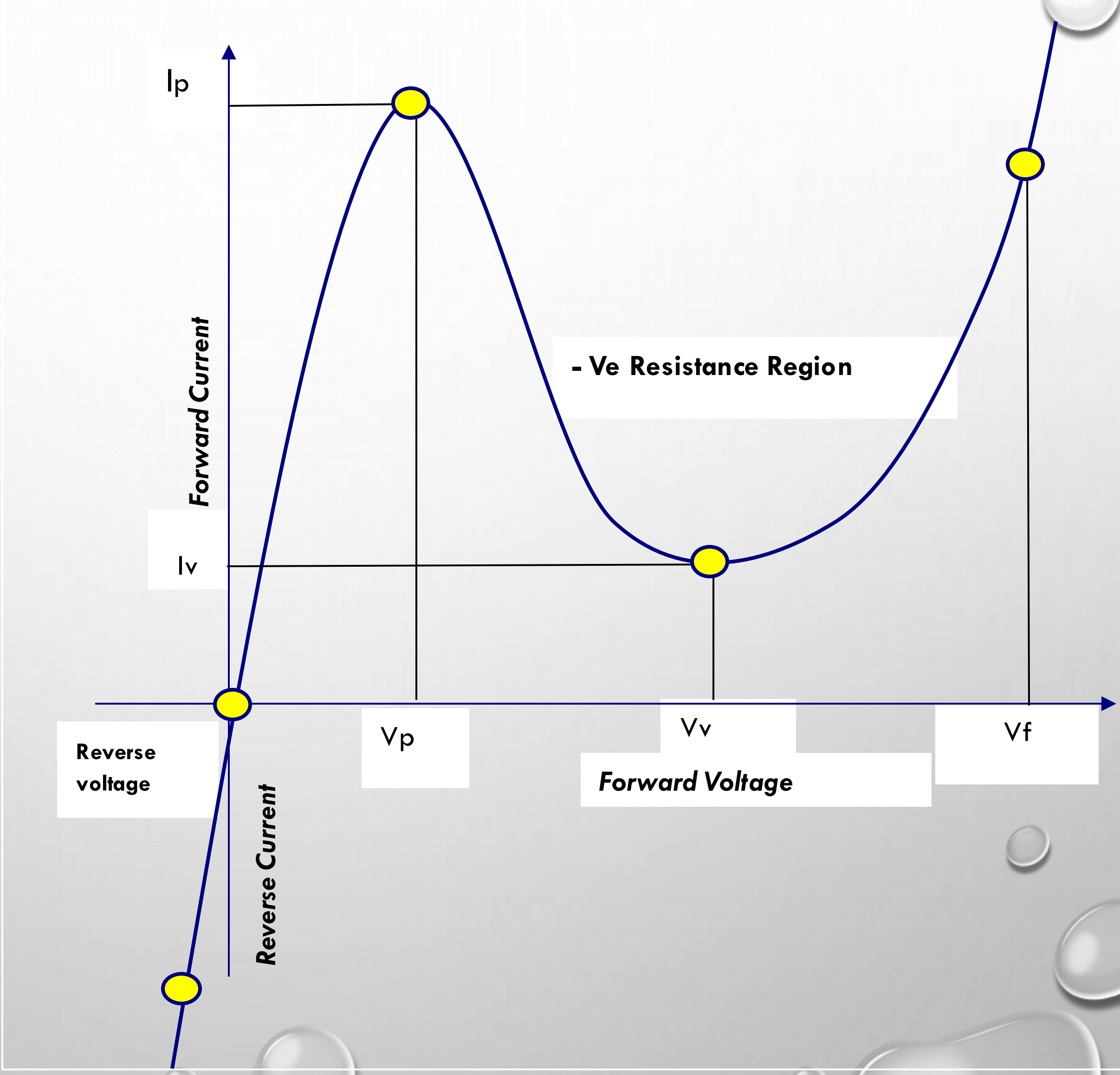
Iv :- Valley Current

Vp:- Peak Voltage

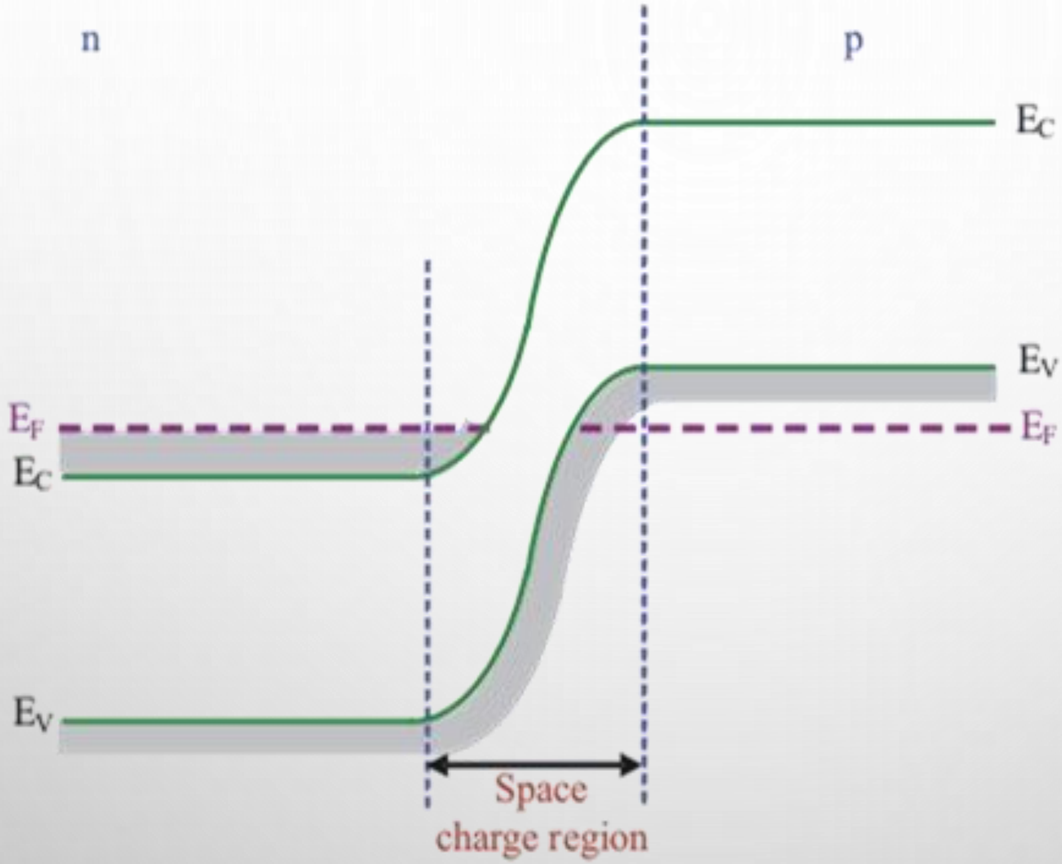
Vv:- Valley Voltage

Vf:- Peak Forward

Voltage



ENERGY BAND DIAGRAM

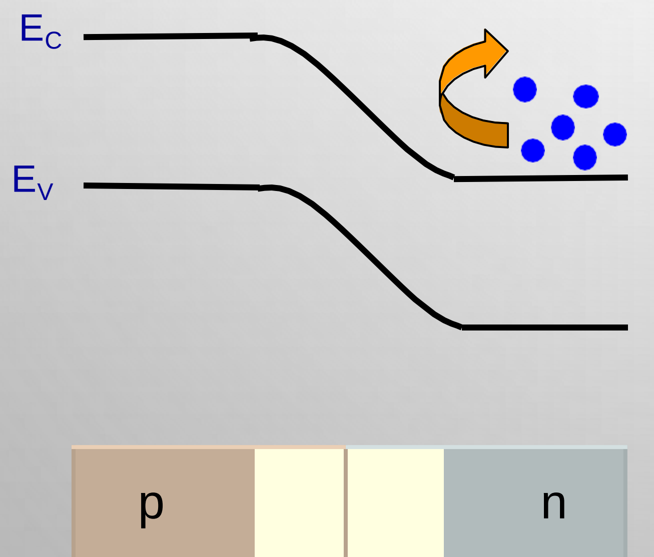


Energy-band diagram of pn junction in thermal equilibrium in which both the n and p region are degenerately doped.

ELECTRON TUNNELING IN P-N JUNCTION

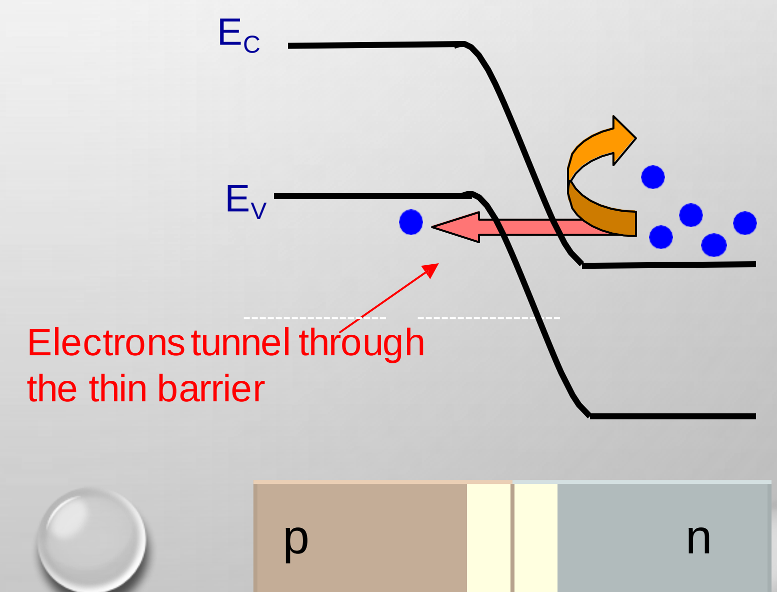
- When the p and n region are highly doped, the depletion region becomes very thin (~10nm).
- In such case, there is a finite probability that electrons can tunnel from the conduction band of n-region to the valence band of p-region
- During the tunneling the particle ENERGY DOES NOT CHANGE

Thick depletion layer



High doping

Thin depletion layer

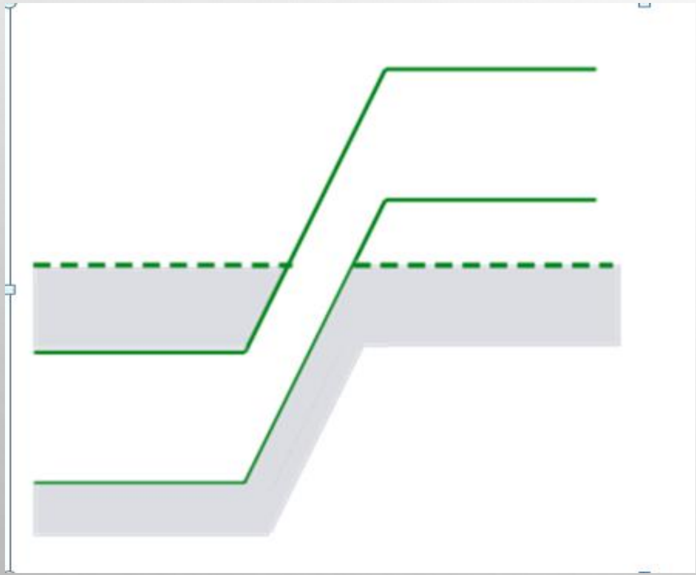


TUNNEL DIODE OPERATION

- When the semiconductor is very highly doped (the doping is greater than N_0) the Fermi level goes above the conduction band for n-type and below valence band for p-type material. These are called degenerate materials.

Under Forward Bias

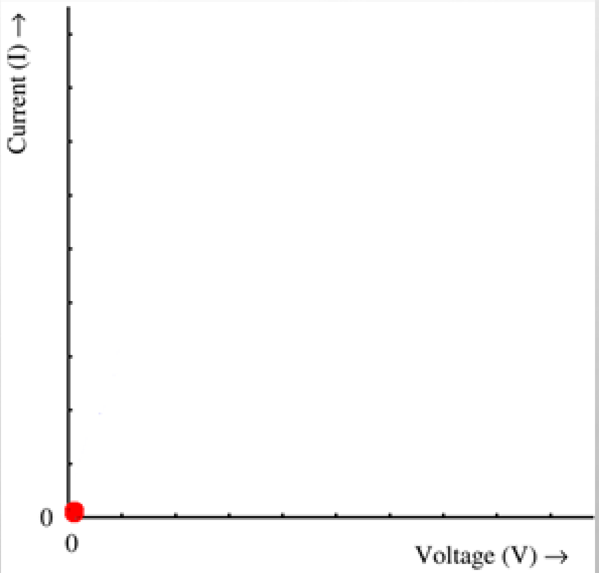
Step 1: At zero bias there is no current flow



E_C

E_V

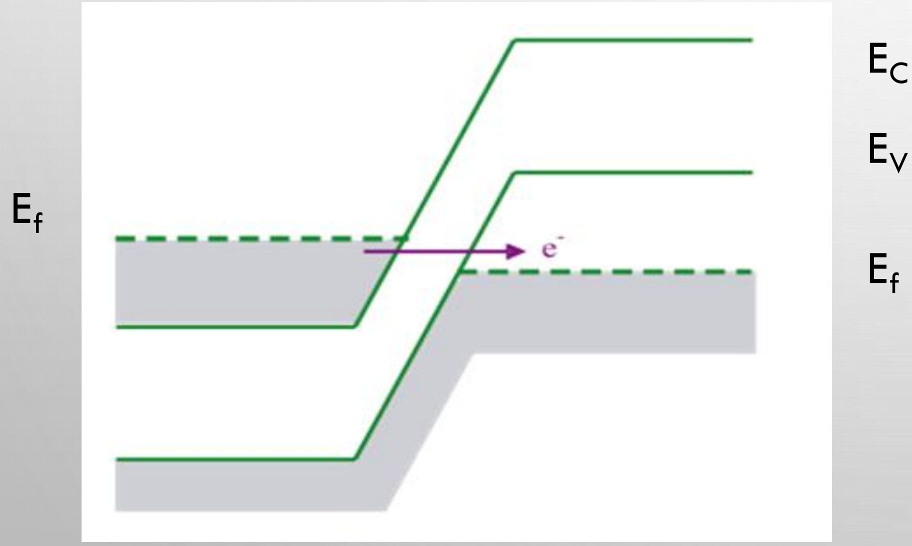
E_f

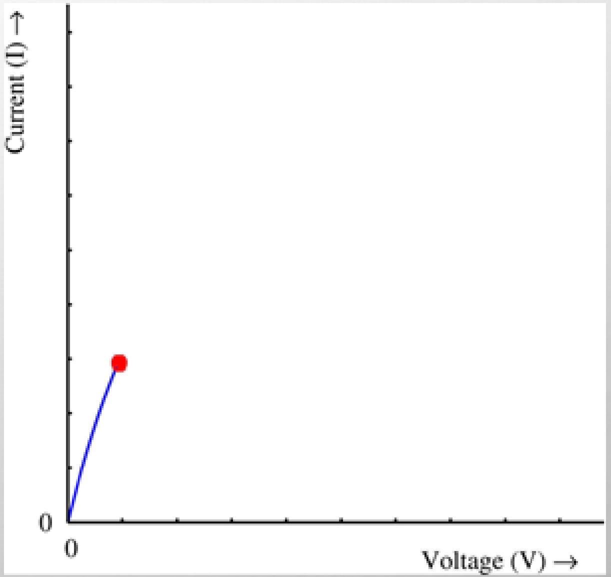


*…CONTINUED…*OPERATION OF A TUNNEL DIODE

Step 2: **A small forward bias is applied. Potential barrier is still very high – no noticeable injection and forward current through the junction.**

However, electrons in the conduction band of the n region will tunnel to the empty states of the valence band in p region. This will create a forward bias tunnel current

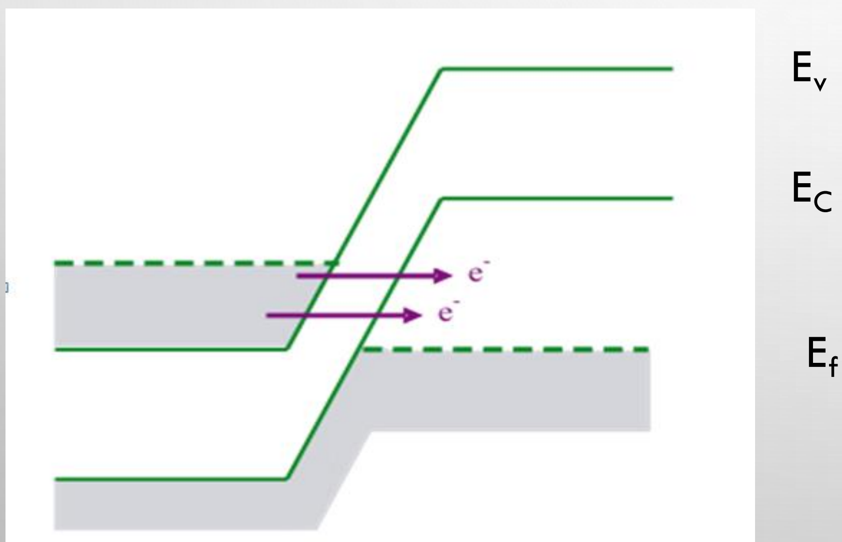


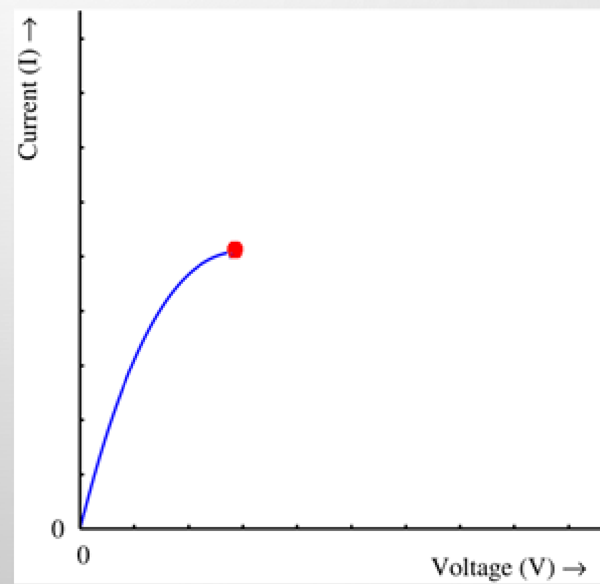


Direct tunneling current starts growing

…*CONTINUED*…TUNNEL DIODE OPERATION

Step 3: **With a larger voltage the energy of the majority of electrons in the n-region is equal to that of the empty states (holes) in the valence band of p-region; this will produce maximum tunneling current**

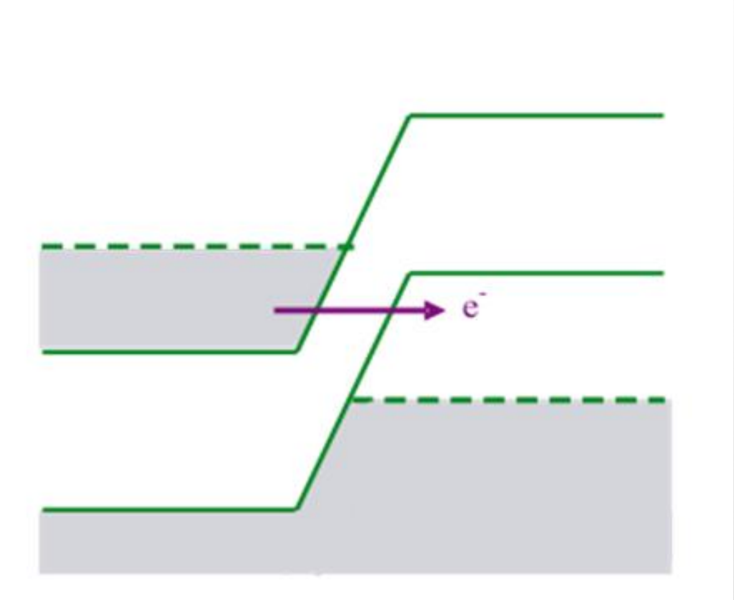




Maximum Direct tunneling current

*…CONTINUED…*TUNNEL DIODE OPERATION

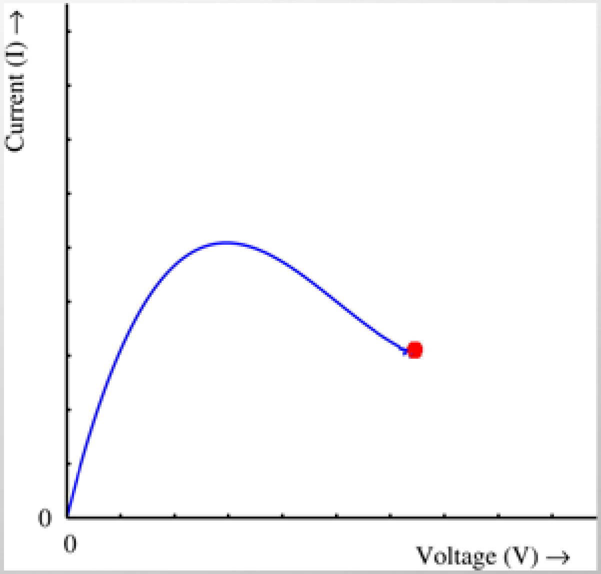
Step 4: **As the forward bias continues to increase, the number of electrons in the n side that are directly opposite to the empty states in the valence band (in terms of their energy) decrease. Therefore decrease in the tunneling current will start.**



E_V

E_C

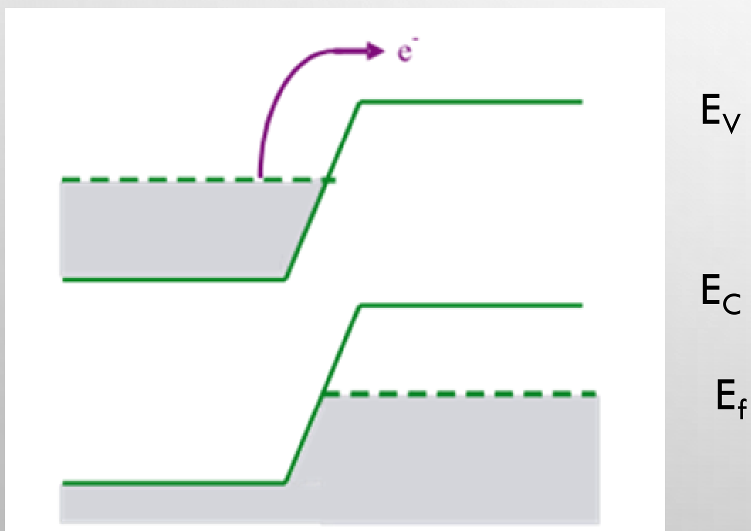
E_f

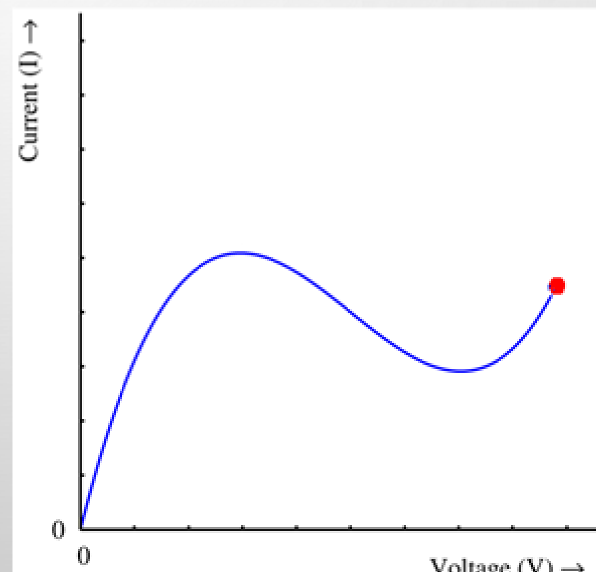


Direct tunneling current decreases

…*CONTINUED*…TUNNEL DIODE OPERATION

<u>Step 5:</u> As more forward voltage is applied, the tunneling current drops to zero. But the regular diode forward current due to electron – hole injection increases due to lower potential barrier.

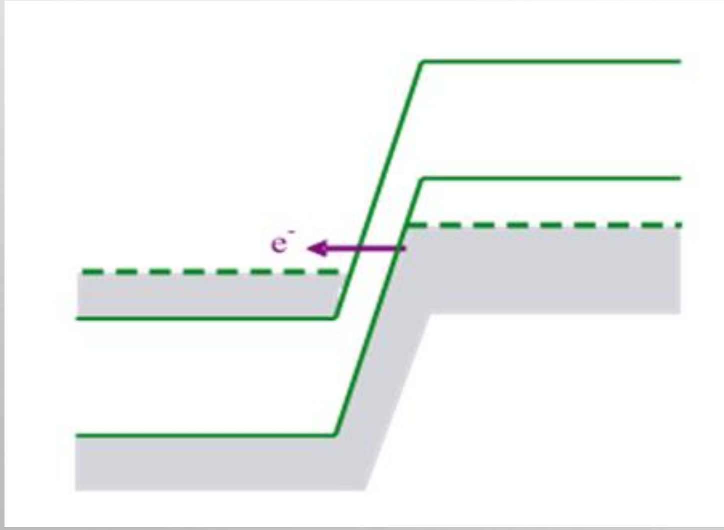




No tunneling current; diffusion current starts growing

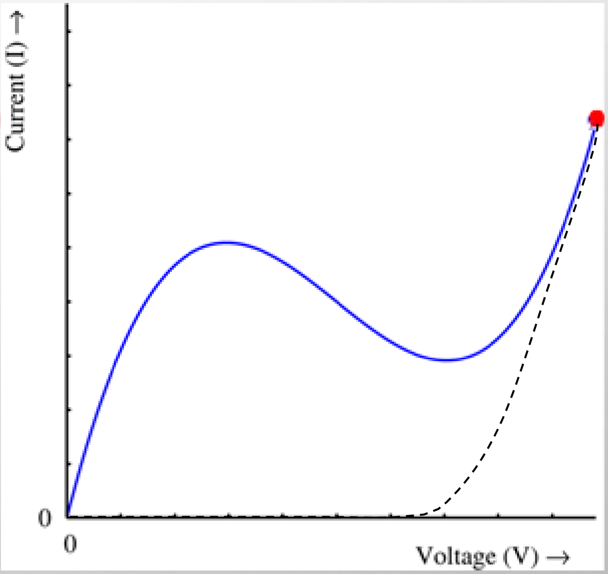
*…CONTINUED…*OPERATION OF A TUNNEL DIODE

Step 6: With further voltage increase, the tunnel diode I-V characteristic is similar to that of a regular p-n diode.



E_V

E_C



TUNNELING DIODE THEORY

- At zero forward bias, the energy levels of conduction electrons in *N*-region of the junction are slightly out of alignment with the energy levels of holes in the *P*-region.

  - As the forward voltage is slightly increased, electron levels start getting aligned with the hole levels on the other side of junction thus permitting some electrons to cross over. This kind of junction crossing is called tunneling.

TUNNELING DIODE THEORY

- As voltage is increased to peak voltage (*VP*), all conduction band electrons in the *N*-region are able to cross over to the valence band in the *P*-region because the two bands are exactly aligned. Hence, maximum current (called peak current *IP*) flows in the circuit.
- After *VP* as the applied voltage is increased, current starts decreasing because the two bands start gradually getting out of alignment.

- It reaches minimum value (called valley current) when the two are totally out of alignment at a forward bias of *VV* (valley voltage).
- For voltages greater than *VV*, current starts increasing again exactly as it does in the case of an ordinary P-N junction diode.
- Tunneling is much faster than normal crossing which enables a tunnel diode to switch ON and OFF much faster than an ordinary diode. That is why a tunnel diode is extensively used in special applications requiring very fast switching speeds like high-speed computer memories and high frequency oscillators .

TUNNEL DIODE APPLICATIONS

- Rectifier
- Switch
- Oscillator
- amplifier

ADVATAGES

The advantages of a tunnel diode are :

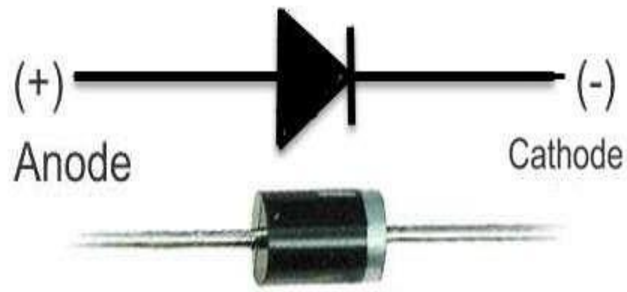
1. low noise
2. ease of operation
3. high speed
4. low power

DISADVANTAGES

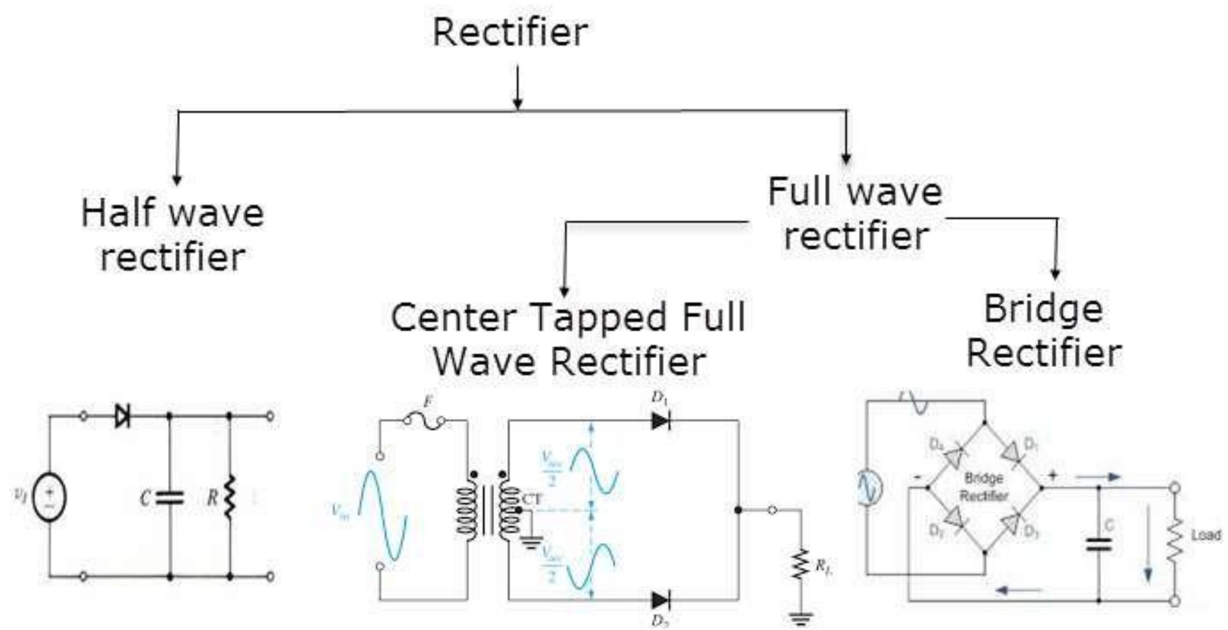
1. THE VOLTAGE RANGE OVER WHICH IT CAN BE OPERATED PROPERLY IS 1 V OR LESS.

2. BEING A TWO-TERMINAL DEVICE, IT PROVIDES NO ISOLATION BETWEEN THE INPUT AND OUTPUT CIRCUITS

RECTIFIERS

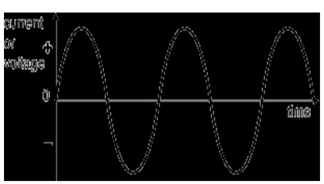


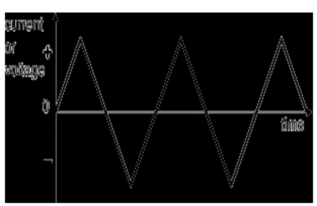
- **A rectifier is a circuit which converts the Alternating Current (AC) input power into a Direct Current (DC) output power. Diode and SCR are primarily used in rectifier circuits.**

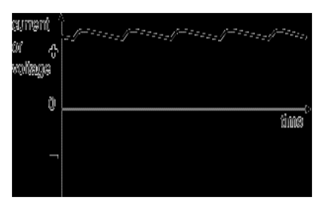


Difference between AC and DC signals.

AC (Alternating current)	DC (Direct Current)
AC signal Flows one way, then the other way, continually reversing direction.	Direct Current signal always flows in the same direction, but it may increase and decrease.
Continually changing between positive (+) and negative (-).	A DC signal is always positive (or always negative), but it may increase and decrease.
Rate of changing direction is called the **frequency** of the AC and it is measured in **hertz (Hz)**.	Frequency is zero.
Average value of signal is zero.	It will always have average value.







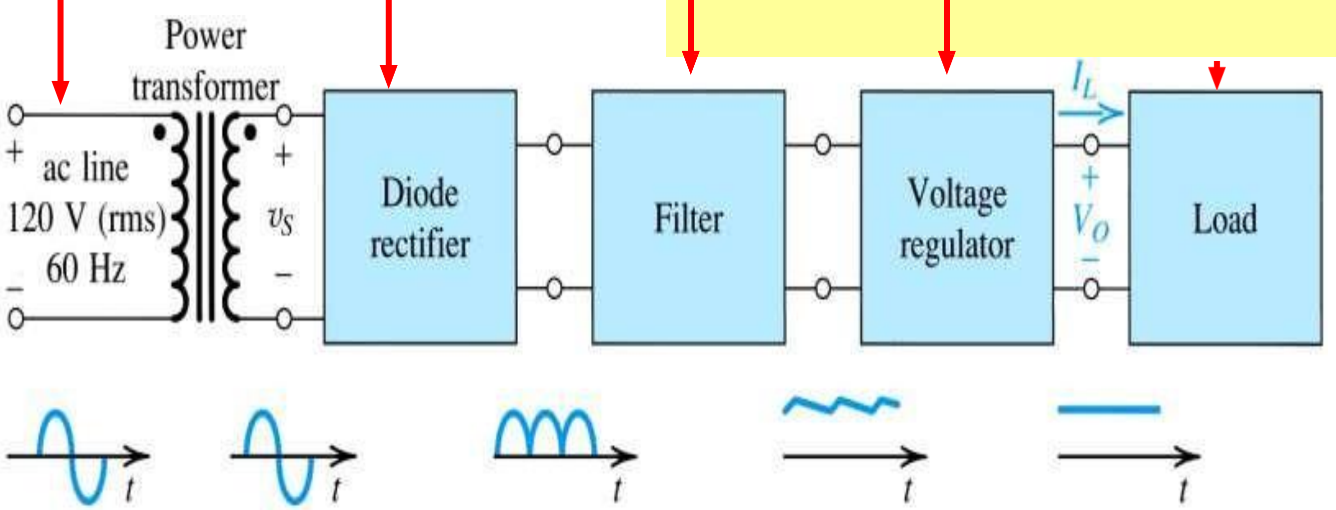
step #1: increase / decrease rms magnitude of AC wave using transformer

step #2: convert full-wave AC to half-wave DC (still time-varying and periodic)

step #3: employ low-pass filter to reduce ripple component by > 90%

step #4: employ voltage regulator to eliminate ripple

step #5: supply dc load



Half Wave Rectifier

- **The process of removing one-half of the input signal to establish a dc level is called *half-wave rectification*.**
- **In Half wave rectification, the rectifier conducts current during positive half cycle of input ac signal only.**

  Negative half cycle is suppressed.

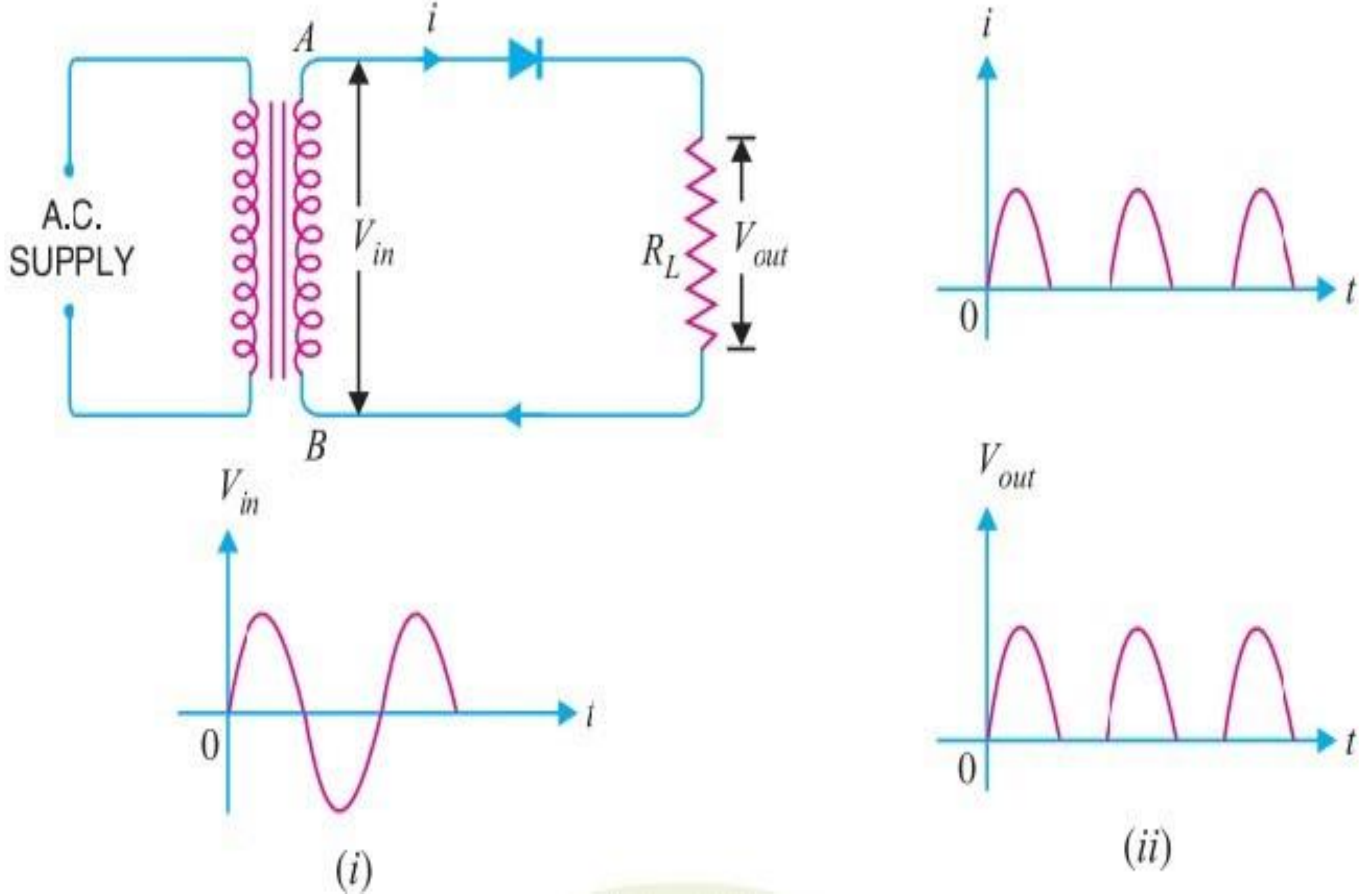


Fig:~ Circuit diagram of Half Wave Rectifier.

Operation

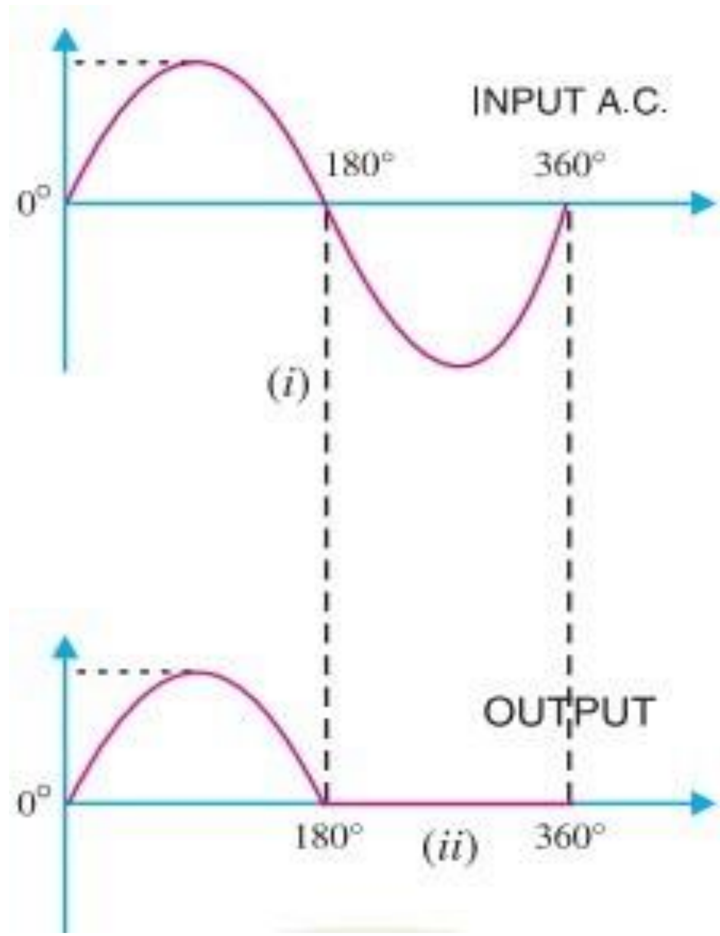
- **AC voltage across secondary terminals AB changes its polarity after each half cycle.**
- **During negative half cycle terminal A is negative so diode is reversed biased and conducts no current.**
- **So, current flows through diode during positive half cycle only.**
- **In this way current flows through load RL in one direction only.**

Output frequency of Half wave rectifier

Output frequency of HWR is equal to input frequency.

This means when input ac completes one cycle, rectified wave also completes one cycle.

$$f_{out} = f_{in}$$



Advantages & Disadvantages

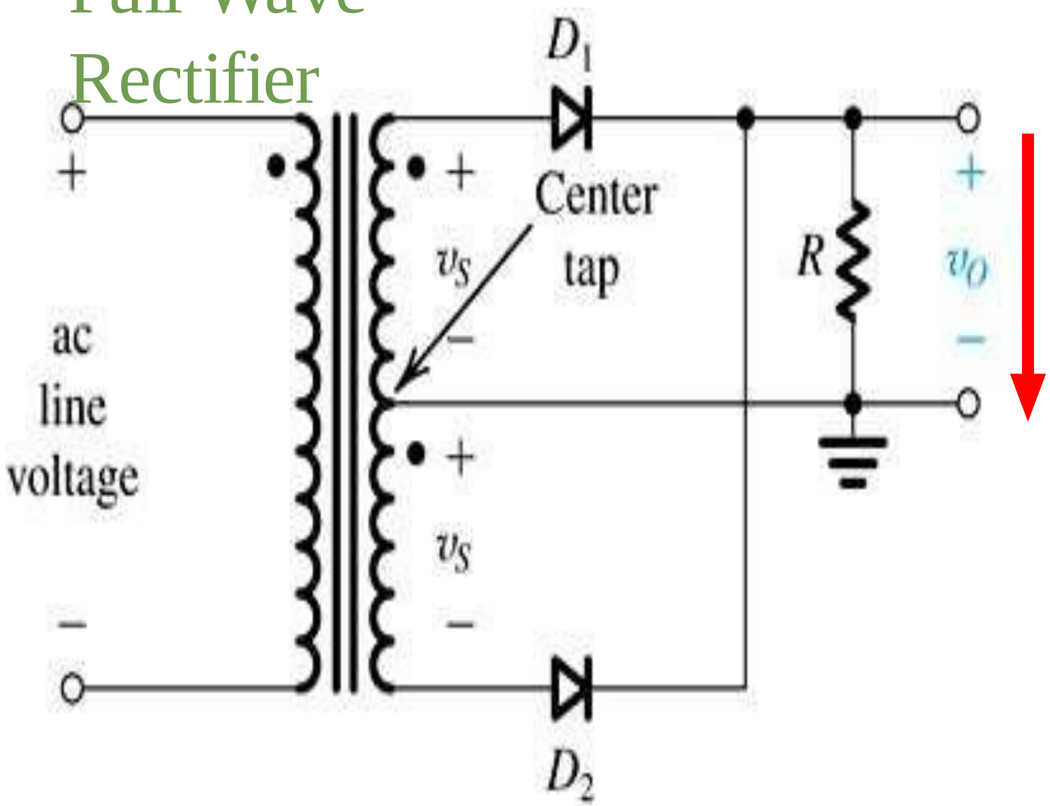
Advantages:~

- **The circuit of half wave rectifier is very simple and of low cost.**

Disadvantages:~

- **The pulsating current in output contains ac components whose frequency is equal to supply frequency. So, filtering is needed.**
- **The ac supply delivers power during half cycle only. So, output is low.**

Full-Wave Rectifier



When instantaneous source voltage is positive, D_1 conducts while D_2 blocks…

when instantaneous source voltage is negative, D_2 conducts while D_1 blocks

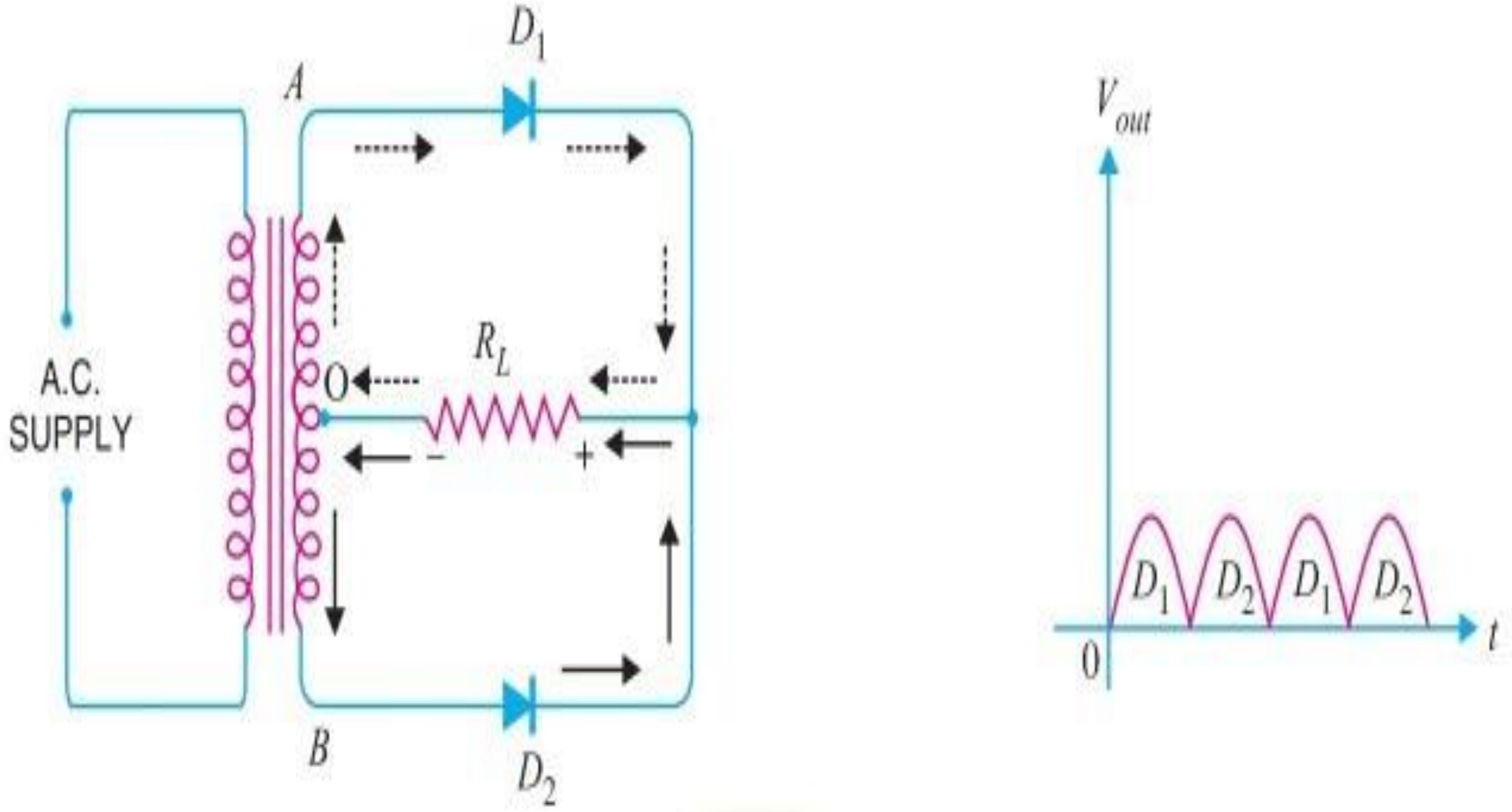


Fig:~ Circuit diagram of Centre tap Full Wave Rectifier.

Full wave Rectifier

- **In Full wave rectification current flow through the load in same direction for both half cycle of input ac.**

- **This can be achieved with two diodes working alternatively.**

- **For one half cycle one diode supplies current to load and for next half cycle another diode works.**

Centre tap full wave rectifier

¬Circuit has two diodes D1 , D2 and a centre tap transformer.

¬During positive half cycle, Diode D1 conducts and

during negative half cycle, Diode D2 conducts.

¬It can be seen that current through load RL is in the

same direction for both the cycles.

Full wave bridge rectifier

- **In full wave bridge rectifier, four diodes are arranged in the form of a bridge.**

- **The main advantage of this bridge circuit is that it does not require a special centre tapped transformer.**

- **The single secondary winding is connected to one side of the diode bridge network and the load to the other side.**

Full Wave Bridge Rectifier

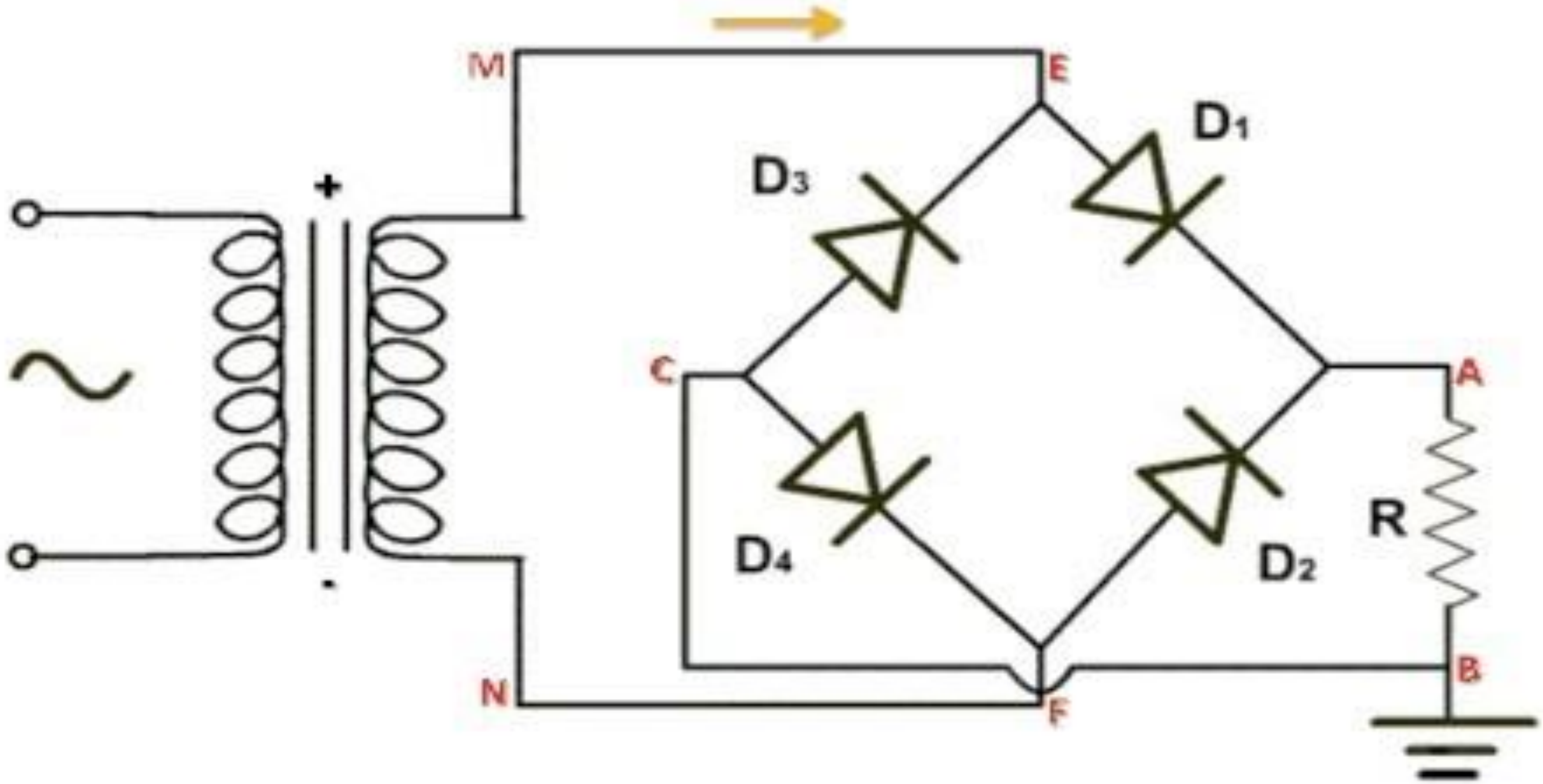
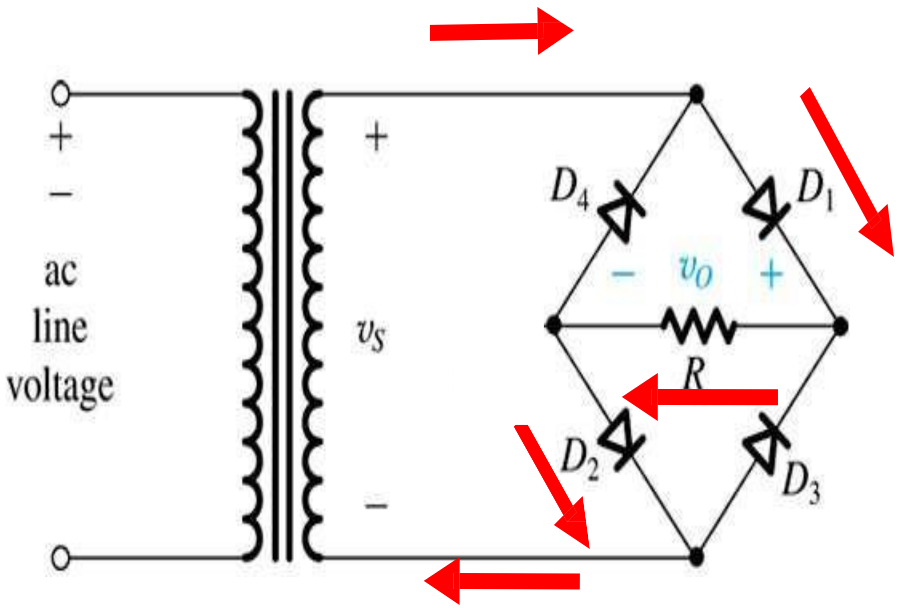


Fig:~ Circuit diagram of Full Wave Bridge Rectifier.

Bridge Rectifier



$PIV = Vm$
Ripple frequency
= 100 Hz

when source voltage is positive, D_1 and D_2 conduct while D_3 *and* D_4 block
when source voltage is negative, D_3 and D_4 conduct while D_1 *and* D_2 block

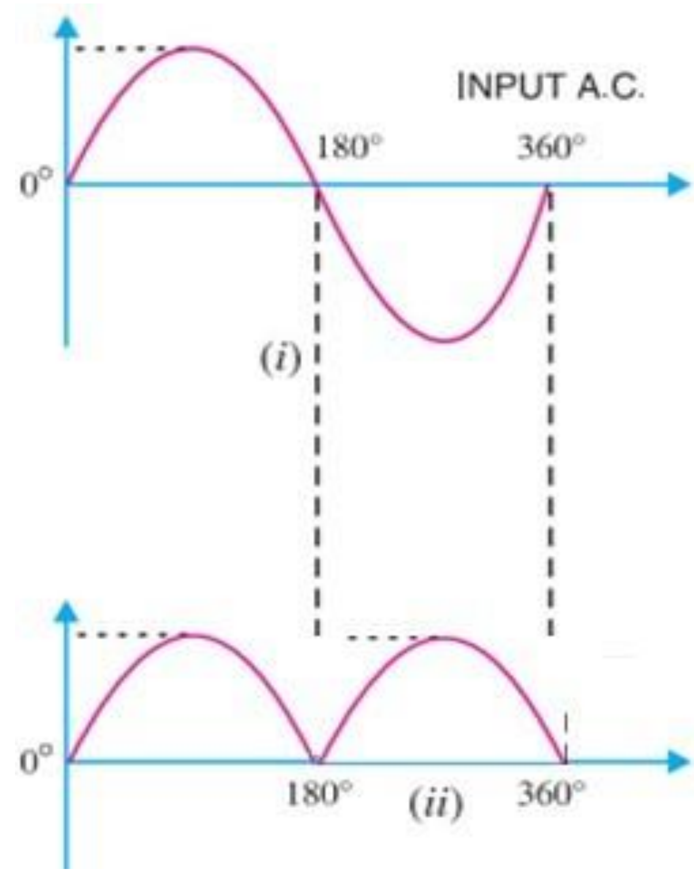
- An alternative implementation of the full-wave rectifier is **bridge rectifier**
- Does not require center-tapped transformer
- Four diodes instead of two

Output frequency of Full wave rectifier

- Output frequency of FWR is equal to double of input frequency.

- This means when input ac completes one cycle, rectified wave completes two cycle.

$$f_{out} = 2 f_{in}$$



Advantages & Disadvantages

- **Advantages:**

I. **Need for centre tap transformer is eliminated.**

II. **Output is twice than that of centre tap circuit.**

- **Disadvantages:**

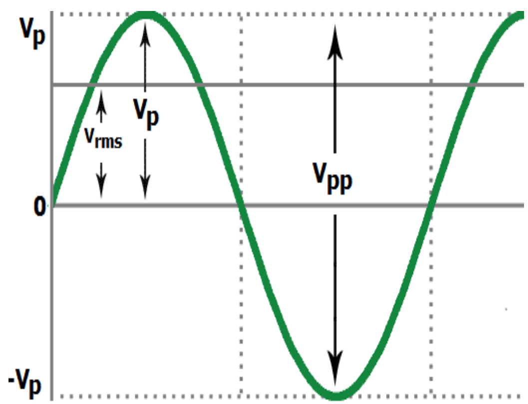
I. **Requires 4 diodes.**

II. **Internal resistance voltage drop is twice than that of Centre Tap Circuit.**

Comparison of Rectifiers

Properties	Half Wave Rectifier	Full Wave Center Tap Rectifier	Full Wave Bridge Rectifier
Number of Diodes	1	2	4
D.C Current	Im / π	2 Im / π	2 Im / π
Transformer Necessary	No	Yes	No
Max Value of Current	Vm / (rf + RL)	Vm / (rf + RL)	Vm / (2rf + RL)
Ripple Factor	1.21	0.482	0.482
O/P Frequency	fin	2 fin	2 fin
Max Efficiency	40.6%	81.2%	81.2%
Peak Inverse Voltage	Vm	2 Vm	Vm

Relationship between Peak-to-peak and rms value.



$$V_{rms} = \frac{1}{\sqrt{2}} * V_p = 0.7071 * V_p$$

$$V_{rms} = \frac{1}{2\sqrt{2}} * V_{pp} = 0.35355 * V_{pp}$$

$$V_{rms} = \frac{\pi}{2\sqrt{2}} * V_{avg} = 1.1107 * V_{avg}$$

Comparison

Sr. No.	Parameter	Half wave	Full wave	Bridge
1.	Number of diodes	1	2	4
2.	Average D.C. current (I_{DC})	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
3.	Average D.C. voltage (E_{DC})	$\frac{E_{sm}}{\pi}$	$\frac{2E_{sm}}{\pi}$	$\frac{2E_{sm}}{\pi}$
4.	R.M.S. current (I_{RMS})	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
5.	D.C. power output (P_{DC})	$\frac{I_m^2 R_L}{\pi^2}$	$\frac{4}{\pi^2} I_m^2 R_L$	$\frac{4}{\pi^2} I_m^2 R_L$
6.	A.C. power input (P_{AC})	$\frac{I_m^2 (R_L + R_f + R_s)}{4}$	$\frac{I_m^2 (R_f + R_s + R_L)}{2}$	$\frac{I_m^2 (2R_f + R_s + R_L)}{2}$
7.	Maximum rectifier efficiency (η)	40.6 %	81.2 %	81.2 %
8.	Ripple factor (γ)	1.21	0.482	0.482
9.	Maximum load current (I_m)	$\frac{E_{sm}}{R_s + R_f + R_L}$	$\frac{E_{sm}}{R_s + R_f + R_L}$	$\frac{E_{sm}}{R_s + 2R_f + R_L}$
10.	PIV rating of diode	E_{sm}	$2\ E_{sm}$	E_{sm}
11.	Ripple frequency	50 Hz	100 Hz	100 Hz
12.	T.U.F.	0.287	0.693	0.812

Half-wave Rectifier : Takeaways

Rectifier Efficiency

Rectifier efficiency is the ratio of output DC power to the input AC power. ***For a half wave rectifier, rectifier efficiency is 40.6%.***

Advantages of Half Wave Rectifier

- Affordable
- Simple connections
- Easy to use as the connections are simple
- Number of components used are less

Disadvantages of Half Wave Rectifier

- Ripple production is more
- Harmonics are generated
- Utilization of transformer is very low
- Efficiency of rectification is low

Applications of Half Wave Rectifier

- **Power rectification**
- **Signal demodulation:** for demodulating the AM signals.
- **Signal peak detector:** for detecting the peak of the incoming waveform.

Full-wave Rectifier : Takeaways

Advantages of Full Wave Rectifier

The rectifier efficiency of a full wave rectifier is high ***(81.2%.)***

The power loss is very low

Number of ripples generated are less

Disadvantages of Full Wave Rectifier

Expensive and complicated circuit.

Applications of Full Wave Rectifier

1. For supplying polarized voltage in welding and for this bridge rectifiers are used.
2. For detecting amplitude of modulated radio signals.

Clippers and Clampers

Clipper Circuits or Limiters or Slicers

- The circuits which are used to clip off unwanted portion of the waveform, without distorting the remaining part of the waveform are called clipper circuits or clippers.
- The half wave rectifier is the best and simplest type of clipper circuit which clips off the negative portion of the input Signal.
- A diode is most important element of any clipper circuit.
- It acts as a switch.
- It makes the circuit open, when reverse biased while it makes the circuit closed when forward biased.

1. **Classification of Clippers**
   - Series clipper
   - Parallel Clipper

2. **Series clipper**

- When the diode is connected in series with the load, it is called Series clipper.
- A series clipper can be used to clip off the entire positive or negative half cycles of input waveforms.
- It also can be used to clip off the portion above the certain reference voltage or below the certain reference voltage.

3. **Parallel Clipper**

- When the diode is connected in parallel to the load, it is called Parallel Clipper.

4. **Types of Series clipper**
   - Series Negative Clipper
   - Series Positive Clipper
   - Clipping Above Reference Voltage V_R
   - Clipping Below Reference Voltage V_R

Series Negative Clipper Circuit

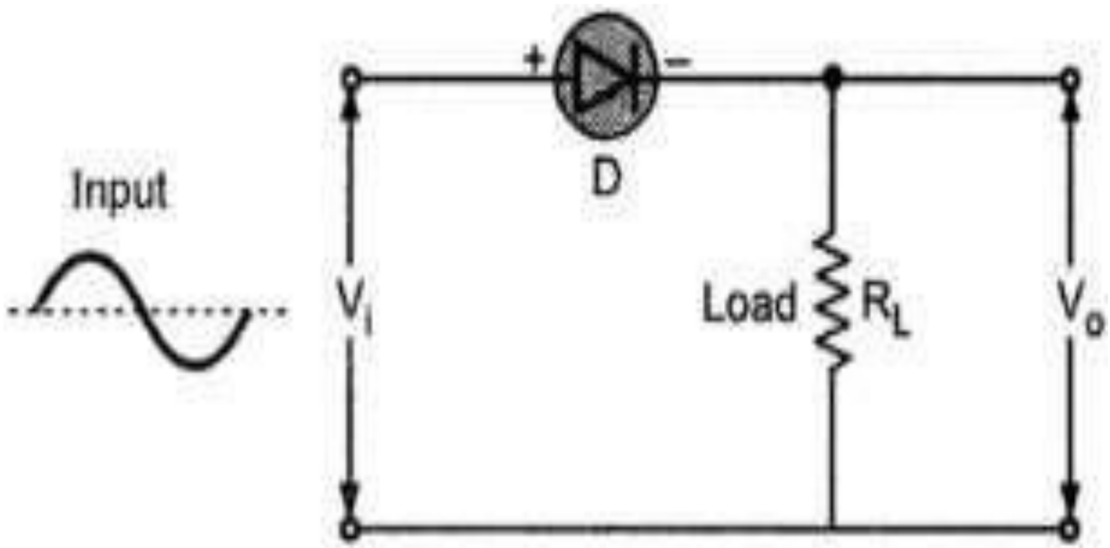
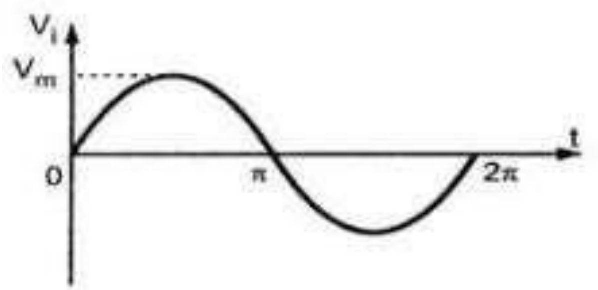


Fig. Negative series clipper

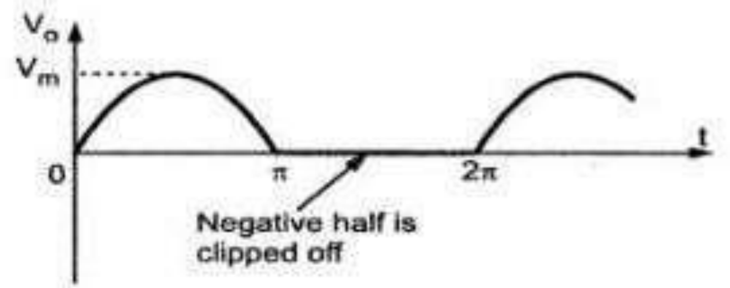
1. Operation:

- Consider a circuit shown in the where diode is connected in series with the load.
- For a positive half cycle, the diode D is forward biased and hence the voltage waveform across R_L looks like a positive half cycle of the input voltage.

- While for a negative half cycle, diode D is reverse biased and hence will not conduct at all. Hence there will not be any voltage available across resistance RL.
- Hence the negative half cycle of input voltage gets clipped off.
- The input waveform and the corresponding output voltage waveform is shown in the Fig.



(a) Input voltage



(b) Output voltage

Fig. Input and Output waveforms

2. Transfer characteristics:

- The graph of output variable against input variable of the circuit is called transfer characteristics of the circuit.
- Thus for the negative series clipper, the graph of V_o against V_i is its transfer characteristics.
- The mathematical equation for such a graph, assuming ideal diode is given by,

$$V_o = V_i \qquad \ldots \text{ for } V_i \geq 0$$

$$V_o = 0, \qquad \ldots \text{ for } V_i < 0$$

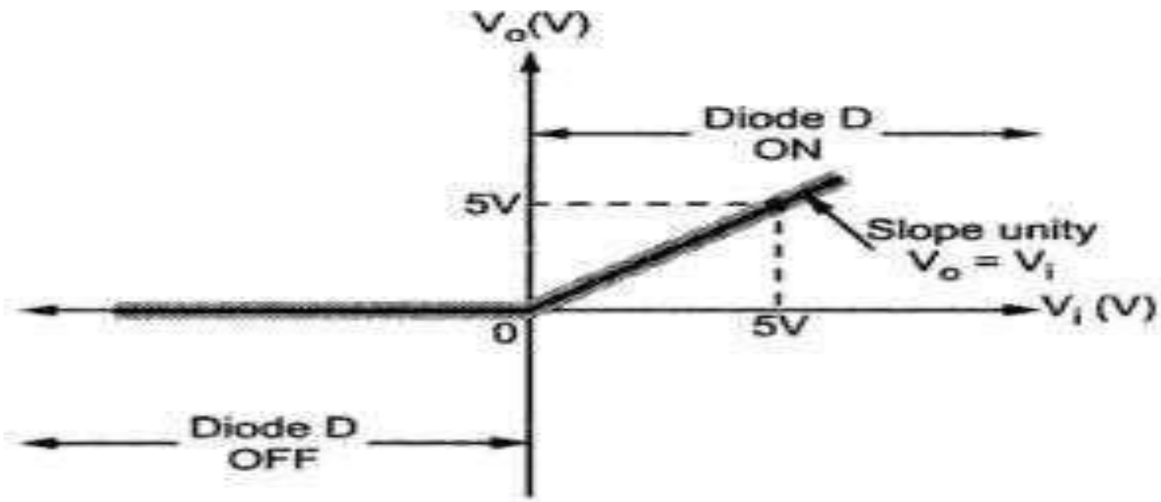
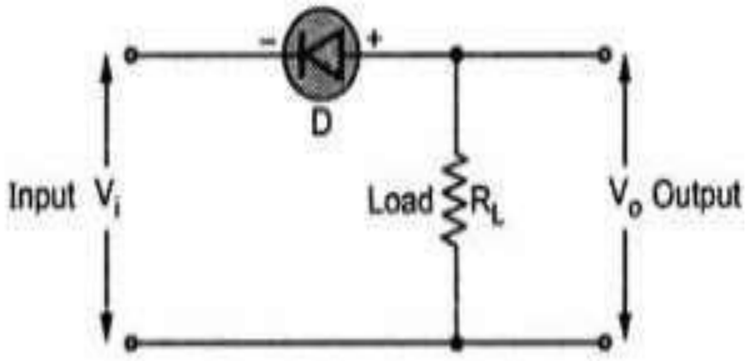


Fig. 1.46 Transfer characteristics with Ideal diode

Series Positive Clipper Circuit

- It is similar to series negative clipper, a circuit which clippers off positive part of the input can be obtained.
- The positive series clipper can be obtained by changing the direction of diode in negative clipper circuit.



Positive series clipper

1. **Operation:**

- For positive half cycle of input, $V_i > 0V$ and diode is reverse biased. Hence it acts as open circuit and V_o=0V.
- For negative half cycle, when V_i<0, the diode conducts.
- The output voltage V_o available is same as input voltage.
- Thus entire negative half cycle of input is available at the output.

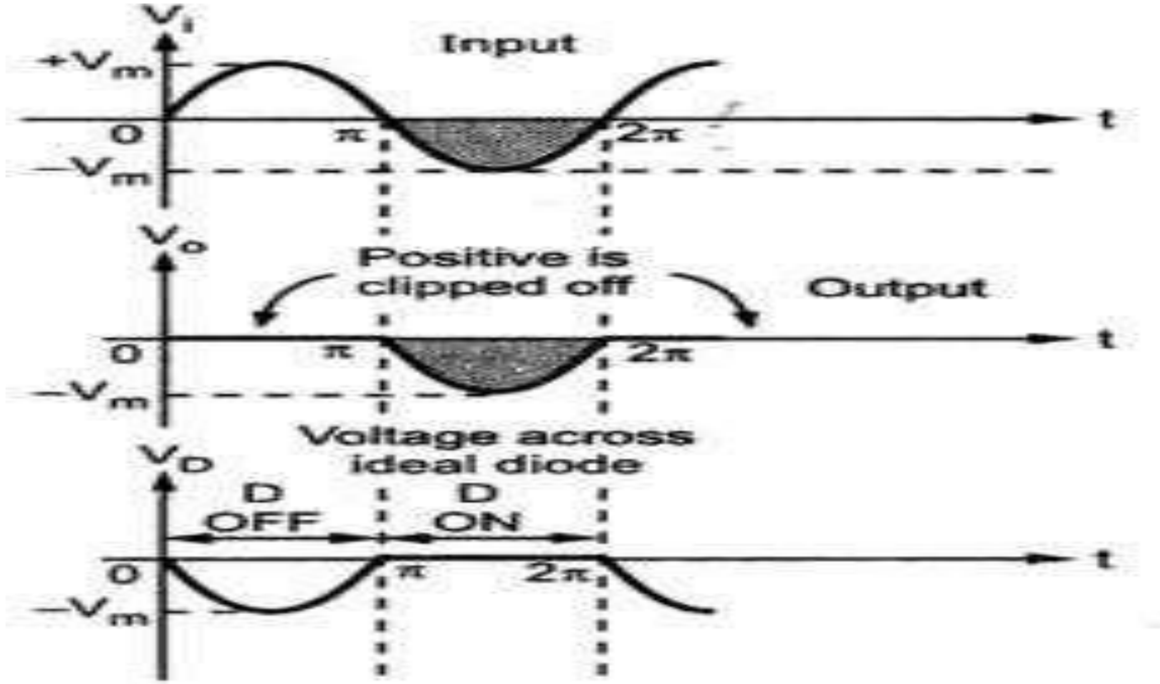


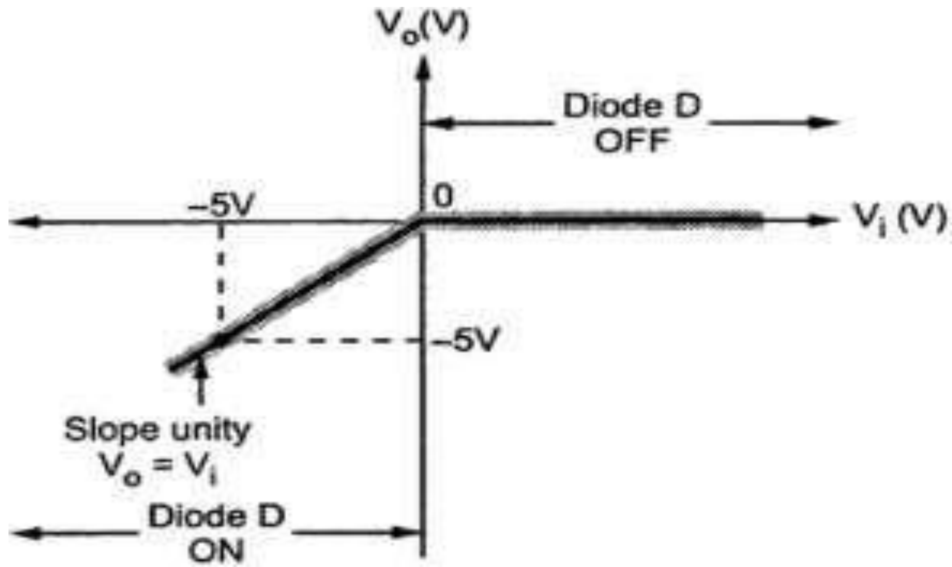
Fig. 1.48 Waveforms of series positive clipper

2. Transfer characteristics:

- With ideal diode, the equation for transfer characteristics is

$$V_o = 0 \qquad \ldots \text{ for } V_i > 0\text{ V}$$

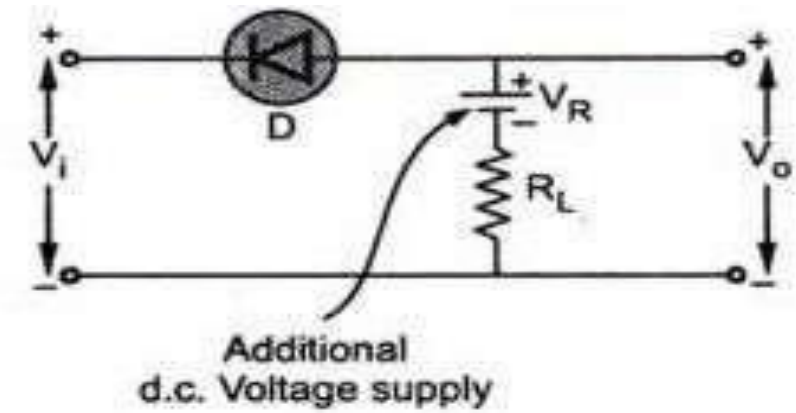
$$V_o = V_i, \qquad \ldots \text{ for } V_i \le 0\text{ V}$$



Transfer characteristics with Ideal diode

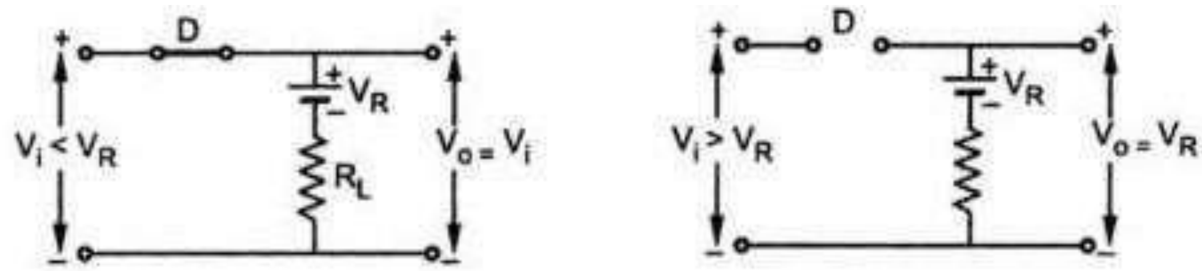
Clipping above Reference Voltage V_R

- The output of the dipper can be adjusted as per the requirement by adding an additional voltage source in series with the load- resistance.
  - The diode D is an ideal diode and hence there is no drop across it when it is forward biased.
  - Thus when forward biased, it acts as a short circuit while when reverse biased it acts as open circuit.



Clipping above V_R

1. **Operation:**
   - When V_i is less than V_R, the diode becomes forward biased
   - In this case the output voltage V_o is equal to input voltage V_i.
   - When V_i is greater than V_R, the diode is reverse biased
   - No current can flow in the circuit as circuit is open and hence output voltage V_o is equal to V_R.



(a) $V_i < V_R$ (b) $V_i > V_R$

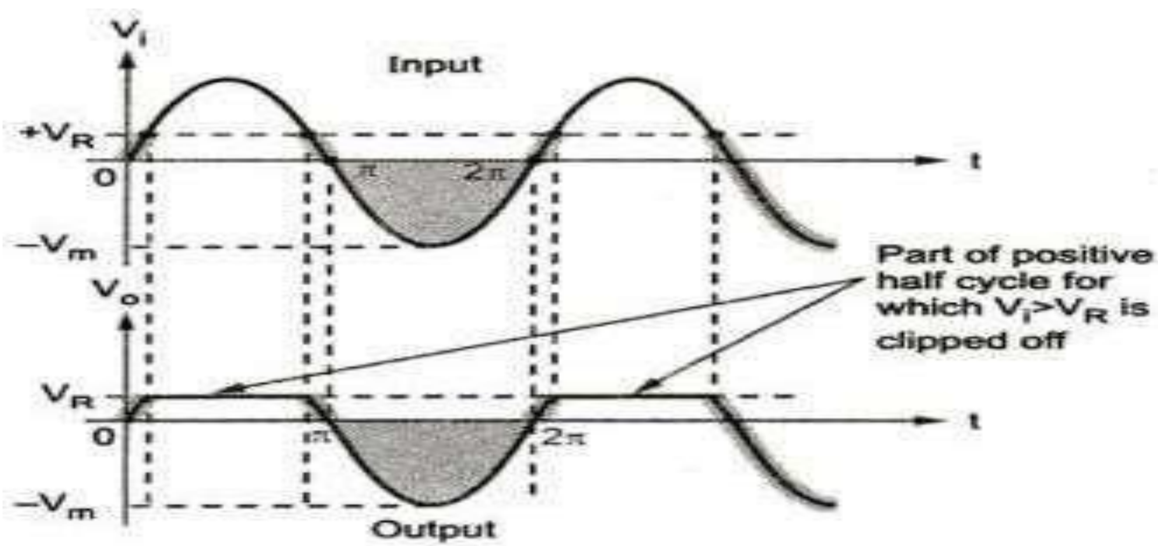


Fig. 1.51 Waveforms for clipping above V_R

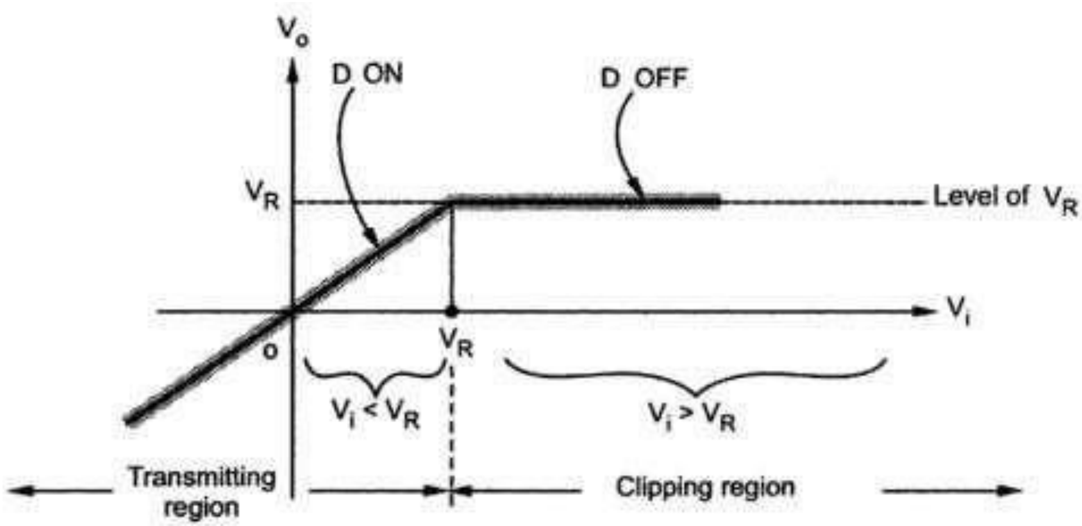
2. **Transfer characteristics:**

- With ideal diode, the equation for transfer characteristics is,

$$V_o = V_i, \qquad \ldots \text{ for } V_i < V_R$$

$$V_o = V_R, \qquad \ldots \text{ for } V_i > V_R$$

- This mathematical representation helps us to sketch the transfer characteristics of the clipper circuit.
- The transfer characteristic is the graph of output voltage V_o against input voltage V_i.



Transfer characteristics

- For the portion till $V_i < V_R$, the graph is straight line. This region is called the transmission region as it transmits V_i at the output as it is.

- While the portion for $V_i > V_R$, the output is constant. This region is called clipping region.

1.23 Clipping below Reference Voltage V_R

we get the clipping circuit which clips the portion of waveform, below the reference voltage V_R.

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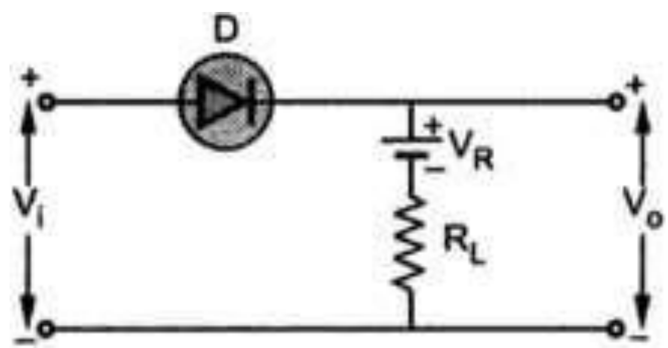
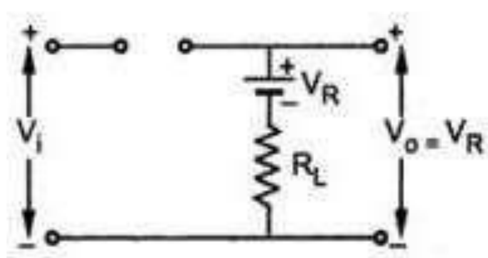
- By changing the orientation of the diode



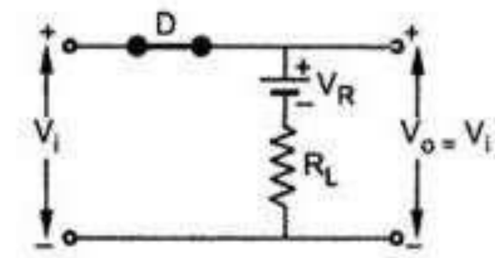
Clipping below V_R

1. **Operation**

- When V_i is less than V_R, the diode is reversed biased and circuit becomes open. The output voltage is equal to V_R as no current flows in the circuit
- When V_i is greater than V_R, the diode D becomes forward biased and circuit
- The output voltage V_o is equal to the input voltage V_i.



(a) $V_i < V_R$



(b) $V_i > V_R$

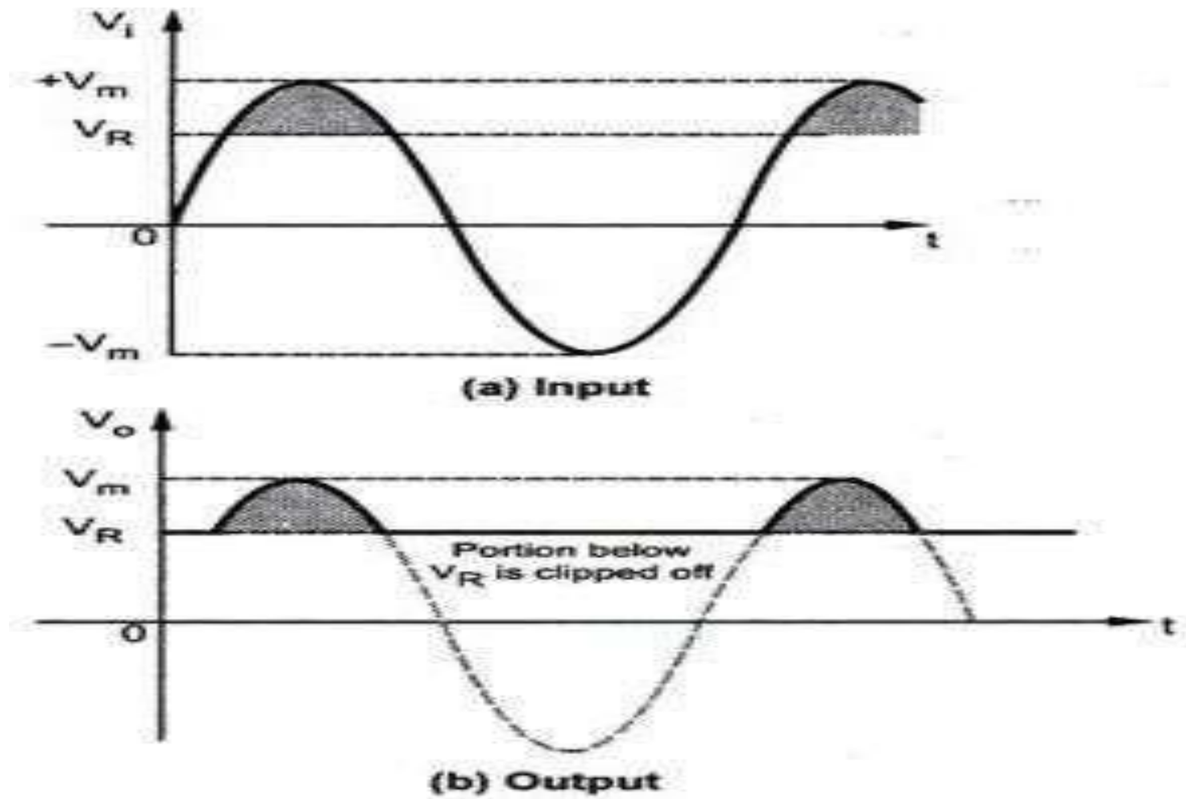


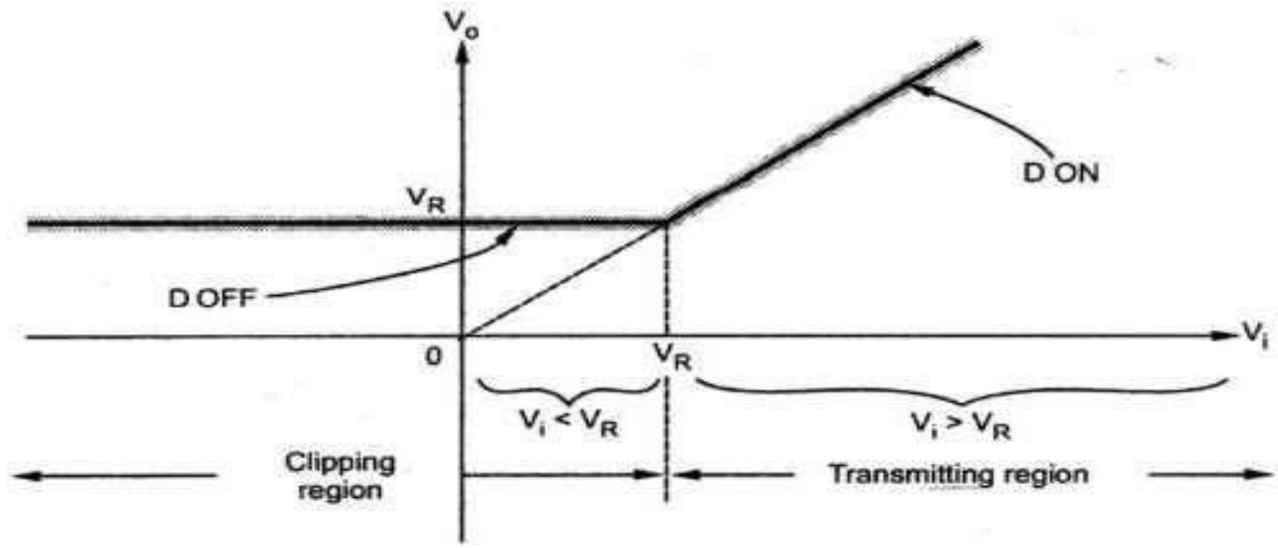
Fig. 1.54 Clipping below V_R

2. Transfer characteristics:

- With ideal diode, the equation for transfer characteristics is,

$$V_o = V_R, \qquad \ldots \text{ for } V_i < V_R$$

$$V_o = V_i, \qquad \ldots \text{ for } V_i > V_R$$



Transfer characteristics

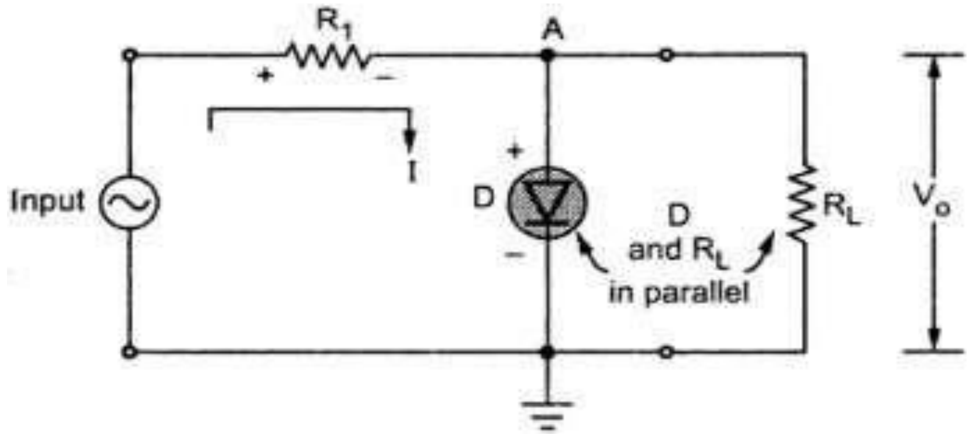
- The region for $V_i < V_R$ is the clipping region while the region for $V_i > V_R$ is the transmitting region.

1.24 Parallel Clippers

- In a parallel clipper circuit, the diode is connected across the load terminals.
- It can be used to clip or limit the positive or negative part of the input signal, as per the requirement.

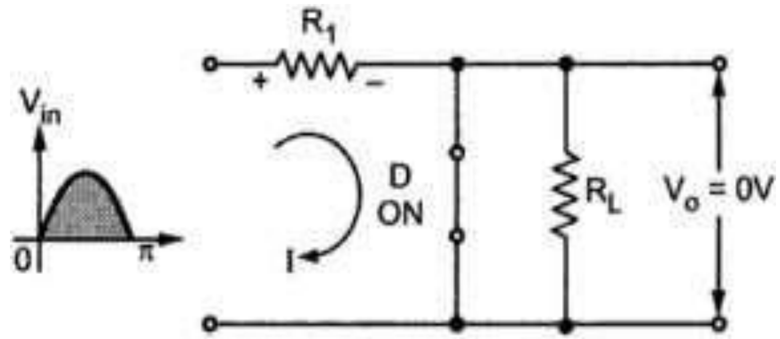
1. Parallel Clipper with Positive Clipping

- The Fig. 1.56 shows the basic parallel clipper circuit in which diode D is connected across the load resistance R_L.
- The resistance R1 is current controlling resistance.



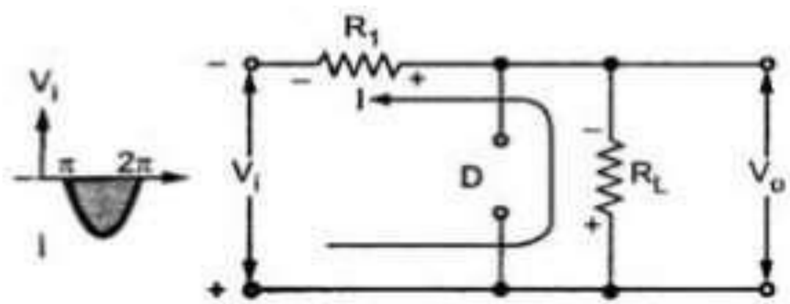
Basic parallel clipper

1. **Operation:**
   - During positive half cycle of the input V_i, the diode D becomes forward biased and remains forward biased for the entire half cycle of the input.
   - As R_L is in parallel with diode no current flows through it and output voltage $V_o = 0V$



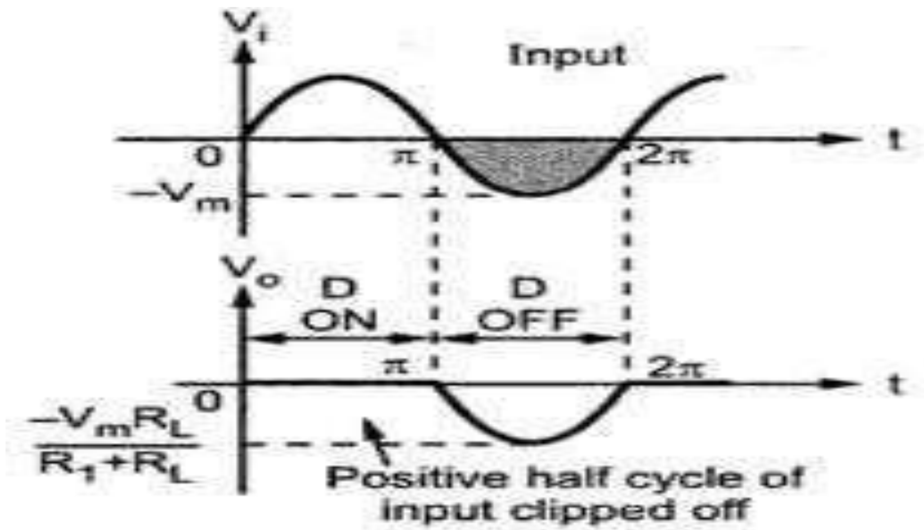
Operation during positive half cycle

- During negative half cycle of input, the diode is reverse biased and acts as open circuit.



Operation during negative half cycle.

- Thus $V_o \propto V_i$ and there exists straight line relationship between the input and output voltage.



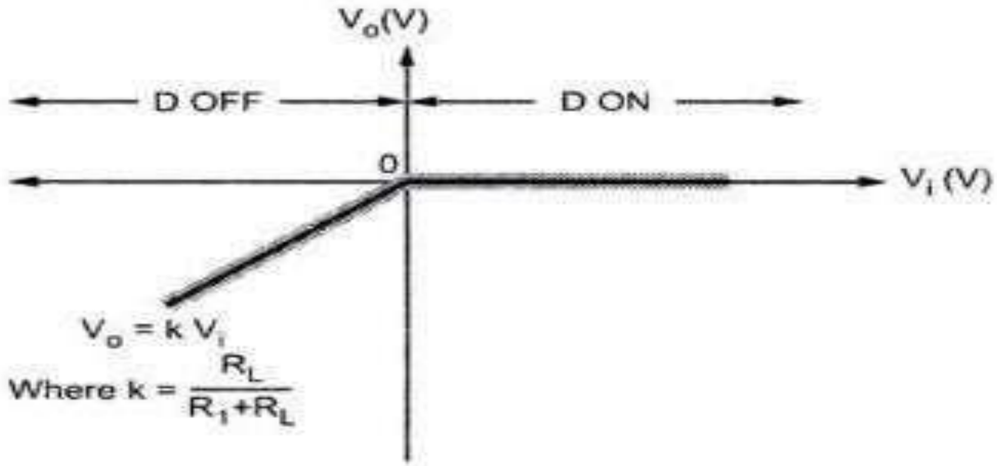
Waveforms for parallel clipper

2. Transfer characteristics:

- The mathematical equations for the transfer characteristics are,

$$V_o = 0 \qquad \text{... for } V_i \geq 0$$

$$V_o = \frac{V_i R_L}{R_1 + R_L}, \qquad \text{... for } V_i < 0$$



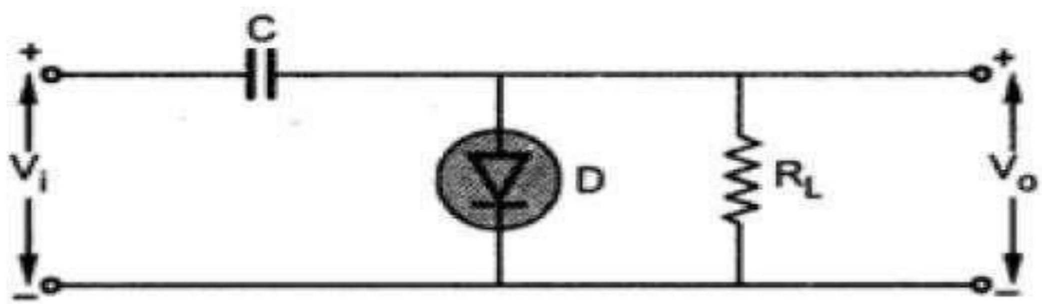
Transfer characteristics of positive parallel clipper

1.25 Clamper Circuits

- The circuits which are used to add a d.c. level to the a.c. output signal are called damper circuits.
- The capacitor, diode and resistance are the three basic elements of a damper circuit. The damper circuits are also called d.c. restorer or d.c. inserter circuits.
- Depending upon whether the positive d.c. or negative d.c. shift is introduced in the output waveform, the dampers are classified as,
  - a) Negative dampers
  - b) Positive dampers

1. Negative Clamper

- A simple negative clamper which adds a negative level to the a.c. output is shown in the Fig. 1.61.
- It consists of a capacitor C, the ideal diode

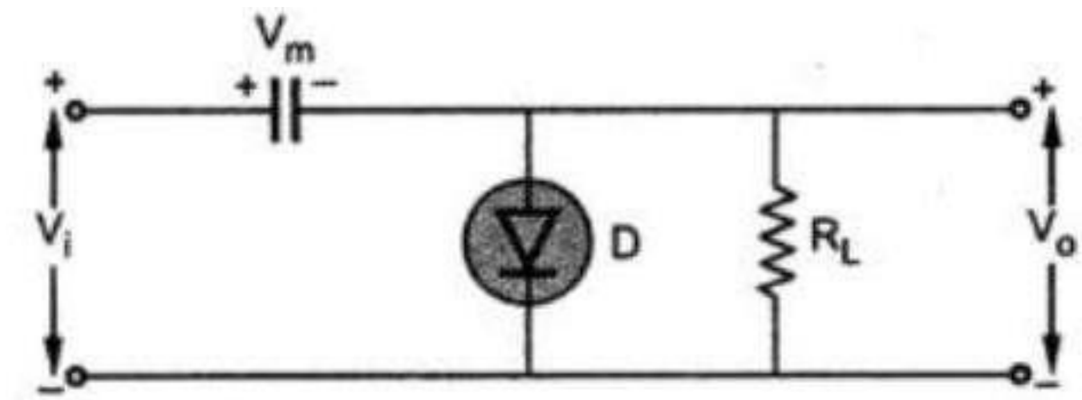


Negative clamper

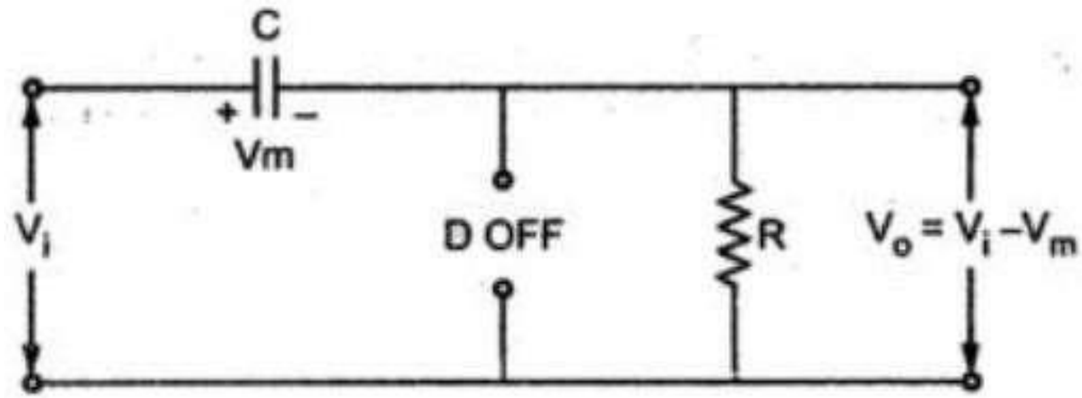
- The following assumptions are mode while analyzing the damper circuit;
  - The diode is ideal in behaviour.
  - The time constant Ţ= RC is designed to be very large by selecting large values of Rand C.

1. **Operation:**

- During the first quarter of positive cycle of the input voltage V_i, the capacitor gets charged through forward biased diode D upto the maximum value V_m of the input signal V_i.
- The capacitor charging is almost instantaneous, which is possible by selecting proper values of C and R_L in the circuit.
- The capacitor once charged to V_m, acts as a battery of voltage V_m



- Thus when D is ON, the output voltage V_o is zero.
- As input voltage decreases after attaining its maximum value V_m, the capacitor remains charged to V_m and the diode D becomes reverse biased.
- Due to large RC time constant the capacitor holds its entire charge and capacitor voltage remains as $V_c = V_m$ as shown in the Fig. 1.63.



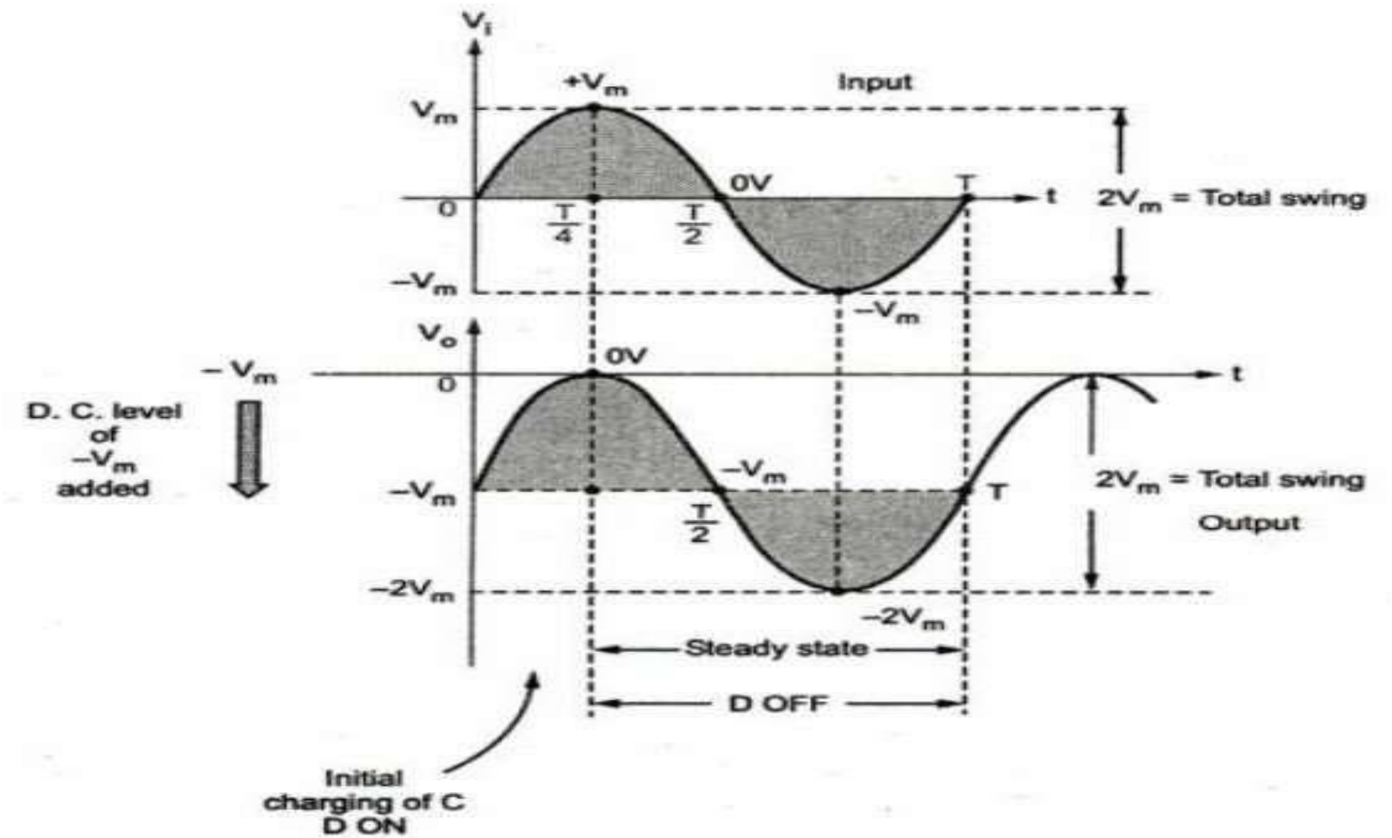
- The output voltage V_o is now given by,
  $V_o = V_i - V_c = V_i - V_m$
- In the negative half cycle of V_i, the diode will remains reverse biased.
- The capacitor starts discharging through the resistance R_L.
- As the time constant R_LC is very large, it can be approximated that the capacitor holds all its charge and remains charged to V_m, during this period also.
- Hence we can write that,

$$V_o = V_i - V_c = V_i - V_m$$

For negative half cycle

$$V_o = -V_m, \qquad \text{for } V_i = 0$$
$$V_o = 0, \qquad \text{for } V_i = V_m$$
$$V_o = -2V_m, \qquad \text{for } V_i = -V_m$$

2. Waveforms:



Negative clamper waveforms

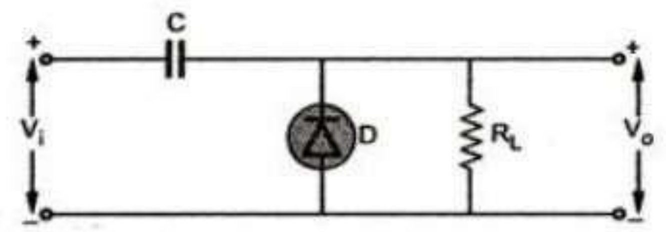
- The peak to peak amplitude of the input is $2V_m$.

- Similarly the peak to peak amplitude of the output is also $2 V_m$.

- Thus the total swing of the output is always same as the total swing of the input, for a clamper circuit.

2. Positive Clamper

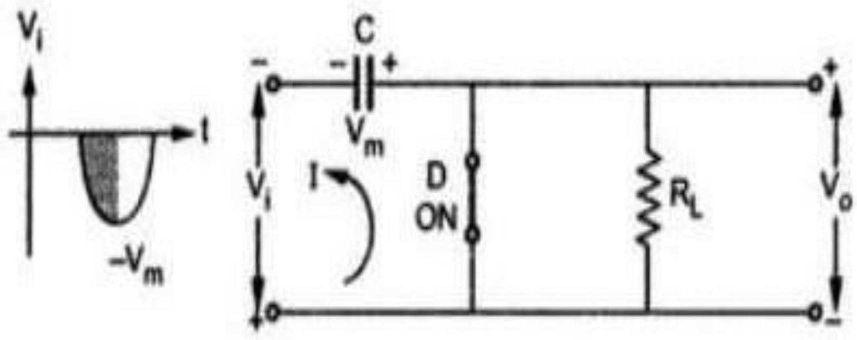
- By changing the orientation of the diode in the negative clamper, the positive clamper circuit can be achieved.



Positive clamper

1. Operation:

- During the first quarter of negative half cycle of the input voltage V_i, diode D gets forward biased and almost instantaneously capacitor gets charged equal to the maximum value V_m of the input signal V_i with the polarities.



- The capacitor once charged to V_m, acts as a battery of voltage V_m with the polarities
- This is because RC time constant is very large hence capacitor holds its entire charge all the time.
- Thus when $V_i = V_m$, the output voltage V_o is $2V_m$.
- Under steady state conditions we can write,

$$V_o = V_i + V_m$$

- In the positive half cycle, the diode D is reverse biased.
- The capacitor starts discharging through R_L.
- But due to large time constant, it hardly gets discharged during positive half cycle of V_i.

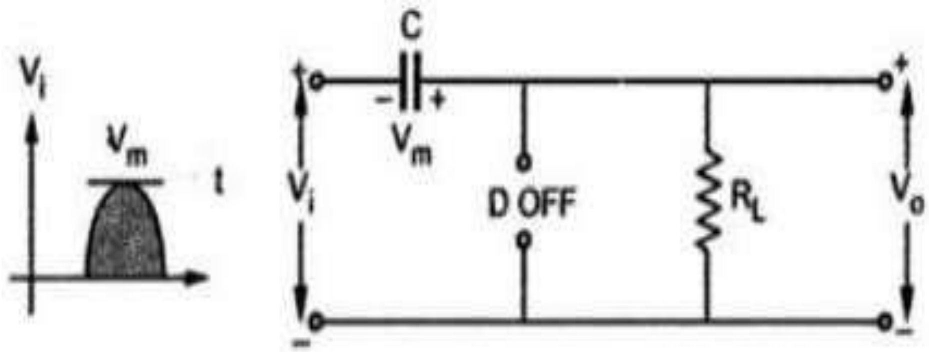


Fig. 1.68 Positive half cycle

- Hence, $V_o = V_i + V_m$

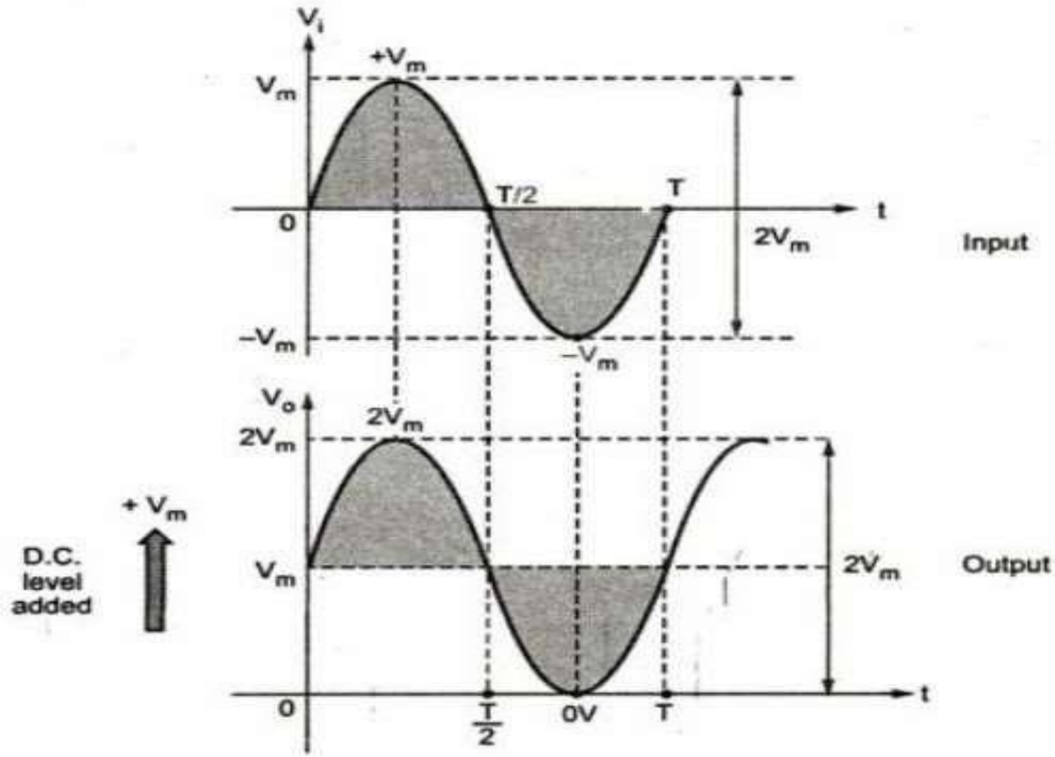
$$V_o = V_m, \quad \text{for } V_i = 0$$

$$V_o = 2V_m, \quad \text{for } V_i = V_m$$

$$V_o = 0, \quad \text{for } V_i = -V_m$$

2. Waveforms:

- Assuming ideal diode, the input and output waveforms



Positive clamper waveforms

Zener Diode As a Voltage Regulator

Zener Diode

- ❖ Zener diodes are a special kind of diode which permits current to flow in the forward direction.

- ❖ It is different from others diodes Zener diodes will also allow current to flow in the reverse direction when the voltage is above a certain value.

- ❖ This breakdown voltage is known as the Zener voltage.

- ❖ Zener diodes are designed in a way where the Zener voltage is a much lower value.

- ❖ There is a controlled breakdown which does not damage the diode when a reverse current above the Zener voltage passes through a Zener diode.

Types of Zener Diodes

- The most common types categorized by power dissipation, nominal working voltage, forward (drive) current, forward voltage, packaging type and maximum reverse current.
- The most common values for nominal working voltage are 5.1 V, 5.6 V, 6.2 V, 12 V and 15 V.
- Forward (drive) current can have a range from 200 uA to 200 A, with the most common forward (drive) current being 10 mA or 200 mA.

Applications of Zener Diode

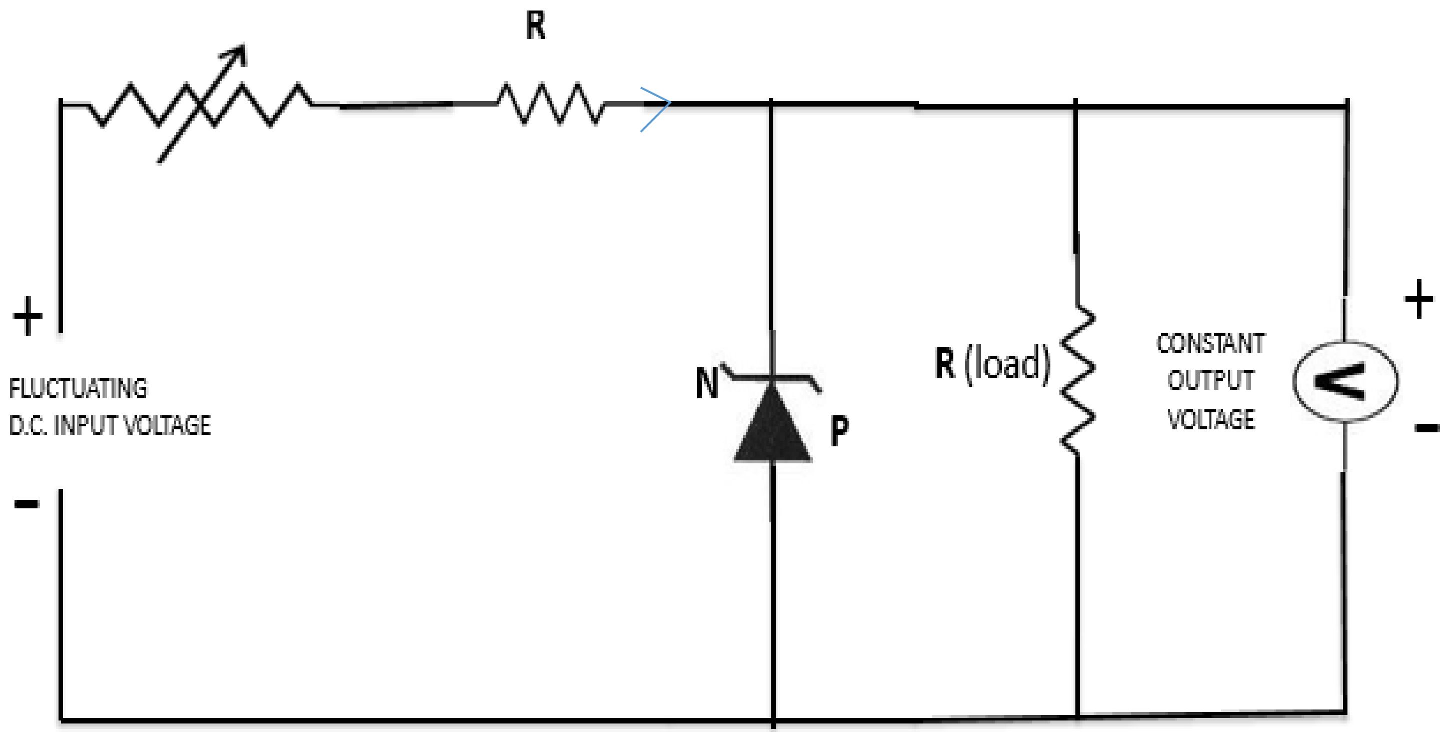
- Zener diodes can be found in several applications. Some of these are:

❖ voltage stabilizers or regulators (in shunt mode), surge suppressors for device protection, peak clippers, switching operations, reference elements and in meter protection applications.

❖ The constant reverse voltage of a Zener diode renders it a very useful component in regulating the output voltage against variations in the load resistance or variations in the input voltage from an unregulated power supply.

❖ The current through the Zener diode will change in order to keep the voltage within the threshold limits of Zener action and the maximum power that it can dissipate.

Zener Diode as Voltage Regulator



Working

- In this the Zener diode is used in its reverse biased region.
- When sufficient reverse voltage is applied electrical break down of the Zener diode occurs at a voltage called Zener voltage V_z .
- Under this condition whatever may be the current, the voltage across the Zener is constant equal to V_z .
- As the output voltage is in parallel with Zener diode it is also constant what ever may be the current.