Semiconductor Diode and Rectifier

1. PN Junction Diode

- Types of semiconductors
- PN junction Diode
- Biasing of PN junction
  - Forward Biasing of PN junction
  - Reverse Biasing of PN junction
- Ideal versus practical diode
- V –I characteristics of PN junction diode

Contd……

2. Rectifiers

- Half – wave Rectifier
- Full – Wave Rectifier
  - Centre-tap full wave rectifier
  - Bridge Rectifier

Conductors, Semiconductors and Insulators

Conductors:

Silver, gold, copper, aluminium etc

Insulators:

rubber, ceramic, glass, wood paper etc

Semiconductors:

germanium, silicon, carbon , etc

Types of Semiconductors:

i. Intrinsic semiconductors
ii. Extrinsic semiconductors

- N - Type Semiconductor(by adding donor impurity)
- P - Type Semiconductor(by adding acceptor impurity)

N - Type Semiconductor

- When a pentavalent impurity(donor impurity) like arsenic, antimony, phosphorus etc, is added to an intrinsic semiconductor, a n-type semiconductor is formed.

P - Type Semiconductor

- When a trivalent impurity(acceptor impurity) like indium, boron, gallium, aluminum etc, is added to an intrinsic semiconductor, a p-type semiconductor is formed.

PN Junction Diode

- When a piece of p-type and n-type semiconductor is joined in such a manner , that crystal structure remains continuous at the boundary , then a new structure **called pn junction** is formed.
- PN junction can not be made simply by joining two pieces. Special fabrication technique is required.
- The fig below shows a pn junction diode with **depletion region** formed at the Junction

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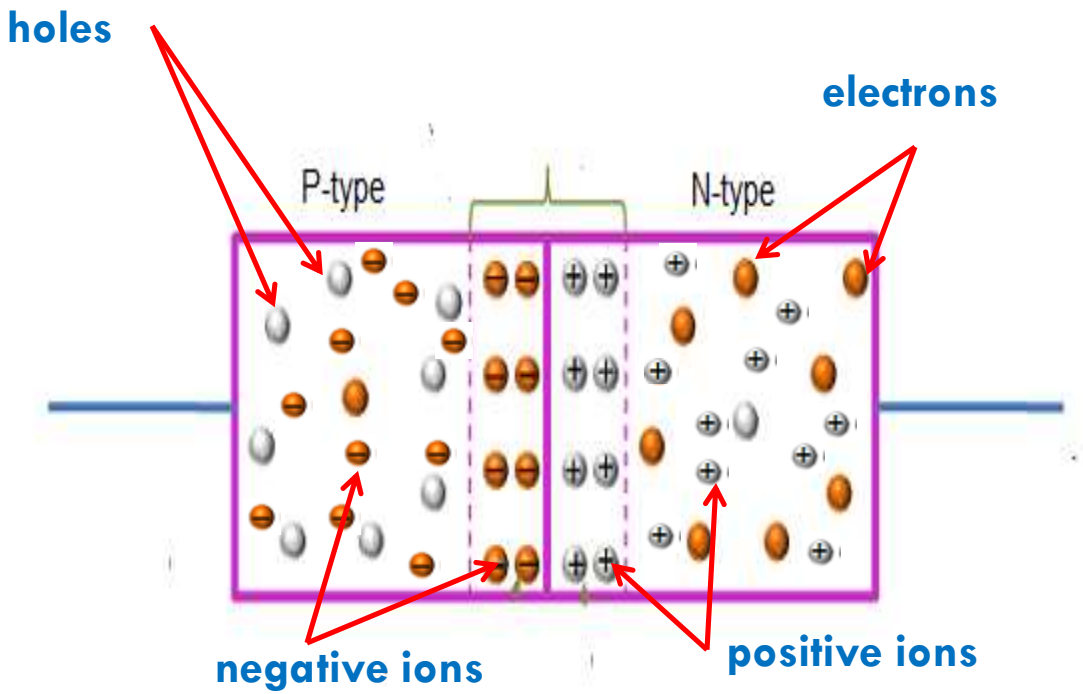

Fig. 1: pn junction diode with depletion layer

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Formation of pn junction diode:

As soon as pn junction is formed, the following actions takes place

- Holes from P-region diffuse into n-region. There they combine with electrons.
- Electrons from N-region diffuse into P-region. There they combine with holes
- There is a difference in concentration of electrons and holes in P and N region. Due to this difference, diffusion of electrons and holes takes place.
- This diffusion takes place only for a short duration of time. After few recombination of holes and electrons, a restraining force is developed in the neighborhood of junction. As a result of this force, further diffusion is not permitted.

Contd….

The formation of this barrier is explained as below

- Due to the process of recombination, all the electrons and holes in the neighborhood of the junction is removed. But negative ion in p-region and positive ion in n-region remain uncompensated in the neighborhood of junction.
- Further holes trying to diffuse into the n region is repelled by positive ions in p region and vice-versa.
- This region having uncompensated acceptor and donor ions is known as **depletion layer**

Contd….

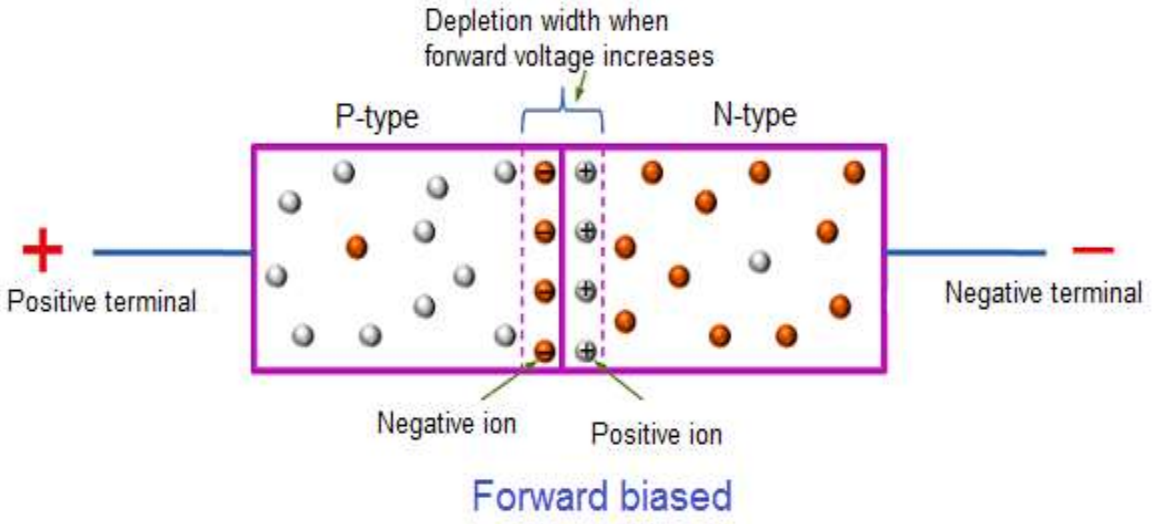
Junction potential or cut-in voltage:

Due to the presence of immobile positive and negative ions on opposite side of the junction, an electric field is created across the junction. This electric field is known as **junction potential or cut-in voltage.**

Biasing of pn Junction

- Forward Biasing of pn junction
- Reverse Biasing of pn junction

i) Forward Biasing of pn junction:



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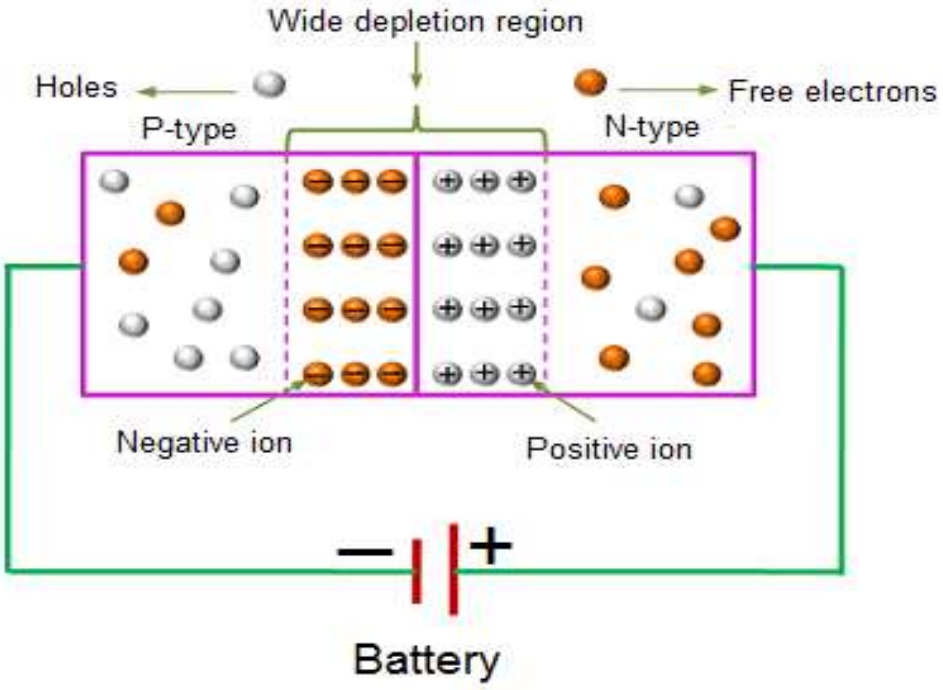
ii) Reverse Biasing of pn junction:



Reverse bias

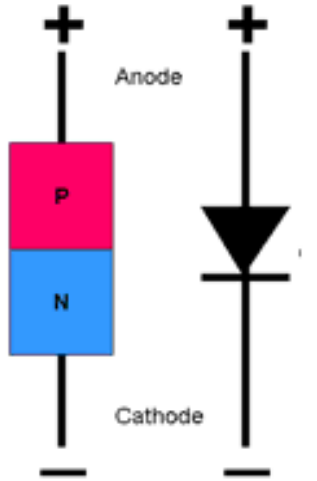
V-I Characteristics of pn junction diode

i. Forward V-I characteristic of diode

ii. Reverse V-I characteristic of diode

i) Forward V-I characteristic of diode:

If the positive terminal of the battery is connected to the p-type semiconductor and the negative terminal of the battery is connected to the n-type semiconductor, the diode is said to be in forward bias. In forward biased p-n junction diode characteristic, V_F represents the forward voltage whereas I_F represents the forward current



Diode (P-N Junction)
Forward Biased

Contd….

The forward V-I characteristic of p-n junction diode is shown in the figure. The horizontal line in the below figure represents the amount of voltage applied across the p-n junction diode whereas the vertical line represents the amount of current flows in the p-n junction diode.

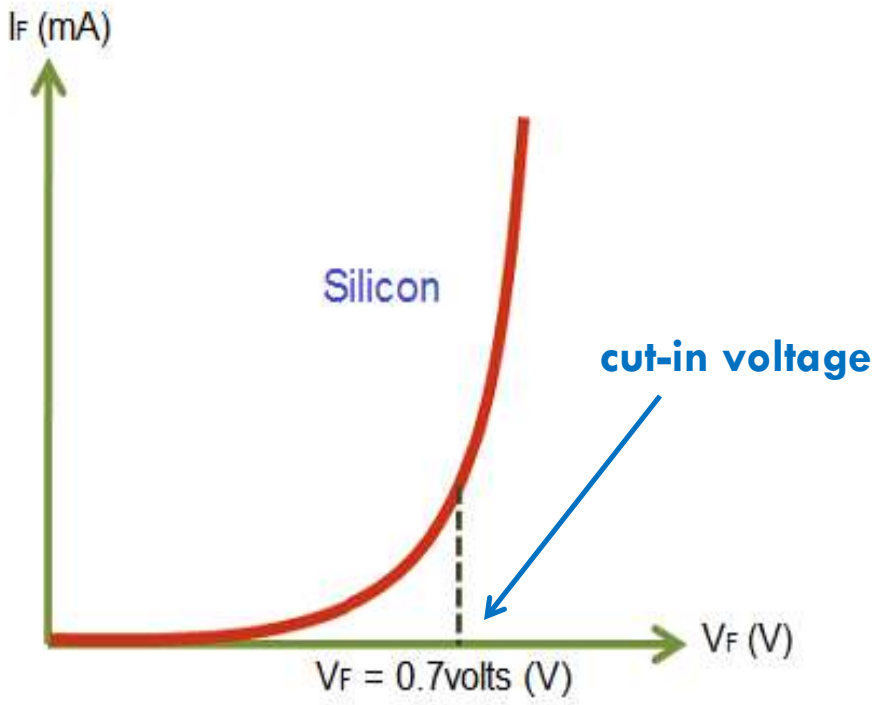


Fig: Forward characteristics of silicon diode

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i) Reverse V-I characteristic of diode:

If the negative terminal of the battery is connected to the p-type semiconductor and the positive terminal of the battery is connected to the n-type semiconductor, the diode is said to be in reverse bias. In reverse biased p-n junction diode, V_R represents the reverse voltage whereas I_R represents the reverse current.

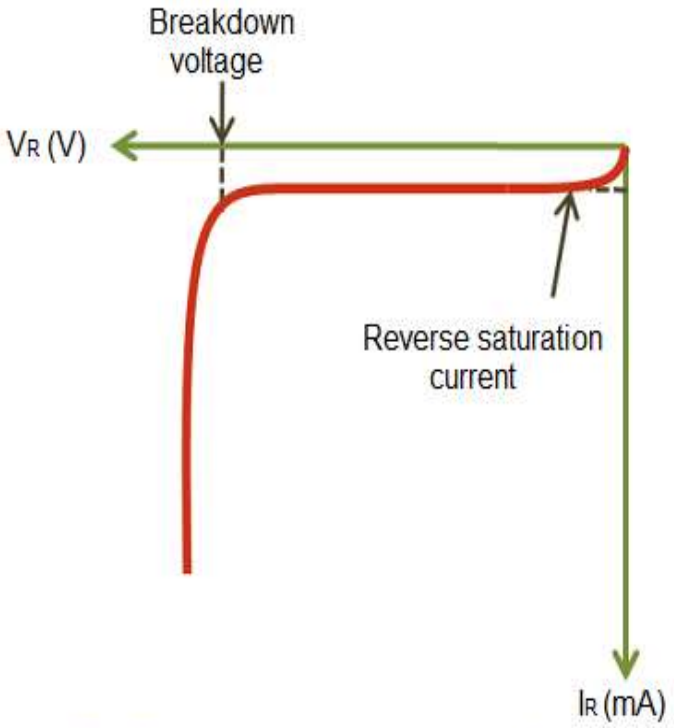

Fig: Reverse characteristics of diode

Drift Current and Diffusion Current:

Drift Current: Under the action of electric field the charge carriers (electrons and holes) in the semiconductor material stops moving randomly and start drifting towards or away the applied electric field depends upon their nature. This drift of charge carriers produces drift current. For drift current external electric field is essential.

Diffusion Current: In semiconductor there may arise a situation where the concentration of charge carriers within the crystal becomes different and hence producing concentration gradient, due to which charge carriers cross the surface to maintain equilibrium and constitute a current which is known as diffusion current. or diffusion current external field is not required any external energy may stimulate this process. It depends upon rate of charge of carrier concentration per unit length.

RECTIFIERS

A rectifier is a device which is used to convert ac voltage into pulsating dc voltage.

Basically there are two types of rectifiers

i. Half-Wave Rectifier

ii. Full Wave Rectifier

Half-Wave Rectifier:

A half-wave rectifier conducts current only during positive half cycle of an ac input voltage. During negative half cycle, no current is conducted and hence no current flows through the load.

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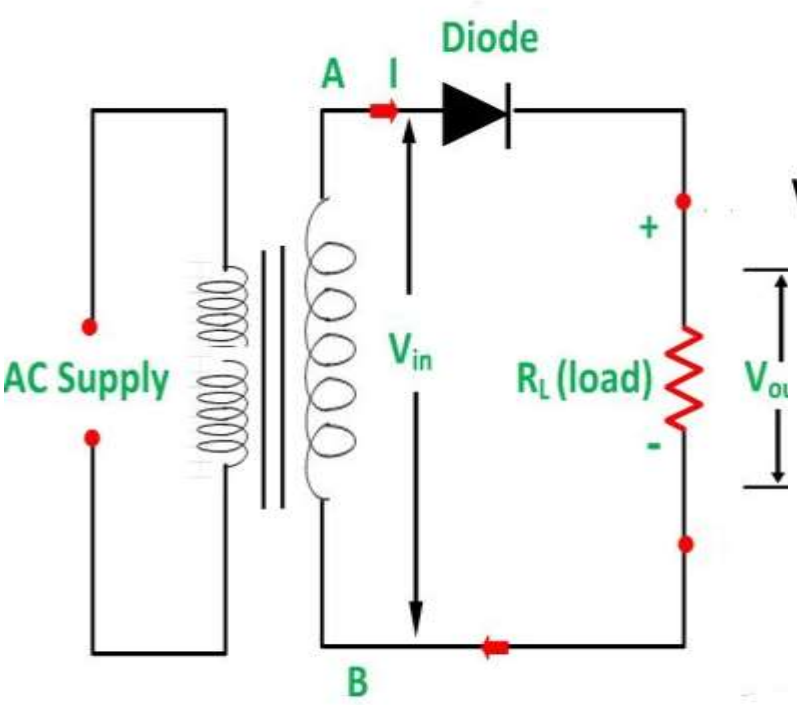
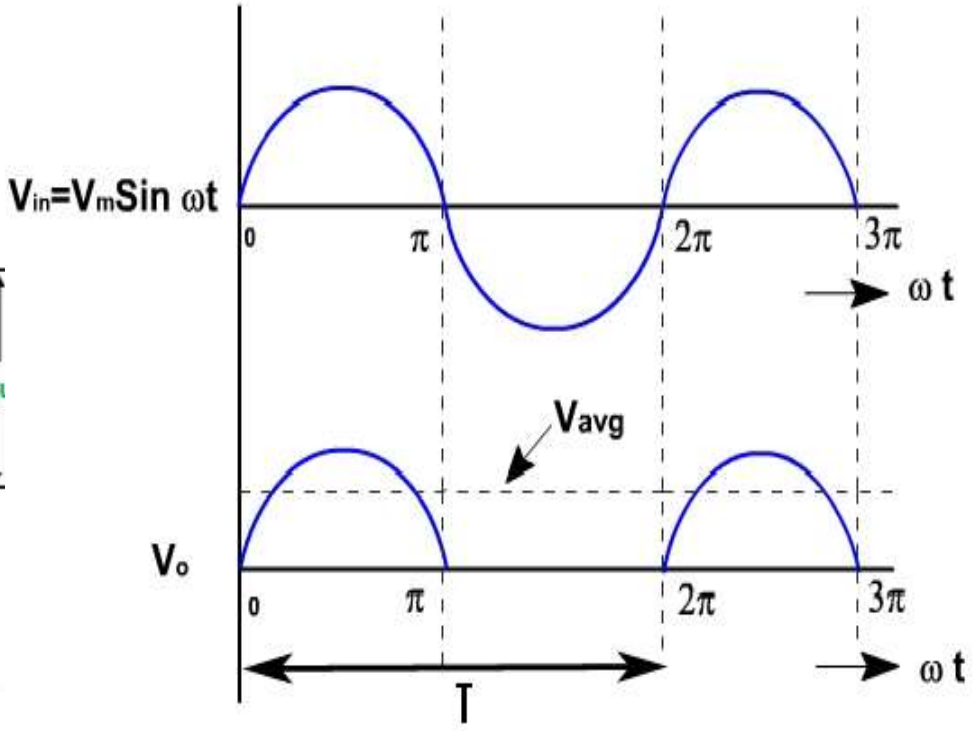


(a) Circuit Diagram



(b) Waveforms

Contd….

Average or dc value of output voltage:

$$V_{dc} = 0.318\ V_m$$

&

$$I_{dc} = 0.318\ I_m$$

Contd….

Peak Inverse Voltage of Half wave Rectifier:

Peak Inverse Voltage is defined as the maximum reverse voltage that a diode can withstand without destroying the junction.

Note: PIV of half wave rectifier = V_m

Contd….

Disadvantages:

i. Output voltage and current are pulsating in nature. Hence, filters are required to produce steady dc current.

ii. The ac supply delivers current only half of the time. Therefore, average output value is low.

Full-Wave Rectifier:

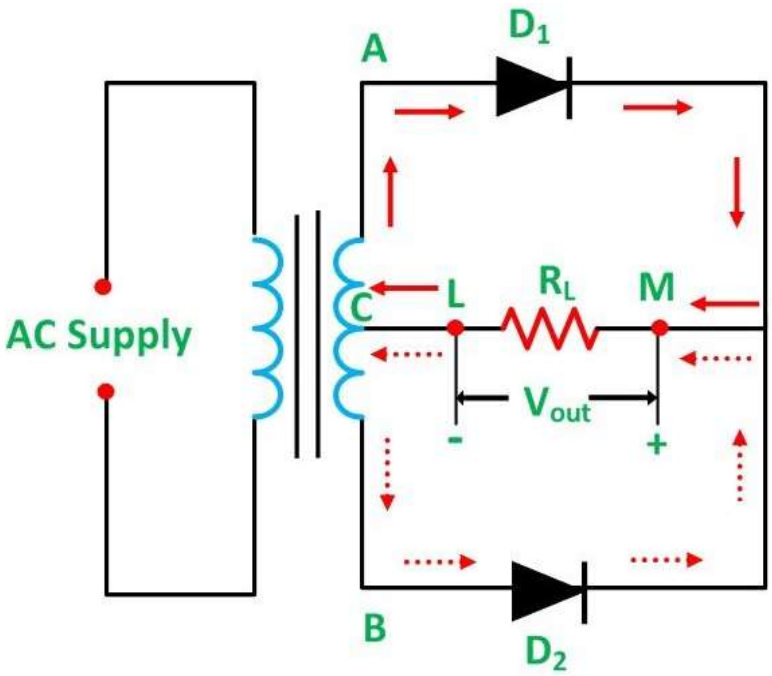
A full-wave rectifier conducts current during both positive half cycle and negative half cycle of ac input voltage. Hence, current flows through the load for both half cycles.

The following two circuits are commonly used for full wave rectification:

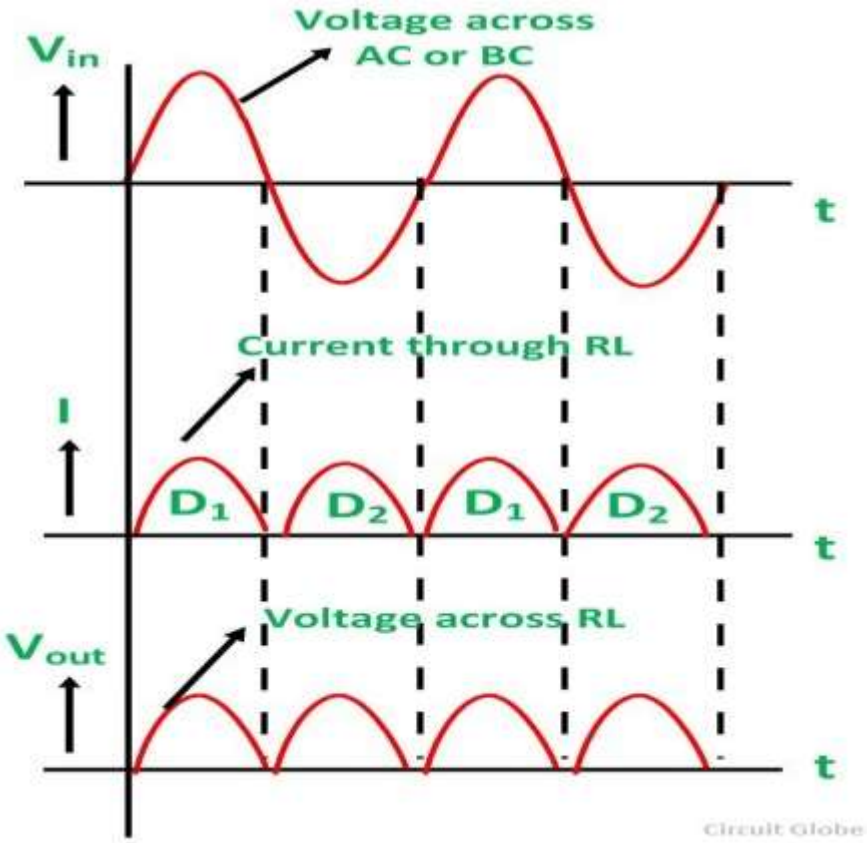
i. Centre-tap full wave rectifier

ii. Full-wave bridge rectifier

Centre-Tap Full Wave Rectifier:



(a) Circuit Diagram



(b) Waveforms

Contd….

Disadvantages of centre-tap full wave rectifier:

i. It is difficult to locate centre tap on the secondary winding

ii. The dc output value is low as each diode utilizes only one half of transformer secondary winding

Note: PIV of full wave rectifier is $2V_m$

Bridge Rectifier:

The need of centre tap power transformer is eliminated in bridge rectifier. It contains four diodes D_1, D_2, D_3 and D_4 connected in the form of a bridge.

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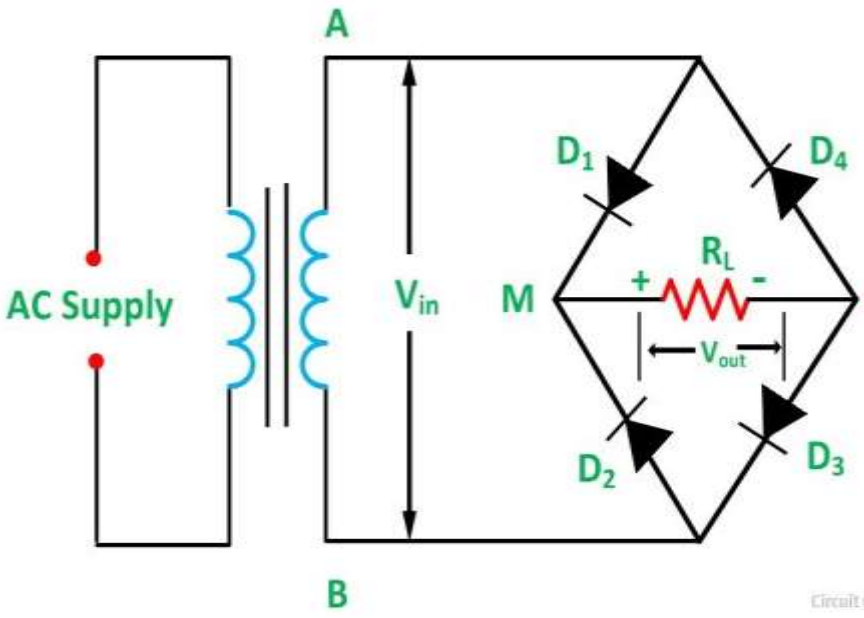
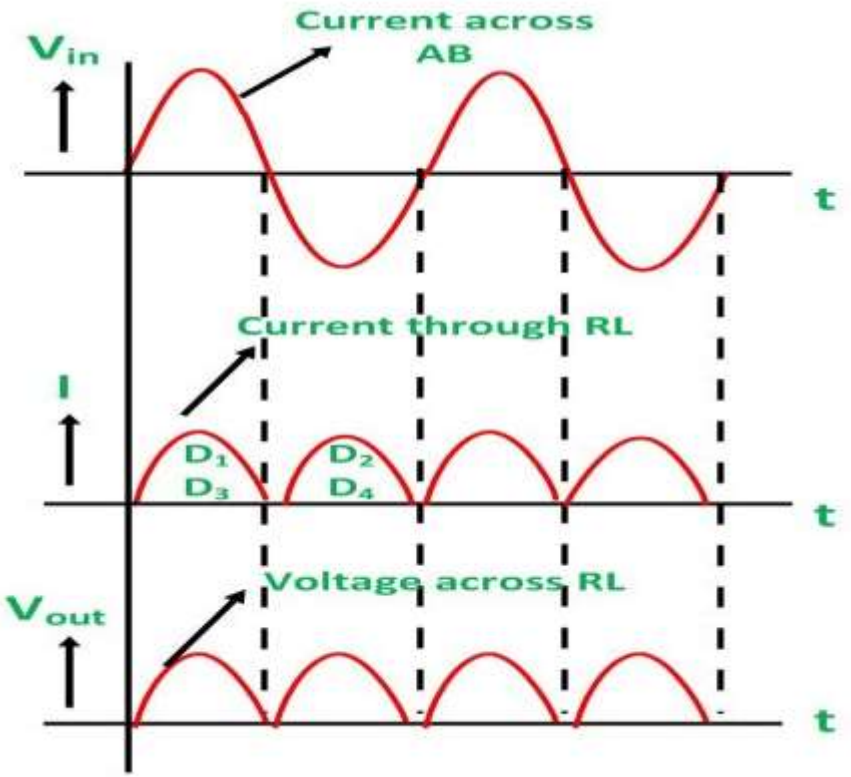


(a) Circuit Diagram



(b) Waveforms

Contd….

Advantages of bridge rectifier over Centre-tap:

i. Bridge rectifier does not require centre tapped secondary winding

ii. No. of turns in secondary winding of transformer must be double in centre -tapped than that in bridge rectifier for obtaining the same output.

iii. In bridge rectifier, PIV rating of V_m is required but in centre tapped PIV rating of $2V_m$ is requited.

Contd….

Disadvantages of bridge rectifier over Centre-tap:

i. Diodes required in bridge rectifier is 4, but in centre tapped, it is only 2.

ii. There is a drop of 0.7 V in Silicon diode, so for low output dc voltage application, the drop of 1.4 V (because of two diodes) in case of Si diode and 0.6V in case of germanium become considerable. Hence for low output dc voltage application, centre-tapped rectifier is preferred.

Contd….

Average or dc value of output voltage and current:

$$V_{dc} = 0.636 V_m$$

&

$$I_{dc} = 0.636\ I_m$$

Thank You