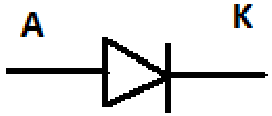
UNIT - 1

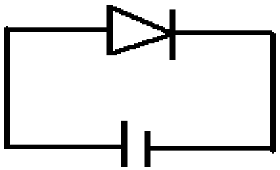
Topics:

1. Review of p-n junction diode
2. Characteristics, parameters and AC equivalent circuit
3. Half-wave diode Rectifier, Ripple factor
4. Full-wave diode rectifier
5. Other full-wave circuits
6. Breakdown diodes and their applications in power supply circuits.

PN JUNCTION DIODE



Forward bias



Forwrad bias

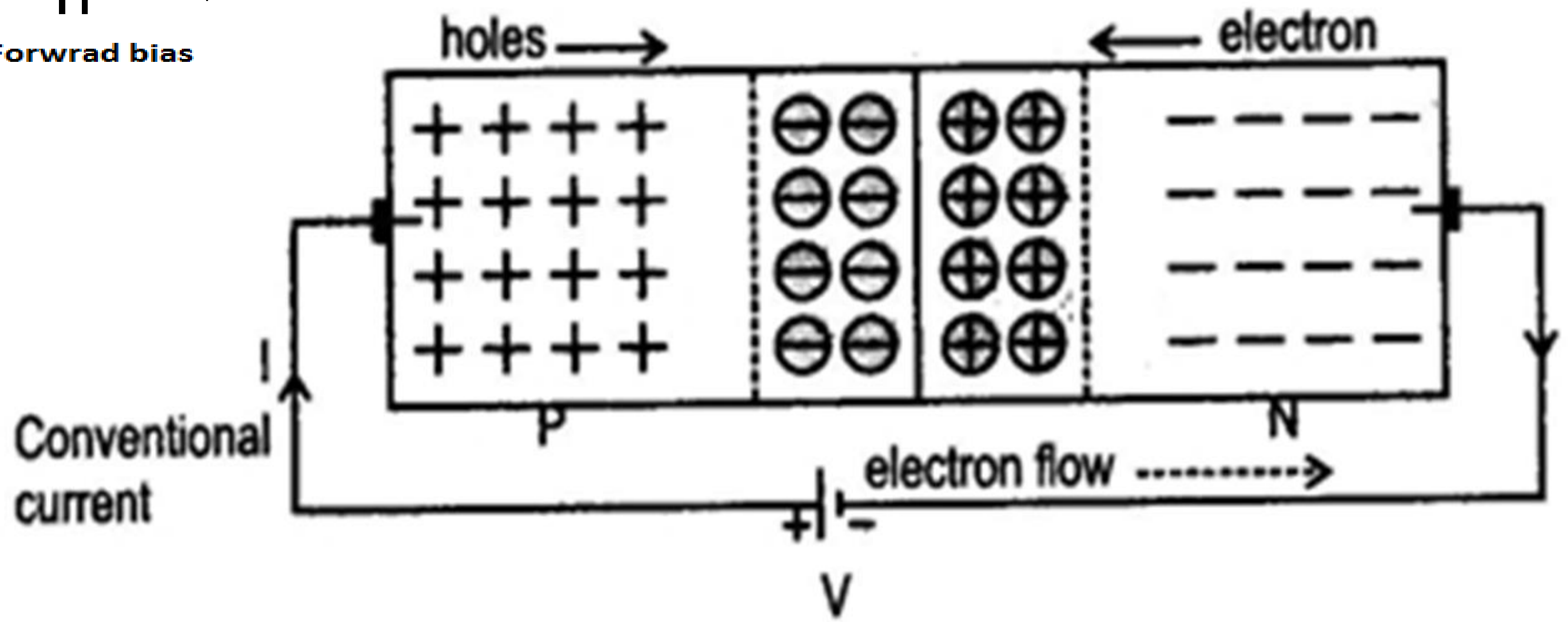


Fig. : Forward biased p-n junction

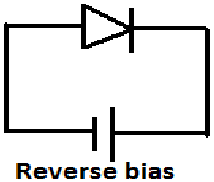
Forward Bias

- PN junction is **forward biased** when a voltage is applied **positiv**e to the **P** side and **negative** to the **N** side
- Depletion region decreases.
- A majority charge carrier current (I_F) flows across a forward biased junction
- The junction forward characteristics is the Graph of VF versus IF
- Forward voltage drop is for si = 0.7,
- Ge =0.3

Reverse Bias

- A pn junction is **Reverse Biased** when a positive voltage is applied to the n-side and negative to p-side.
- Depletion region increases
- A small minority charge carrier current IR flows across RB junction
- The reverse saturation current Io tends to be constant regardless of the reverse bias voltage VR

Reverse bias



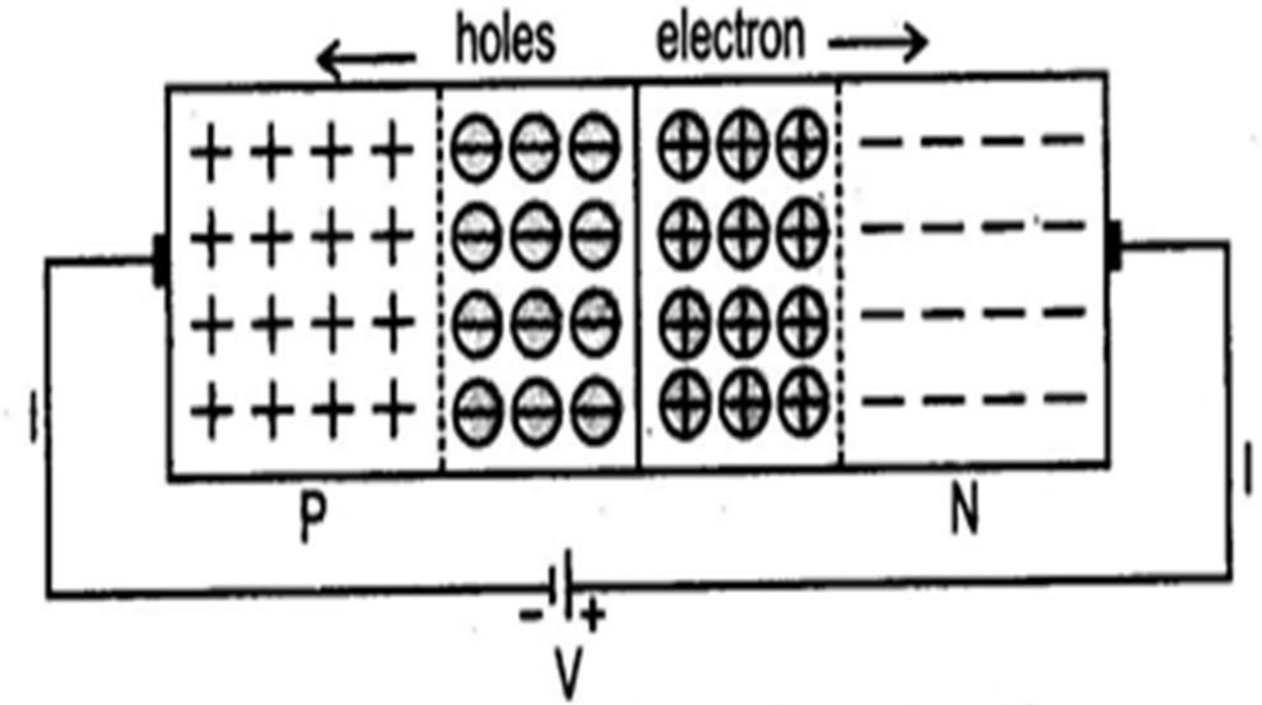
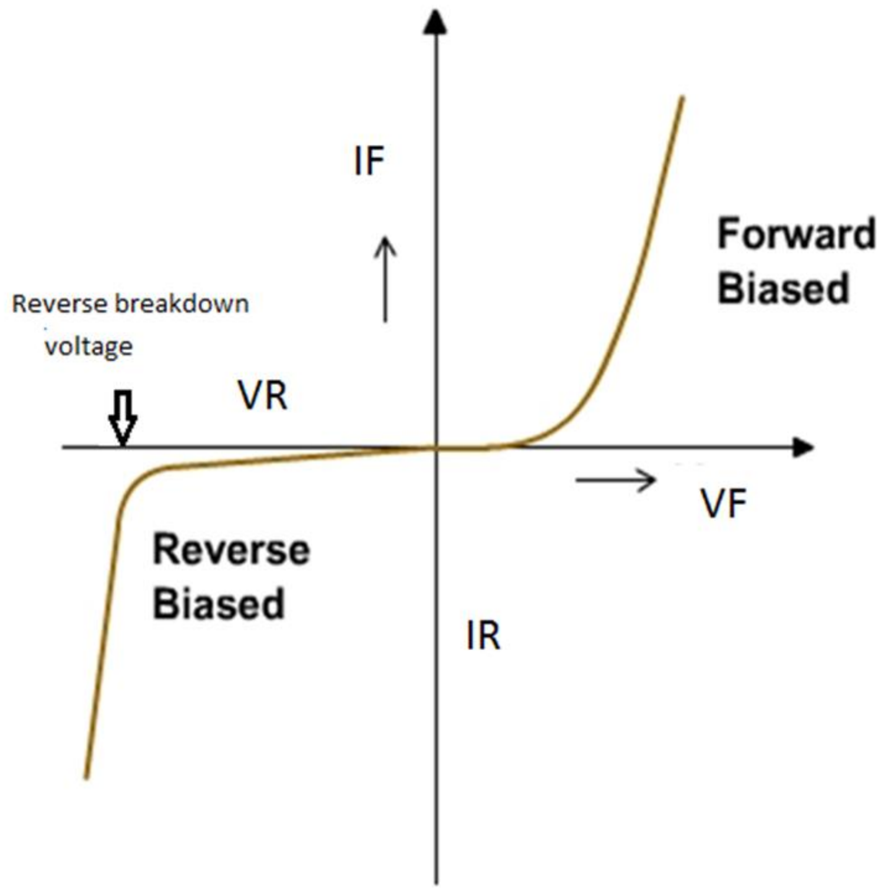


Fig.: Reverse biased p-n junction

Forward and Reverse characteristics of PN junction diode



PN junction diode parameters

- VF : Forward voltage of a diode
- IF : Forward Current of a diode
- VR: Reverse Voltage of a diode
- IR : Reverse current of a diode

Important parameters

- Breakdown Voltage: It is the reverse voltage at which pn junction breaks down with sudden rise in reverse current.
- Knee Voltage: It is the forward voltage at which the current through the junction starts to increase rapidly.

Static and Dynamic Resistance

- Static Resistance : It is the constant resistance or DC resistance of the diode at a particular constant forward current.

- Dynamic Resistance : It is the resistance offered to changing levels of forward voltage. (Also known as incremental resistance or ac resistance)

Shockley equation

(or)

(**Diode** Junction currents and voltages)

The equation relating pn junction current and voltage levels is called the shockley equation.

$$I_D = I_0(e^{V_D/\eta V_T} - 1)$$

I_D is the junction current through the diode,

I_0 is the reverse saturation current

V_D is the applied biasing voltage (junction voltage).

V_T is the thermal equivalent voltage and is approximately 26 mV at room temperature. The equation to find V_T at various temperatures is:

$$V_T = \frac{kT}{q}$$

- $k = 1.38 \times 10^{-23}$ J/K T = temperature in Kelvin $q = 1.6 \times 10^{-19}$ C

- η is the emission coefficient for the diode.
- For a silicon diode η is around 2 (low currents)
- For germanium η is 1. (higher currents)

RECTIFIERS

A device which is capable of converting an AC waveform into unidirectional (dc) waveform called as rectifier.

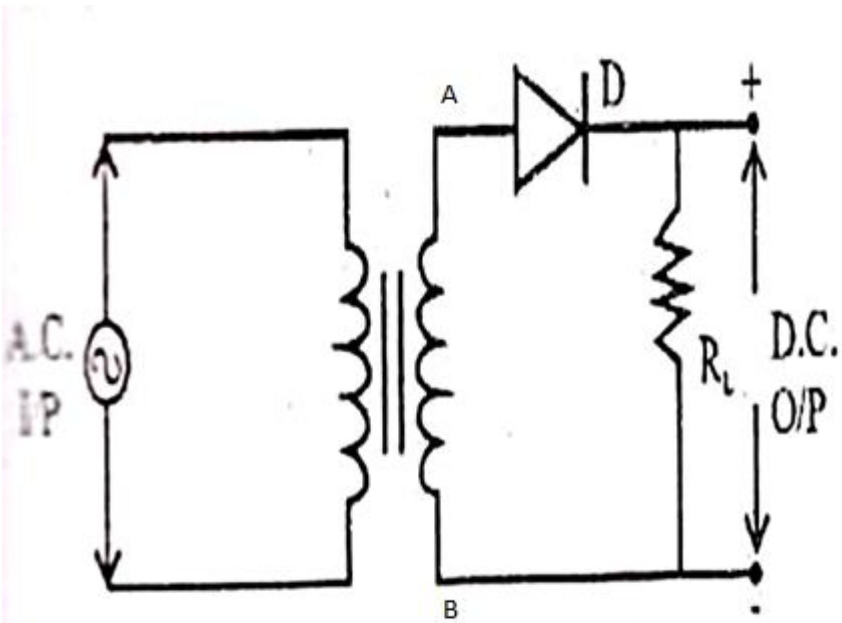
Rectifiers can be classified as

Half wave rectifier

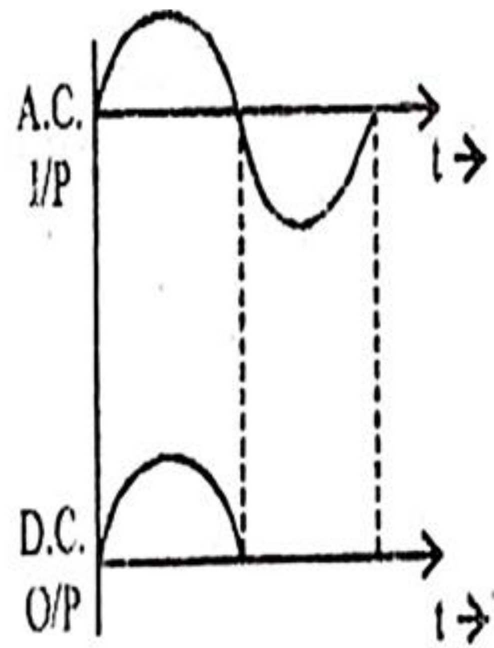
Full wave rectifier:

- Center tap full wave rectifier(2 diodes)
- Bridge rectifier (4 diodes)

Half wave rectifier



a) Half wave Rectifier



b) Wave forms

Working..

- During positive half cycle of input signal end A becomes positive with respect to end B.
- This makes the diode forward biased. hence it conducts current.
- During negative half cycle of input signal end A becomes negative with respect to end B.
- This makes the diode reverse biased. hence it conducts no current.
- Thus current flows through diode during positive half cycle only. this same current flows through load resistor.

Half wave Rectifier

V_m = Voltage maximum (or) Peak voltage $I_m = V_m / R_L + R_f$

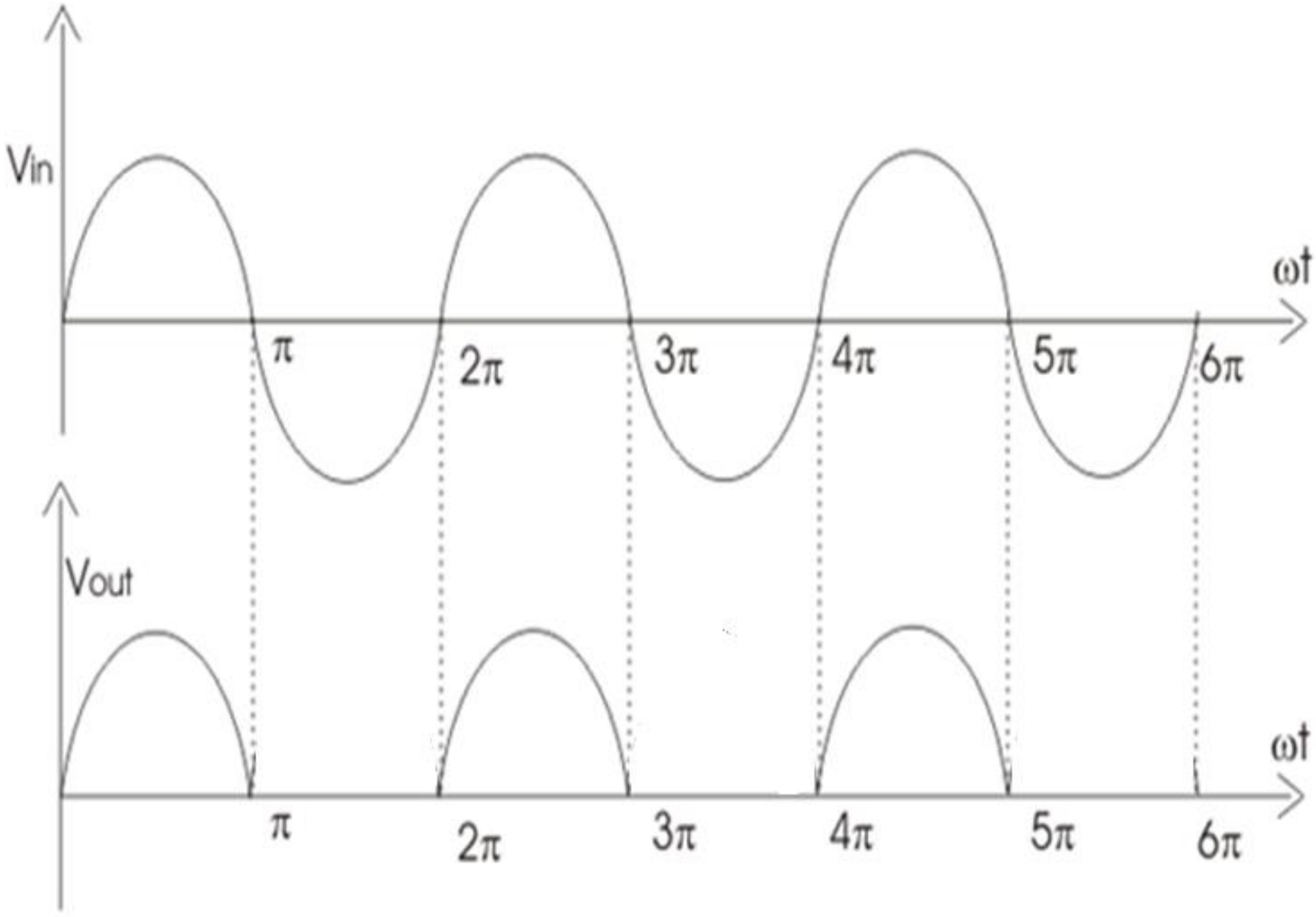
V_{rms} = votage root mean square value, I_{rms} = Current roo tmean square value

V_{dc} = Voltage average (or) voltage dc, I_{dc} = Current average (or) Current dc

$$V_{rms} = \frac{V_m}{2} \qquad I_{rms} = \frac{I_m}{2}$$

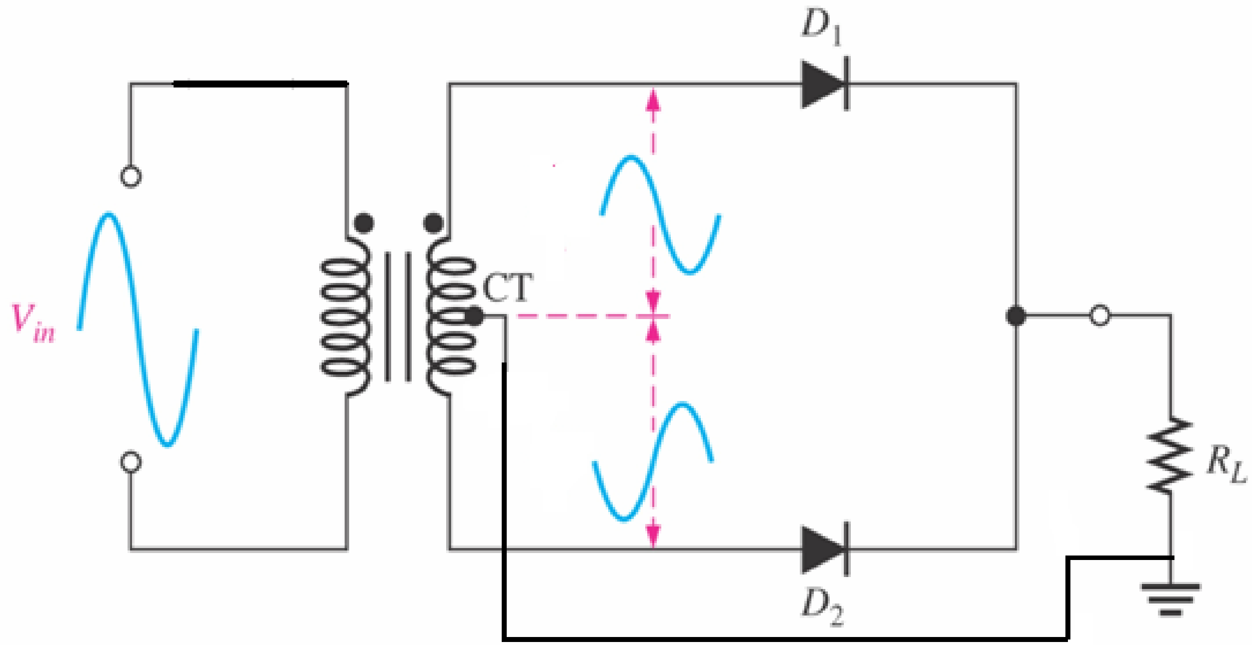
$$V_{dc} = \frac{V_m}{\pi} \qquad I_{dc} = \frac{I_m}{\pi}$$

Half wave rectifier



Full wave Rectifier

A center-tapped full-wave rectifier.



Full-wave Rectifier

- The full-wave rectifier circuit uses two diodes, and its input voltage is supplied from a transformer with a centre-tapped secondary winding.
- The circuit is combination of two half-wave rectifier circuits, each supplied one half of the transformer secondary.
- When the transformer output voltage is positive at the top, the anode of the $D_1$is positive, and the centre tap of the transformer is connected to the cathode of D_1 by R_L

- Load current (I_L) flows from the top of the transformer secondary through D1,throuth R_L from top to bottom, and back to the transformer secondary centre tap.

- During this time, the polarity of the voltage from the bottom half of the transformer secondary caused diode D_2 to be reverse-biased,

- During the negative half-cycle of the transformer output, the polarity of the transformer secondary voltage caused D_1 to be reverse-biased and D_2 to be forward-biased .I_L flows from the bottom terminal of the transformer secondary through diode D_2, through R_L from top to bottom, and back to the transformer centre tap.

- The output waveform is the combination of the two half-cycles, that is a continuous series of positive half cycles of sinusoidal waveform. this is also called positive full-wave rectification.

Full wave Rectifier

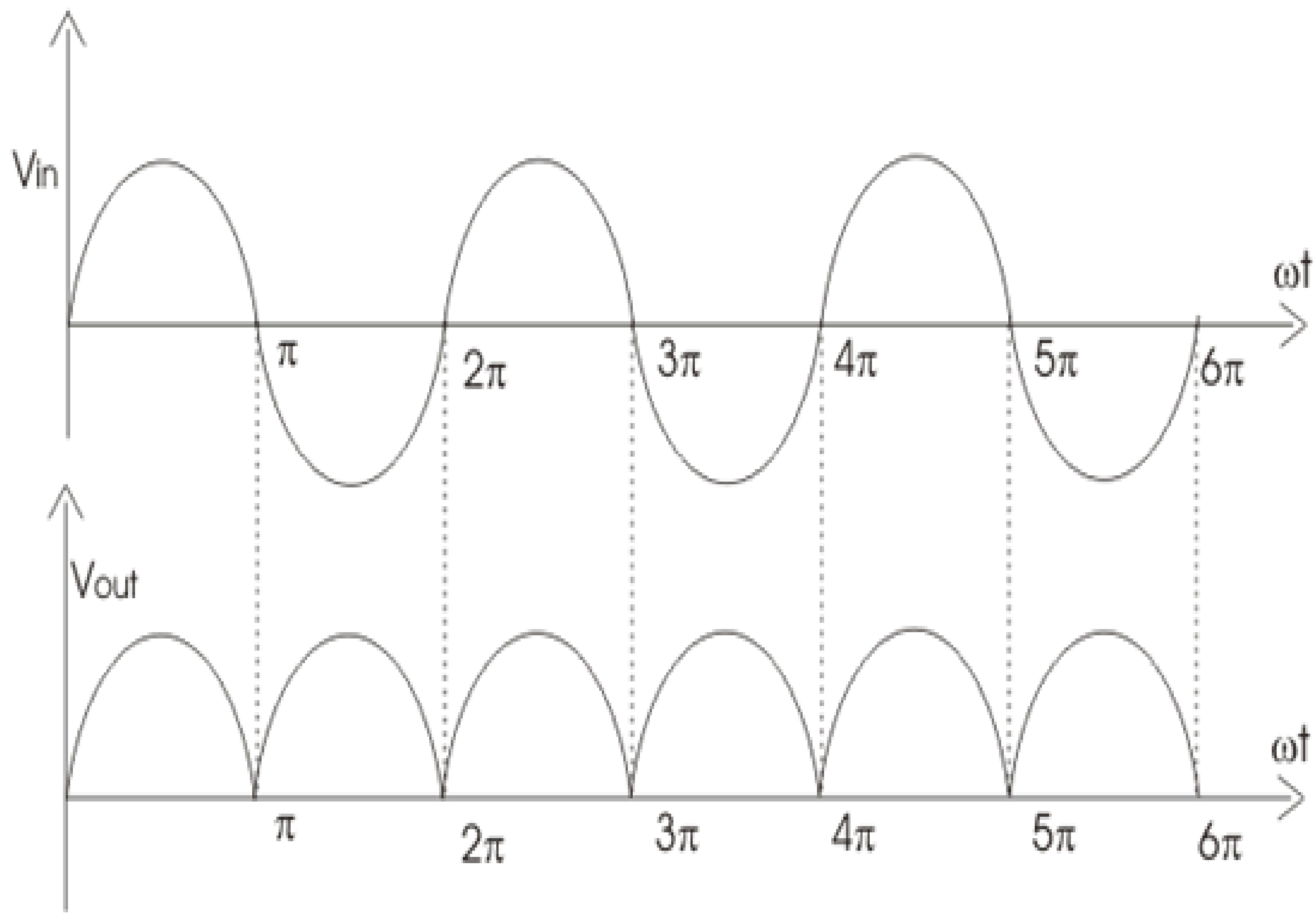
$$V_{rms} = \frac{Vm}{\sqrt{2}}$$

$$I_{rms} = \frac{Im}{\sqrt{2}}$$

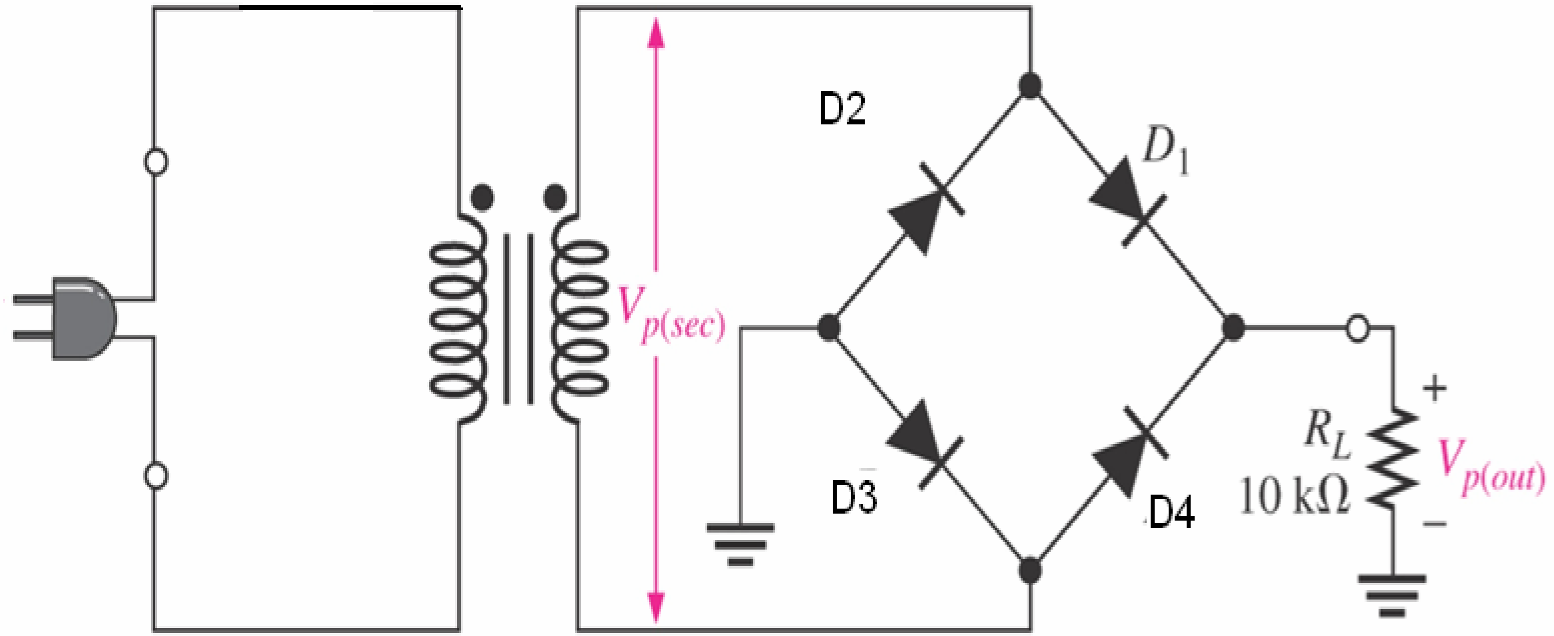
$$V_{dc} = \frac{2Vm}{\pi}$$

$$I_{dc} = \frac{2\,Im}{\pi}$$

Out put waveform of full wave Rectifier



Full wave **Bridge Rectifier**



Bridge Rectifier

- The centre-tapped transformer used for the full wave rectification is more expensive and requires more space than additional diodes.
- So the bridge rectifier is the circuit most frequently used for full-wave rectification.
- The bridge rectifier circuit consist of four diodes connected .diodes D1 and D2 are series-connected. and D3 and D4 are series connected

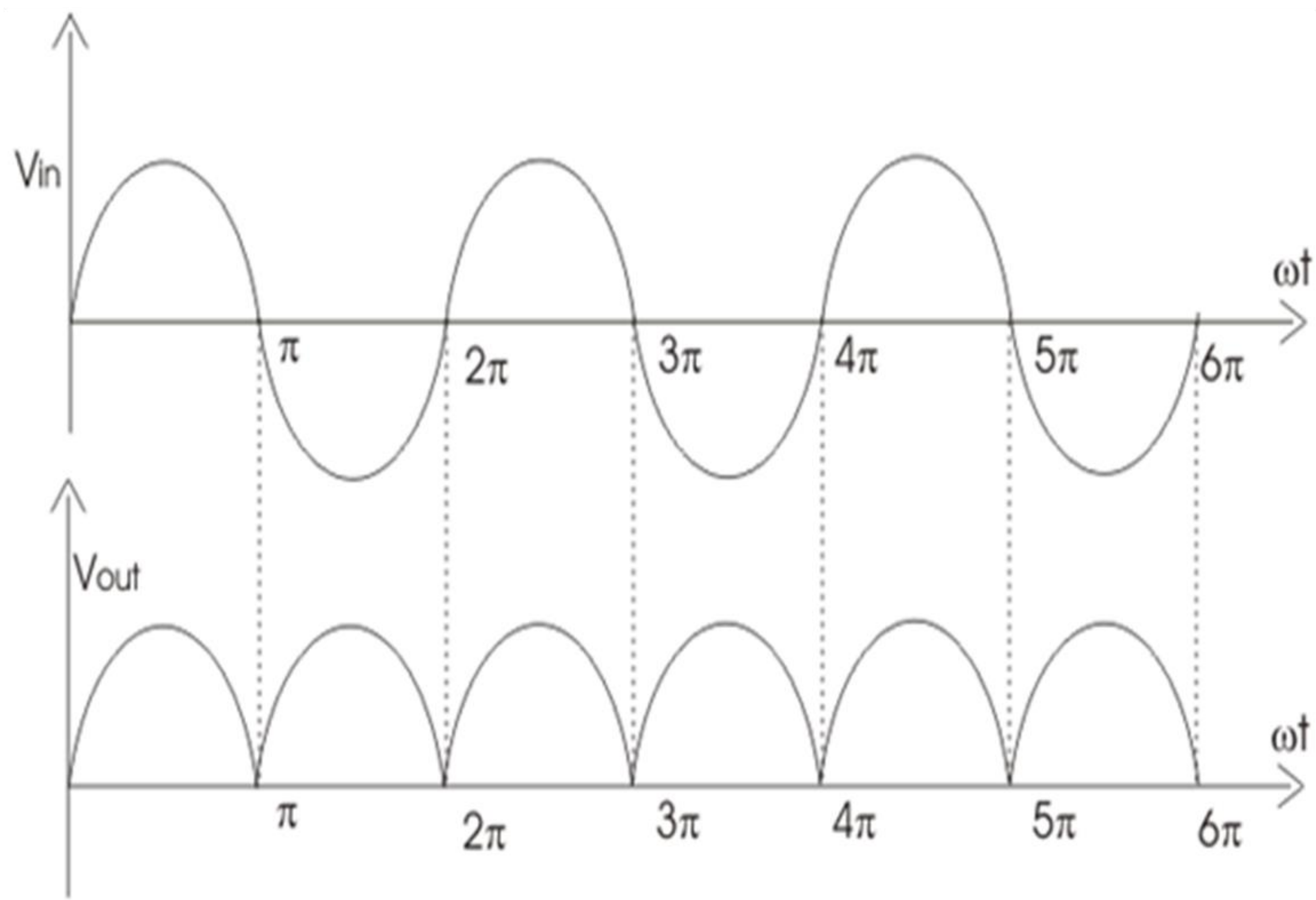
- The ac input terminals are connected at the junction of D1 and D2 and the junction of D3 and D4.
- The positive output terminal is at the cathodes of D1 and D4 and negative output is at the anodes of D2 and D3
- During positive half cycle of input voltage, diodes d1 and d4 are forward biased and load current flows ,
- During negative half cycle of input voltage diodes d3 and d4 are forward biased and load current flows,

Full wave Rectifier (Bridge)

$$V_{rms} = \frac{Vm}{\sqrt{2}} \qquad I_{rms} = \frac{Im}{\sqrt{2}}$$

$$V_{dc} = \frac{2Vm}{\pi} \qquad I_{dc} = \frac{2\,Im}{\pi}$$

Out put waveform of full wave Rectifier



Peak Inverse Voltage (PIV)

Peak inverse voltage (PIV) : It is the maximum Reverse voltage across a diode when diode is Reverse biased

Half-wave rectifier: V_m

Full -wave rectifier (center taped) : $2\ V_m$

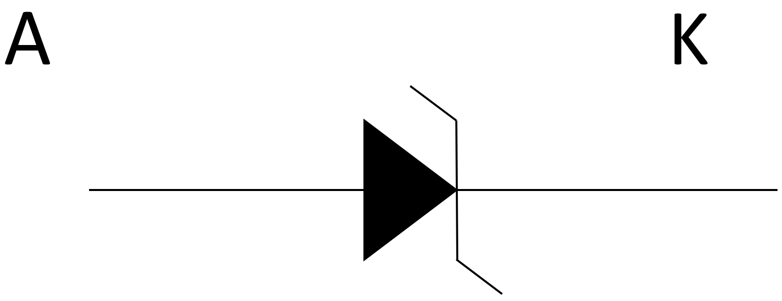
Full wave rectifier (Bridge) : V_m

Comparison of Rectifiers

s.no	particular	Half wave rectifie	Centre-tap full wave rectifier	Bridge rectifier
1	No.of diodes	1	2	4
2	Dc current	$\frac{Im}{\pi}$	$\frac{2Im}{\pi}$	$\frac{2Im}{\pi}$
3	Rms current	$\frac{Im}{2}$	$\frac{Im}{\sqrt{2}}$	$\frac{Im}{\sqrt{2}}$
4	Efficiency	40.6%	81.2%	81.2%
5	Ripple factor	1.21	0.48	0.48
6	Output frequency	f_{in}	$2f_{in}$	$2f_{in}$
7	Peak Inverse voltage	v_m	$2v_m$	v_m

Break down Diodes

Zener diode symbol



- When the reverse voltage reaches breakdown voltage in normal PN junction diode, the current through the junction and the power dissipated at the junction will be high. Such operation is destructive and diode gets damaged

- If the diode is heavily doped:
- Depletion layer will be thin
- The break down occurs at the lower voltages.
- The break down or Zener voltage depends upon the amount of doping.

Zener and Avalanche breakdown

- There are two mechanisms that cause breakdown in reverse biased PN junction

- Zener break down
- Avalanche breakdown

Zener breakdown

- Zener diode is heavily doped than ordinary diode, with a very narrow depletion region.
- The electric field strength (Volts/width) produced by a reverse bias voltage can be very high.
- The high intensity electric field caused electrons to break away from their atoms, this is termed as **ionization by electric field** also called zener break down.
- Zener breakdown usually occurs with reverse bias voltage less than 5V

Avalanche breakdown

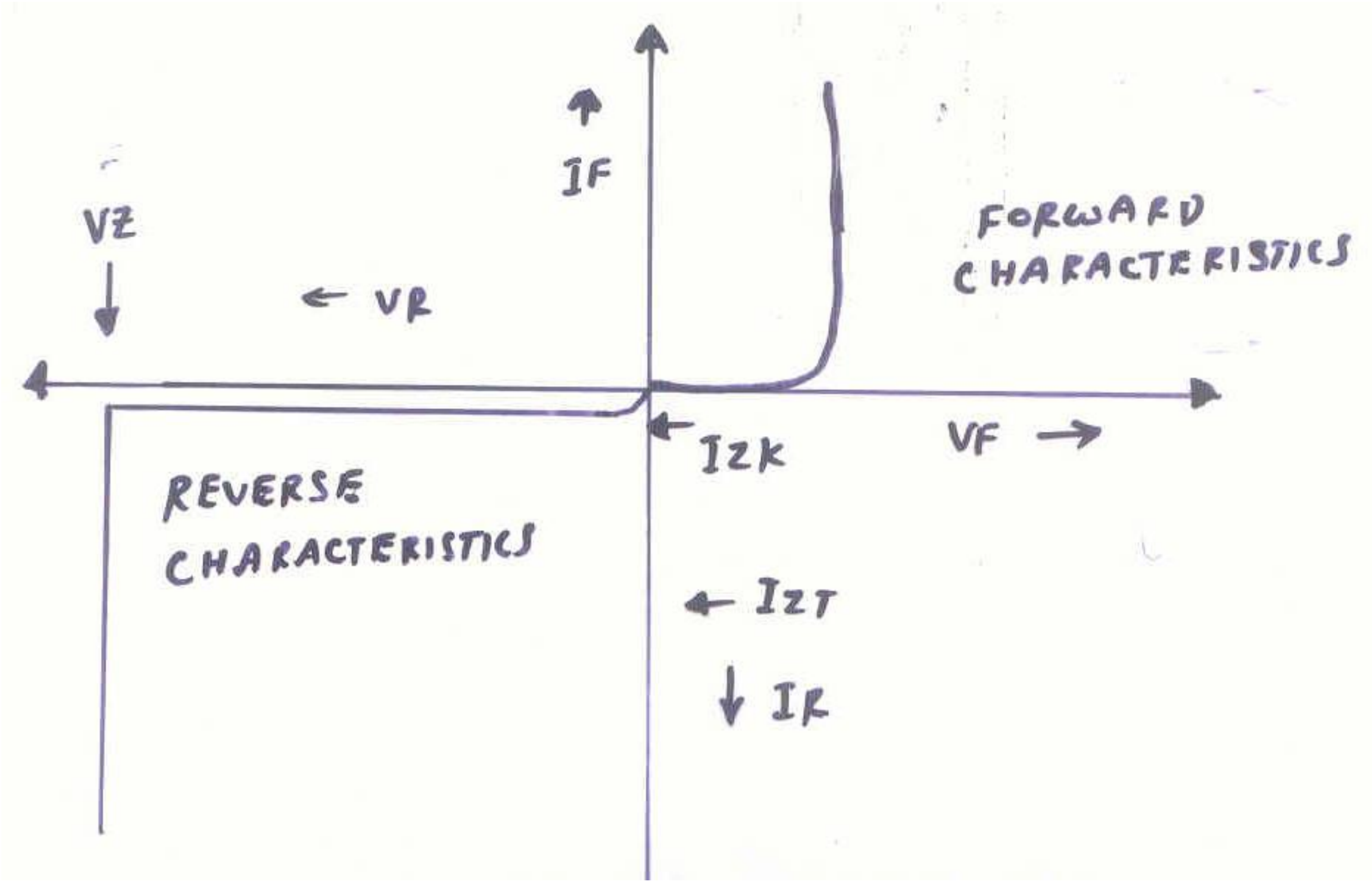
- The electrons in the reverse saturation current can be given sufficient energy to cause other electrons to break free when they strike atoms with in the depletion region, this is termed as **ionization by collision**.
- The released in this way collide with other atoms to produce more free electrons in an avalanche effect
- Avalanche breakdown is normally produced by reverse voltage level above 5v

- Zener and Avalanche are two different types of breakdown. The name zener diode is commonly applied to all breakdown diodes

Zener diode Characteristics

- Zener diode is always connected in reverse bias condition
- A zener diode has sharp break down voltage, called zener voltage V_z
- The forward characteristics are just like ordinary diode.

Characteristics of zener diode



Parameters of zener diode

- V_z Zener break down voltage
- I_{ZT} Test current for measuring V_z
- I_{ZK} Reverse current near the Knee of the characteristics, the minimum current to sustain breakdown
- V_F,I_F is Forward voltage and Forward current
- V_R,I_R is Reverse voltage and Reverse current