Two Terminal Device
Lecture 2

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Drift Velocity:

This is the average velocity attain by charged particles in a materials due to electric field.

In general, electrons in conductor will propagate randomly at Fermi velocity resulting in an average velocity of zero.

Applying an electric field add to this random motion a small net flow in one direction known as drift.

Drift velocity is proportional to current.

In a resistive materials it is proportional to magnitude of external field.

Hence Ohm’s Law can be explained by drift velocity

$$u = \mu E$$

Where u is the drift velocity, μ is the electron mobility and E is the electric field.

When Potential Difference is applied across a conductor free electrons gain velocity in the direction opposite to electric field between successive collisions acquiring a velocity in that direction in addition to random motion. As a result drift velocity of electrons which is superimposed on random motion. Due to this drift velocity there is a net flow of electrons opposite to direction of field.

Electron Mobility:

It is the characteristic of electrons how can it move through a metal or semiconductor when pulled by an electric field.

In case of holes it is known as Hole Mobility.

When an electric field is applied across a piece of material, the electrons respond by moving with an average velocity or drift velocity (v_d).

Electron Mobility is defined as

$$\mu_d = \mu E$$

Unit is cm^2/VS or mt^2/VS

What is the Conductivity?

Conductivity is proportional to the product of mobility & carrier concentration.

For semiconductor, such as transistor behaviour depends on mobility.

Therefore it is an important parameter in case of semiconductor. Higher mobility leads to better device parameter. It depends on impurity, concentration, temperature & electric field.

Zener Diode:

It is actually a PN diode working under reverse bias condition.

The characteristic beyond Turn Over Voltage becomes almost vertical line. Thus in this region of its characteristic the reverse voltage across the diode remains almost constant.

Therefore a Zener Diode is used as voltage reference device for stabilizing a voltage at a predetermined value.

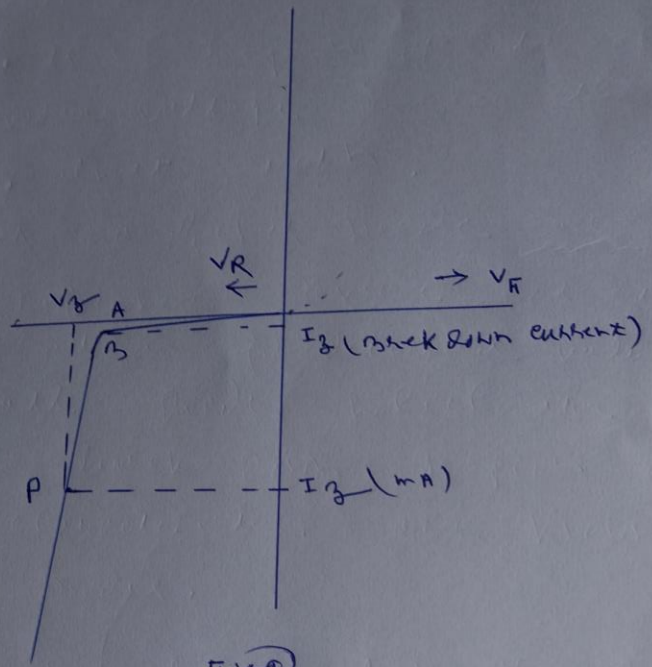

Fig (i)

Fig (ii)

However all diode which are operate in the break down region of their reverse characteristic are known as Zener Diode.

For normal operation of a Zener Diode in the break down region, the current through the diode should be limited by an external circuit to a suitable value, such that the power dissipated across the junction is within the power holding capability.

If this precaution is not observed in proper way, the diode will be damaged.

Zener dynamic impedance

$$r_Z = \frac{\delta V_z}{\delta I_Z}$$

Zener diode can be used as voltage regulator in an unregulated power supply.

Advantage of Semiconductor Diode:

a) It is manufactured within very wide range

b) It is solid state device, long operation of life.

c) It is small & physically strong.

d) It does not require heating filament

e) It is operated at very low voltage.

Single Phase Half Wave Rectifier:

The AC voltage to be rectified is connected to the primary coil of the power transformer (T).

The anode of the diode is connected to one end of the secondary coil of the transformer. The cathode is connected to the load resistance (R_L)

Under the action of a sinusoidal AC voltage of frequency ($\frac{\omega}{2\pi}$) applied to the primary coil of the transformer, the AC voltage across the secondary of the transformer, which is applied to the diode in series with (R_L)

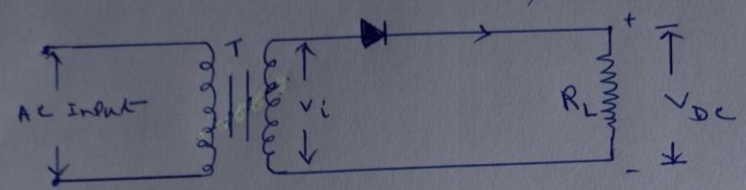

Fig (iii) Half wave Rectifier

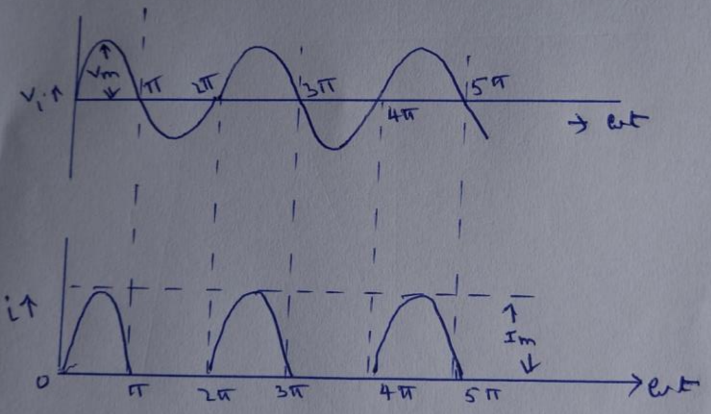

Fig (iv) Input & output wave.

Therfore

$$V_i = V_m\, sin\omega t$$

Where V_m is the maximum transformer secondary voltage.

During the half cycle of (V_i) when the P-region of the diode is positive with respect to the N-region the diode is in forward biased condition. Hence current flows from P to N through the diode. Now during the next half cycle when the P-region is negative with respect to N-region the diode is in reverse biased condition. Hence there is no current flows through the diode.

Consequently the current through (R_L) is unidirectional and it flows in the form of half sine wave separated by a period of 180^0.

The unidirectional current pulses are represented by

$$i = \frac{V_m \, sin\omega t}{R_L + R_f}$$

$$= I_m \; sin\omega t, \text{ when } 0 \leq \omega t \leq \pi$$

$$= 0, \text{ when } \pi \leq \omega t \leq 2\pi$$

Where R_f is the dynamic forward resistance of the diode and I_m is the maximum value of the current given by

$$I_m = \frac{V_m}{R_L + R_f}$$

The corresponding voltage across R_L is also in the form of half sine waves in phase with the current pulses. Since in one cycle of the AC input voltage one current pulse is obtained, the frequency of the pulses is the same as that of the input voltage.

Average DC current through R_L is

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i \, d\,(\omega t)$$

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m sin\omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0.\, d(\omega t)\right]$$

$$I_{dc} = \frac{1}{2\pi} I_m \int_0^{\pi} sin\omega t\, d(\omega t)$$

$$I_{dc} = \frac{I_m}{2\pi} [-cos\omega t]_0^{\ 2\pi}$$

$$I_{dc} = \frac{I_m}{\pi}$$

Again The **rms** value of the current is

$$I_{rms} = \frac{I_m}{2}$$

The AC ammeter connected in series with the diode will give the rms value of the current. It should be noted that this value is not the same as the rms value of sinusoidal current which is $\frac{I_m}{\sqrt{2}}$.

The power Pi supplied to the circuit from the AC source is given by

$$P_i = {I_{rms}}^2(R_L + R_f\ )$$

$$P_i = (I_m|2)^2\ (R_L + R_f\ )$$

Average Power supply to the load:

$$P_{dc} = {I_{dc}}^2 R_L$$

$$P_{dc} = (I_m|2)^2$$

Efficiency:

Now the efficiency of the rectifier is given by

$$\eta = \frac{Power\ supplied\ to\ the\ load}{Total\ input\ AC\ power}$$

$$\eta = \frac{P_{dc}}{P_i} \times 100\%$$

$$\eta = \frac{(I_m/\pi)^2 R_L}{(I_m/2)^2 (R_L + R_f)} \times 100\%$$

$$\eta = \frac{40.6}{1 + \frac{R_f}{R_L}} \%$$

If $R_f \ll R_L$, the efficiency (η) is maximum. Hence the theoretical value of efficiency is 40.6 %

Ripple Factor:

In the rectifier circuit the unidirectional load current is in the form of half sine waves. In any rectifier circuit even with filters we get unidirectional load current with periodically alternating components. A measure of the alternating components is given by the ripple factor(γ)

$$\gamma = \frac{rms\ value\ of\ all\ AC\ components}{Average\ or\ DC components}$$

$$\gamma = \frac{{I_{rms}}'}{I_{dc}} \qquad \gamma = \frac{{V_{rms}}'}{V_{dc}}$$

I_{rms}' and V_{rms}' are the rms value of AC component of output current and voltage.

Here

$$I_{dc}^2 + I'^2_{rms} = I_{rms}^2$$

Dividing I_{dc}^2 we get

$$1 + \frac{I'^2_{rms}}{I_{dc}^2} = \frac{I'^2_{rms}}{I_{dc}^2}$$

$$\frac{I'^2_{rms}}{I_{dc}^2} = \frac{I'^2_{rms}}{I_{dc}^2} - 1$$

$$\frac{I'_{rms}}{I_{dc}} = \sqrt{\frac{I'^{2}_{rms}}{I_{dc}^{2}} - 1}$$

In case of half wave rectifier

$$= \frac{I'_{rms}}{I_{dc}} = \frac{I_m/2}{I_m/\pi} = \frac{\pi}{2} = 1.57$$

$$\gamma = \sqrt{(1.57)^2 - 1} = 1.21$$

For half wave rectifier

$$\gamma > 1$$