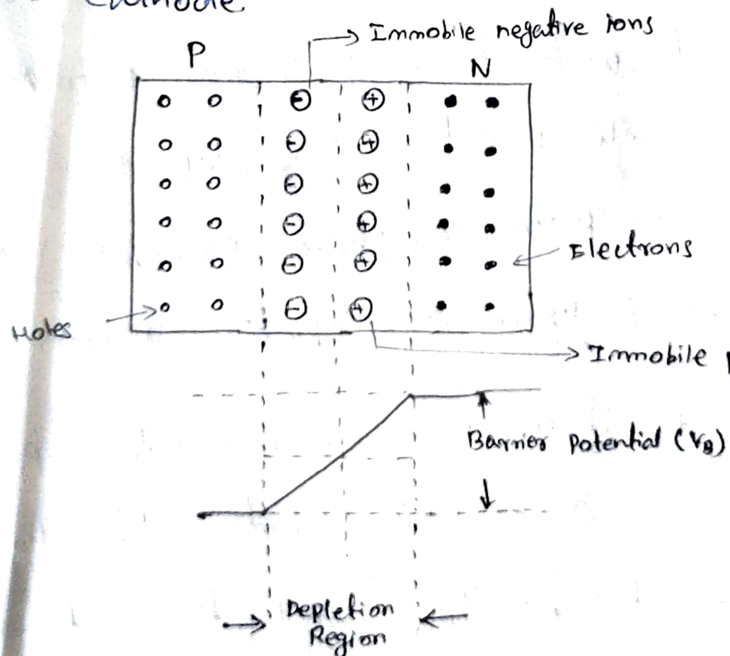
PN Junction (or) Diode:

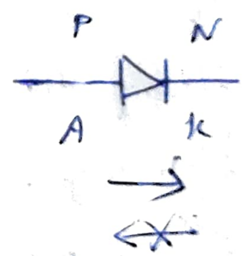
Evocation:

Introduction:

* A junction is formed between a sample of 'p' type semiconductor and a sample of 'N' type semiconductor joined together then this device is called the PN Junction.

* The formation of PN Junction is also called as Diode, because it has two electrodes one for p region named as anode and the other for 'N' region named as cathode.





* The N type semiconductor has high concentration of free electrons while P type semiconductor has high concentration of holes. At the junction there is a tendency for the free electrons to move

towards the P side and holes to the N side and vice versa. This process is known as diffusion. The diffusion is the process by which charge carrier move from high concentration area to low concentration area.

* When a free electrons diffusing from N side into P side recombine with holes and leaves a negatively charged immobile ions near the junction of P side. Similarly holes diffusing from P side into N side recombine with electrons and leaves a positively charged immobile ions near the junction of N side.

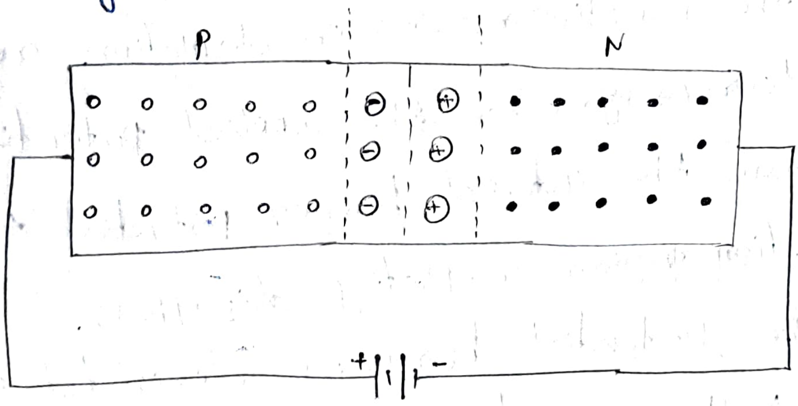
* After certain extent the immobile positive ions deposited across the N region prevents further charge carrier diffusion from P region into N regions, similarly the immobile negative ions deposited across the N regions into P region. These immobile ions forms a region, it is known as depletion region.

* The existence of these immobile ions develops the potential difference across the junction, this potential acts as barrier for further conduction between the junction. Thus, this potential is named as barrier potential or cut in voltage of semiconductor diode. The value of barrier potential is 0.3 V for germanium diodes and 0.7 V for silicon diodes.

Operation of a PN Junction:

(1) Forward Bias:

* In an unbiased PN junction, there is No flow of current. A PN junction connected to an external voltage source is called as biased PN junction. By this biasing the width of depletion region is controlled which results in control of it's resistance and current flow is possible.
* When an external voltage is applied to the PN junction, in such a way that it cancels the potential barrier and permits the current flow, it is called as biasing



* When the positive terminal of a battery is connected with P-type semiconductor and the negative terminal is connected with N-type semiconductor provides the forward bias to PN junction.

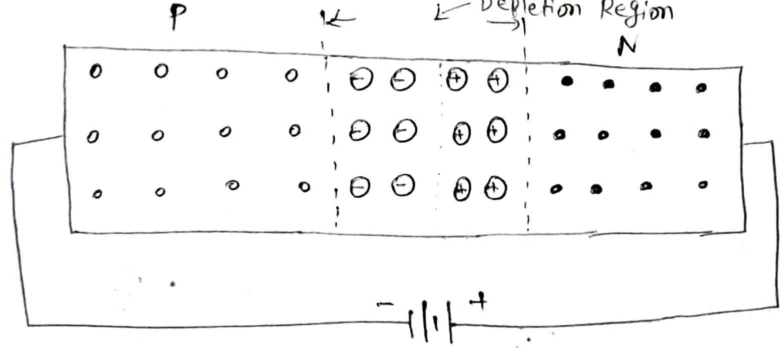
* The applied forward Potential establishes an electric field opposite to the potential barrier. Therefore the potential barrier is reduced. As the potential barrier is very small (0.3 V for Ge and 0.7 V for Si), a small forward voltage is sufficient to completely eliminate the barrier Potential, thus the junction resistances becomes zero.

* In other words, the applied positive potential repels the holes in the 'P' region so that the holes move towards the junction and applied negative Potential repels the electrons in the N region towards the junction results in depletion region starts decreasing. when the applied potential is more than the internal barrier potential then the depletion region completely disappear.

* once the potential barrier is eliminated by a forward voltage, junction establishes the low resistance Path for the entire circuit, thus a current flow in the circuit is called as forward current.

(ii) Reverse Bias:

* When an external voltage is applied to PN Junction in such a way that it increases the Potential barrier then it is called as reverse bias. Here the -ve terminal is connected to P type and +ve terminal is connected to N type semiconductor.



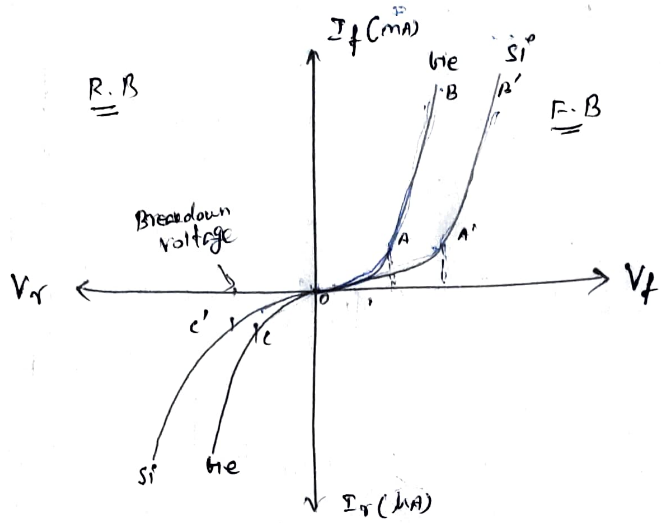
* when reverse bias voltage is applied to the junction, all the majority carriers of p region are attached towards the -ve terminal of the battery and the majority carriers of the N region attached towards the positive terminal of the battery, hence the depletion region increases.

* The applied reverse voltage establishes an electric field which acts in the same direction of the Potential barrier ∴ the resultant field at the junction is strengthend and the barrier width is increased. This increased potential barrier prevents the flow of charges carriers across the junction. so high resistance path established

V-I characteristics of PN Junction:

(i) Forward Bias:

* Here, on varying this voltage slowly, at some forward voltage the potential barrier is eliminated and current starts flowing. This voltage is known as thershold voltage (V_{th}) (or) cut in voltage (or) knee voltage



* As, the forward applied voltage increases beyond threshold voltage, the forward current rises exponentially. It should be remembered that if the forward voltage is increased beyond a certain safe value, it produces an extremely large current which may destroy the junction due to overheating.

* In portion of OA (or) OA' even if the large variation in applied voltage small variation in the current flowing through the diode because of the depletion region occurs. At point A', $V_f = V_{th} = V_B$ hence the depletion region disappears result in which the current linearly increases in portion AB (or) AB'. This portion is known as linear operating region of diode.

∴ The forward resistance is

$$R_f = \frac{\Delta V_f}{\Delta I_f}$$

(ii) Reverse Bias:

* Under this condition, a storg depletion region is formed across the junction, it offers very high resistance, thus very small current flows o_c and o_c'.

* In this case the junction resistance becomes very high and practically no current flows through the circuit. If the reverse voltage is further increased, the kinetic energy of the electrons become so high that they knock out electrons from semiconductor atoms. At this stage breakdown of junction occurs results in there is a sudden rise of reverse current. This current is known as reverse saturation current.

The Reverse resistance is

$$R_r = \frac{\Delta V_r}{\Delta I_r}$$

Application:

* As switches
* Power supply
* Digital Systems
* As rectifiers
* clippers, & clampers
* communication systems.

Recall:

* what is diode?
* How diode will conduct in F.B & R.B?
* what is the application of Diode.
* what is diffusion, depletion region?

Hour-2

Zener Diode:

Evocation:

Introduction:

* In a general purpose PN diode the doping is light, as a result of this the breakdown voltage is high. If a p and N region are heavily doped then the breakdown voltage can be reduced.
* When the doping is heavy, even the reverse voltage is low, the electric field at barrier will be so strong thus the electrons in the covalent bands can break away from the bonds. This effect is known as zener effect.

Concept:

* A diode which exhibits the zener effect is called a zener diode. Hence it is defined as a reverse biased heavily doped PN Junction diode which operates in breakdown region. The zener diodes have been designed to operate at voltages ranging from a few volts to several hundred volts.
* zener breakdown occurs in junctions which is heavily doped and have narrow depletion layers. The breakdown voltage sets up a very strong electric field. This field is strong enough to

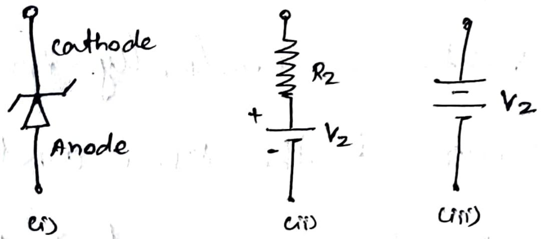
break the covalent bonds thereby generating electron hole pairs.

* Even a small reverse voltage is capable of producing large number of current carrier, when a zener diode is operated in the breakdown region care must be taken to see that the power dissipation across the junction is within the power rating of the diode otherwise heavy current flowing through the diode may destroy it.

ZD → [illegible]

D → [illegible]

Equivalent circuit of zener diode:

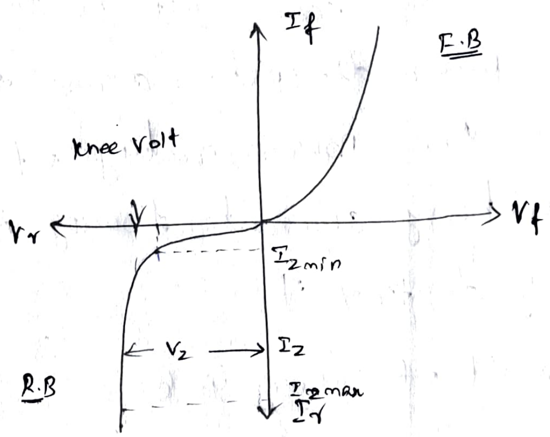


When the reverse bias voltage across of zener diode exceeds the breakdown voltage V_z, the current increases very sharply. It means that voltage across zener diode is constant at V_z even though the current through it changes. Therefore in breakdown region, a zener diode may be represented by a battery of voltage V_z in series with the zener resistance.

V-I characteristics of zener diode:

The forward characteristics of a zener diode is similar to that of a PN junction diode.

* The reverse current that is present at the orgin and the knee of the curve is due to the reverse leakage current due to the minority carriers. This current is specified by stating it's value at 80% of the zener voltage V_Z.



* As the Reverse voltage is gradually increased, the breakdown occurs at the knee and the current increases rapidly. To control this current a suitable external resistance has to be used. The maximum permissible value of the current is denoted by I_{zmax}. The min usable current is I_{zmin}.

* The voltage across the terminals of the diode for a current I_Z which is the approximate midpoint of the linear range of the reverse characteristics is called the zener voltage (V_Z).

Applications:
* voltage Regulators * clippers * meter Production
* Reshapping waveform

Recall: * what is the diff. b/w zener & Avalanche breakdown?

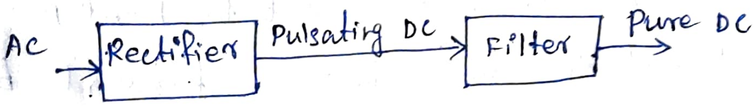
Rectifiers:

Evocation:

Introduction:

Many electronic derices need DC Voltage sources. It is not very conrenient to rely on batteries for such voltages. circuits which are used to convert AC voltage to DC voltage are called rectifiers.

Actually, a rectifier convert the AC voltage to a unidirectional (Pulsating) voltage. when this voltage (or current) is passes through a filter, we get a voltage (or current) of more nearly costant value.



Concept:

Types of uncontrolled Rectifiers:

(i) Half-wave Rectifier:

* It consists of transformer, diode and load resistance. Here diode act as a switch i.e under forward biased condition, it is a closed switch and reverse biased condition, it is a open switch. The transformer used to step down the input voltage.

* The sinusoidal AC voltage is fed to transformer primary winding. The voltage across the secondary winding is $V_s = V_m \sin\omega t$. V_m is the maximum value of the input voltage.

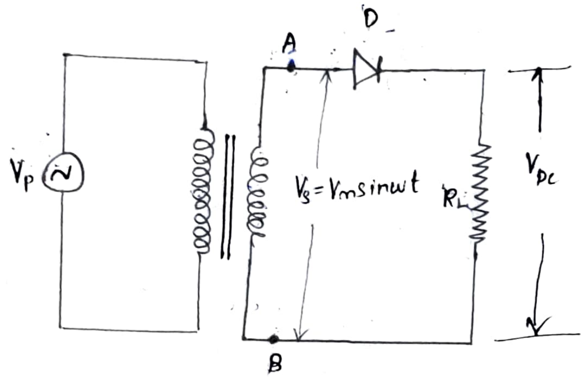


Fig (1)

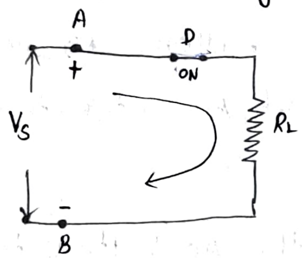


Fig (2)

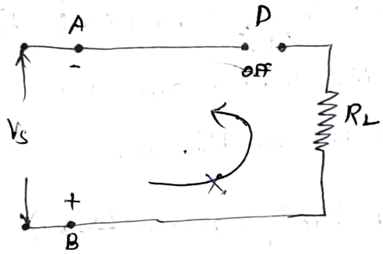


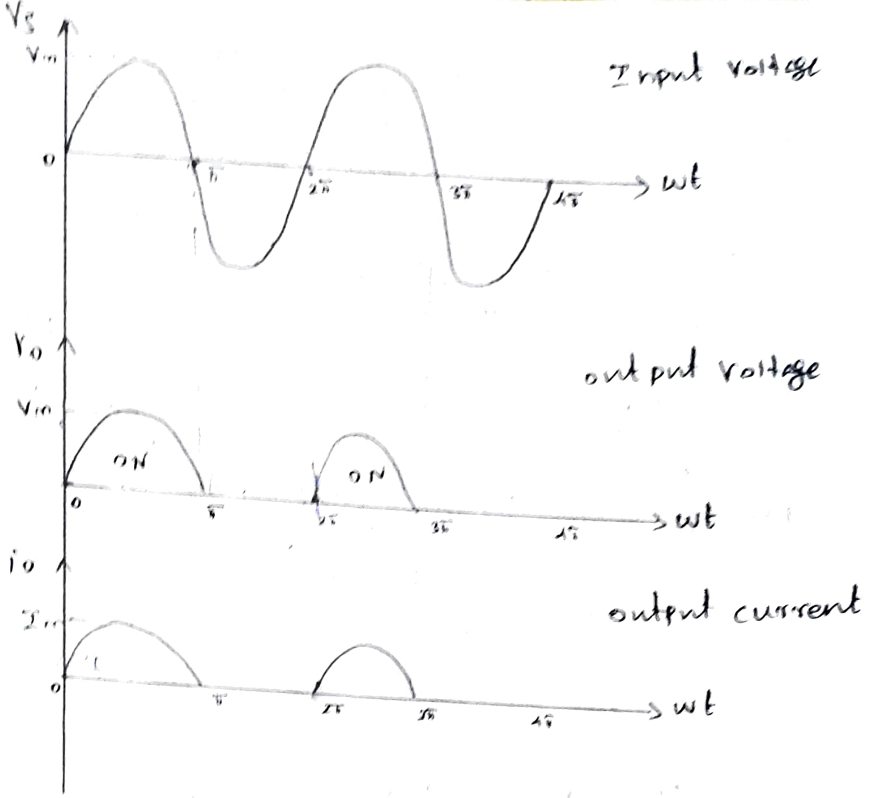
Fig (3)

Operation:

* During +ve half cycle of the input voltage (0 to π), the point A is +ve with respect to point B. During this period, the diode becomes forward biased and it act as a closed switch. The entire positive input voltage is applied across the load. The current path is A - D - R_L - B.

* During -ve half cycle (π to 2π) of the input voltage, the point B is +ve with respect to point A. During this period, diode becomes reverse biased. Then it act as a open switch. There is no output voltage across load. The entire -ve half cycle input voltage appears across the diode. There is no current in the load.

* Here the output voltage is not a steady state DC but only a pulsating DC. Here, we are using only half-cycle of the input voltage. That's why it is called a half-wave rectifier.



DC output voltage (V_{dc}):

Input voltage $V_s = V_m \sin\omega t$

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_s \cdot d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \cdot d\omega t$$

$$= \frac{V_m}{2\pi}\left[\int_0^{\pi} \sin\omega t \cdot d\omega t + \int_{\pi}^{2\pi} 0 \cdot d\omega t\right]$$

$$= \frac{V_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{V_m}{2\pi} \times 2$$

$$V_{dc} = \frac{V_m}{\pi}$$

DC output current (I_{dc}):

$$I_{dc} = \frac{V_{dc}}{R_L} \Rightarrow \frac{V_m}{\pi \cdot R_L}$$

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

RMS output voltage (V_{orms}):

$$V_{orms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \cdot \sin^2\omega t \cdot d\omega t}$$

$$= \sqrt{\frac{V_m^2}{2\pi} \int_0^{\pi} \left(\frac{1-\cos 2\omega t}{2}\right) d\omega t}$$

$$= \sqrt{\frac{V_m^2}{4\pi} (\pi)}$$

$$V_{orms} = \frac{V_m}{2}$$

RMS load current (I_{orms}):

$$I_{orms} = \frac{V_{orms}}{R_L} \Rightarrow \frac{V_m}{2R_L}$$

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

Dc output power (P_{dc}):

$$P_{dc} = I_{dc}^2 \cdot R_L \Rightarrow \frac{I_m^2}{\pi^2} \cdot R_L$$

AC Input Power (P_{in}):

$$P_{in} = I_{orms}^2 \cdot R_L \Rightarrow \frac{I_m^2}{4} \cdot R_L$$

Rectifier Efficiency:

$$\eta = \frac{P_{dc}}{P_{in}} \Rightarrow \frac{\frac{I_m^2}{\pi^2} \cdot R_L}{\frac{I_m^2}{4} \cdot R_L} \times 100$$

$$\eta = 40.6\ \%$$

Ripple Factor:

$$R.F = \frac{I_{ac}}{I_{dc}} \Rightarrow \frac{\sqrt{I_{orms}^2 - I_{dc}^2}}{I_{dc}} \Rightarrow \sqrt{\left(\frac{I_{orms}}{I_{dc}}\right)^2 - 1}$$

$$= \sqrt{\frac{(I_m/2)^2}{(I_m/\pi)^2} - 1}$$

$$RF = 1.21$$

Peak Inverse Voltage (PIV):

This is the maximum voltage with which the rectifier has to withstand during reverse biasing.

$$PIV = V_m$$

Transformer utilisation factor (TUF):

It is defined as the ratio of dc power delivered to the load to the ac rating of a transformer secondary.

$$TUF = \frac{P_{dc}}{P_{ac.\,rated}} \Rightarrow \frac{\left(\frac{I_m}{\pi}\right)^2 . R_L}{\frac{V_m}{\sqrt{2}} . \frac{I_m}{\sqrt{2}}}$$ $[\because P_{ac.r} = V_{ac.r} . I_{ac.r}]$

$[\because V_m = I_m . R_L]$

$$= \frac{\frac{I_m^2}{\pi^2} . R_L}{\frac{I_m^2}{2\sqrt{2}} . R_L}$$

$TUF = 28.6\ \%$

Advantages:

* simple circuit
* Low cost

Disadvantages:

* Low rectification efficiency
* Low TUF
* High ripple factor

Hour-4

(ii) Centre Tapped fullwave Rectifier:

It consists of two diodes, one centre-tap transformer and load resistor. By centre tapping, the impedance of the two halves of windings are equal. Thus the voltages in the two halves are 180° out of phase (or) when point A of secondary is maximum positive value, C is at maximum negative value.

operation:

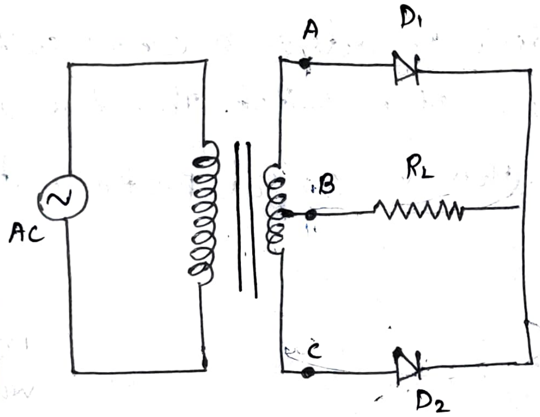


Fig (a)

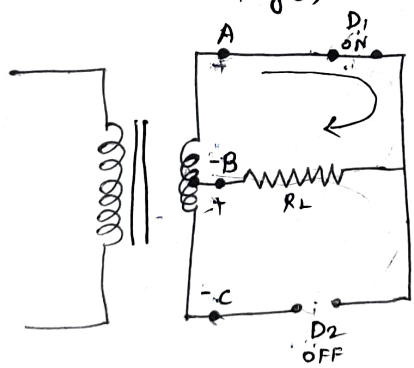


Fig (b)

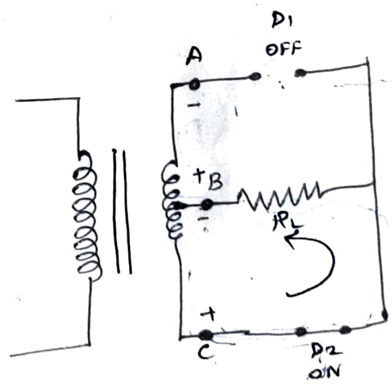


Fig (c)

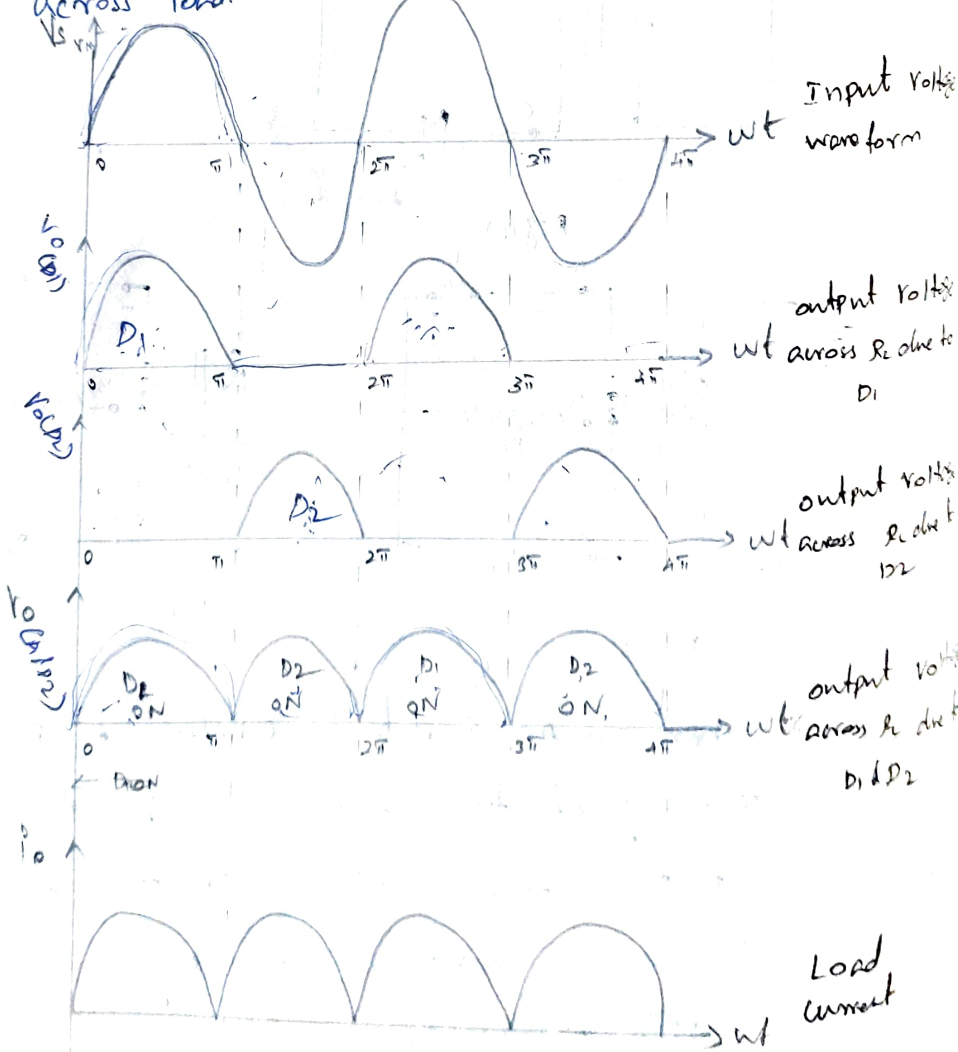
* When an AC input is applied to primary winding of transformer, as per the principle of transformer theory, it transferred to the secondary winding without changing the supply frequency.

* During the positive half cycle of the input voltage, the terminal A is more positive than

terminal 'c' thus diode D_1 ... biased than diode D_2.

* Thus diode D_1 act as a closed switch and diode D_2 act as a open switch. The current path is $A - D_1 - R_L - B$. Therefore, we can get positive output voltage across load.

* During the negative half cycle of the input voltage the terminal c is more positive than terminal ..., thus diode D_2 becomes more forward biased than diode D_1. Thus diode D_2 acts as a closed switch and diode D_1 acts as a open switch. Then the current path is $C - D_2 - R_L - B$. Here we can get positive output voltage across load.



Average output Voltage (V_{dc}):

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m . \sin\omega t . d\omega t$$

$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_0^{\pi}$$

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

Average output current (I_{dc}):

$$I_{dc} = \frac{2I_m}{\pi}$$

RMS output voltage (V_{orms}):

$$V_{orms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} V_m^2 . \sin^2\omega t . d\omega t}$$

$$= \sqrt{\frac{V_m^2}{\pi}\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right) . d\omega t}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\left(\omega t - \frac{\sin 2\omega t}{2}\right)_0^{\pi}}$$

$$= \sqrt{\frac{V_m^2}{2\pi}(\pi)}$$

$$V_{orms} = \frac{V_m}{\sqrt{2}}$$

RMS load current (I_{orms}):

$$I_{orms} = \frac{I_m}{\sqrt{2}}$$

DC output power (P_{dc}):

$$P_{dc} = I_{dc}^2 . R_L \Rightarrow \frac{4I_m^2}{\pi^2} . R_L$$

AC input Power (P_{in}):

$$P_{in} = I_{orms}^2 . R_L = \frac{I_m^2}{2} . R_L$$

Efficiency:

$$\eta = \frac{P_{dc}}{P_{in}} \times 100$$

$$= \frac{\frac{4I_m^2}{\pi^2} . R_L}{\frac{I_m^2}{2} . R_L} \times 100$$

$\eta = 81\%$

Ripple factor:

$$RF = \frac{\sqrt{I_{orms}^2 - I_{dc}^2}}{I_{dc}^2}$$

$$= \sqrt{\left(\frac{I_{orms}}{I_{dc}}\right)^2 - 1}$$

$$RF = \sqrt{\frac{I_m/\sqrt{2}}{2I_m/\pi} - 1}$$

$$RF = 0.48$$

Peak Inverse voltage (PIV):

It's defined as the maximum (or) Peak voltage that a diode can withstand under reverse biased condition.

Here assume during +ve half cycle of input, D_1 i conduction and D_2 is off. The maximum voltage at the lower part of the transformer is Vm and the Voltage drop across the R_L due to diode D_1 conducting in Vm.

∴ Thus PIV = Vm + Vm

PIV = 2Vm.

Transformer utilisation factor (TUF):

$$\% TUF = \frac{(TUF)_p + (TUF)_s}{2}$$

$$= \frac{81.1 + 57.2}{2}$$

% TUF = 69.15 %

Advantages:

* The output voltage & transformer efficiency are higher.
* Low ripple factor
* Higher TUF

Disadvantages:

* PIV of diode is high
* Usage of additional diode & transformer i's needed so costl

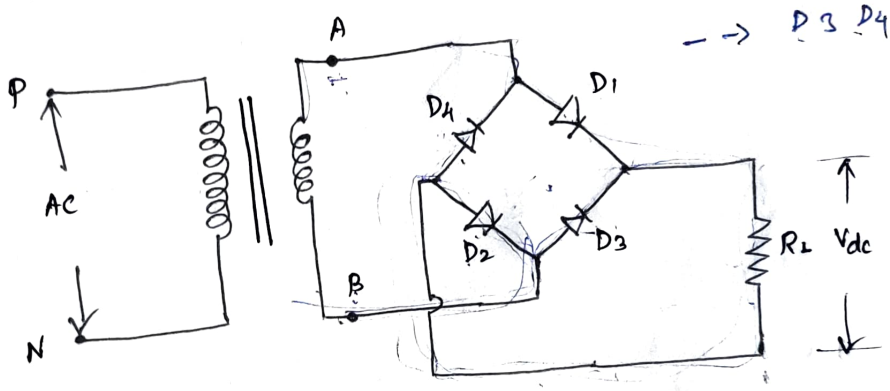
(iii) Full wave bridge rectifier:

The full wave rectifier uses a centre tap transformer, whose secondary voltage is twice the output voltage. The diode must also have ratings of twice the peak inverse voltage of that used in half wave rectifier circuits. In the bridge rectifier circuit, the centre-tap transformer is eliminated and also the PIV rating of the diodes is not so large.

operation:

+ → D_1 D_2.

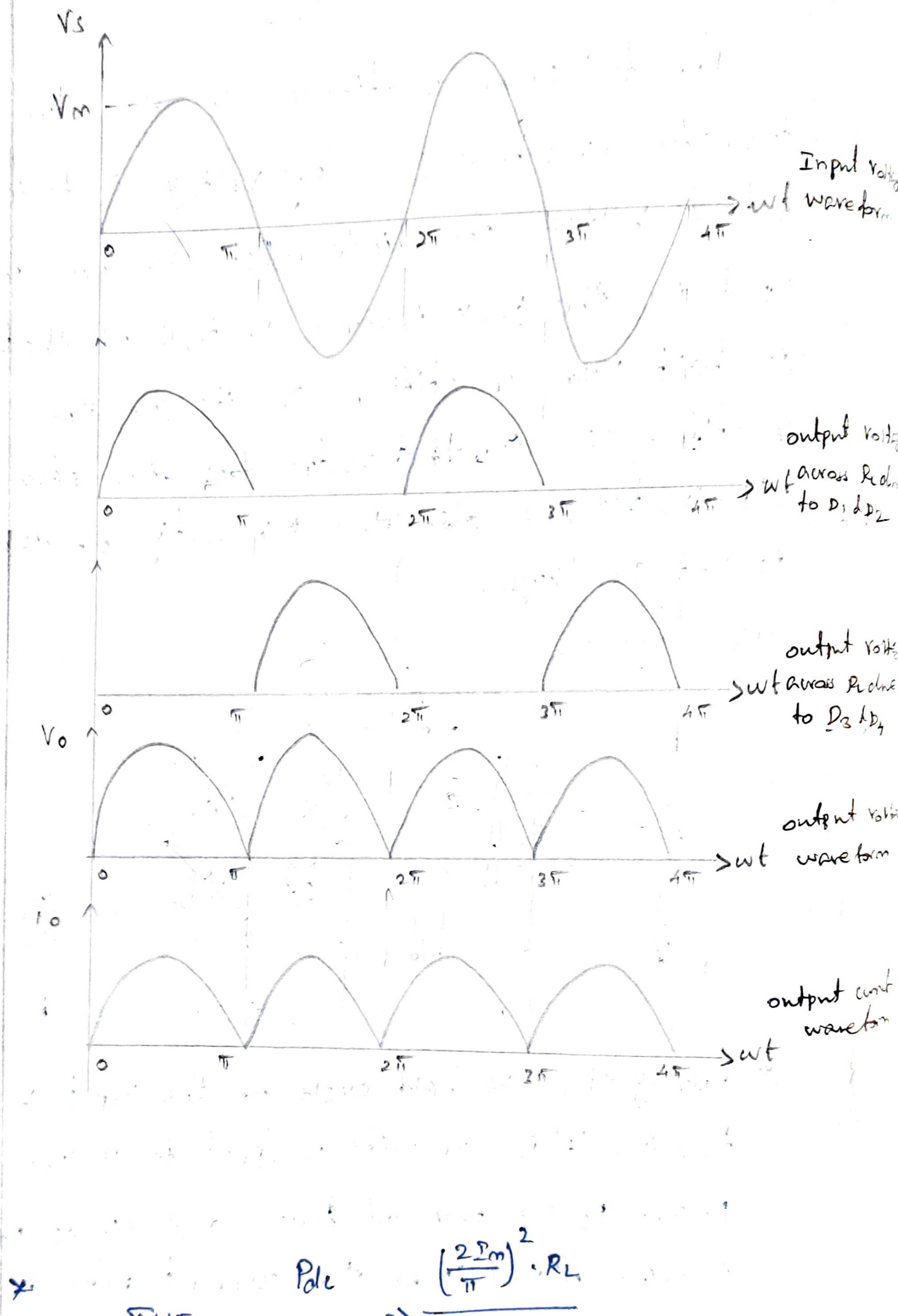
− → D_3 D_4



* During the +ve half cycle of the input voltage, the terminal 'A' is +ve with respect to B. Thus diodes D_1 and D_2 are forward biases and diodes D_3 and D_4 reverse biased. Then the current path is $A - D_1 - R_L - D_2 - B$

* During -ve half cycle of the input voltage, the terminal 'B' is positive with respect to terminal 'A'. Thus diodes D_3 and D_4 are forward biased and diodes D_1 and D_2 reverse biased. The current path is $B - D_3 - R_L - D_4 - A$.

→ The derivations for bridge rectifiers are same as that of centre tapped FWR, except TUF.



$$* \quad TUF = \frac{P_{dc}}{V_{orms} \cdot I_{orms}} \Rightarrow \frac{\left(\frac{2I_m}{\pi}\right)^2 \cdot R_L}{\frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}}$$

$TUF = 81\%$

Advantages:

* Transformer with centre tap in secondary is not required.
* It's suitable for high voltage application
* Better transformer utilisation factor.

Disadvantages:

* Additional two diodes are required.
* Rectifier efficiency is slightly reduces than the FWR, because the additional voltage drop and losses are higher as the two diodes are connected in series.

Applications:

* Battery charging
* for DC Motors

Recall:

* what is rectifier?
* what are the classification of Rectifiers?
* what is the differen between half, center tap & Full wave rectifiers?
* what is the application of Rectifiers?

Hours-5

Voltage Regulators:

Evocation:

Going to show the stablizer.

Introduction:

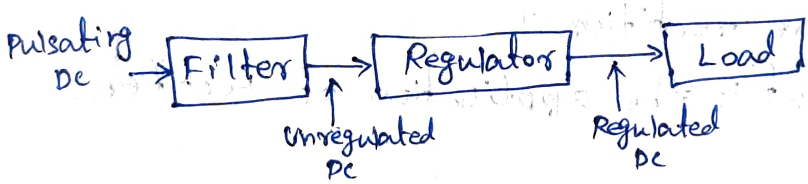
It is an electronic circuit that maintains a nearly constant output voltage, but in practice the output voltage of an unregulated power supply varies due to the following reasons

(i) change in input supply voltage

(ii) change in load resistance

(iii) change in temperature

To overcome the above mentioned difficulties, Voltage regulators are needed. A voltage regulator is connected between filter and load.



Concept:

(i) Load regulation:

It's defined as the change in the regulated output voltage when the load current changes from minimum to maximum.

$$\% \text{ Load regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

(ii) Line regulation:

It's defined as the change in regulated load Voltage for a specified range of line voltage.

$$\% \text{ Line regulation} = \frac{V_{HL} - V_{LL}}{V_{Nominal}} \times 100$$

Types of voltage regulators:

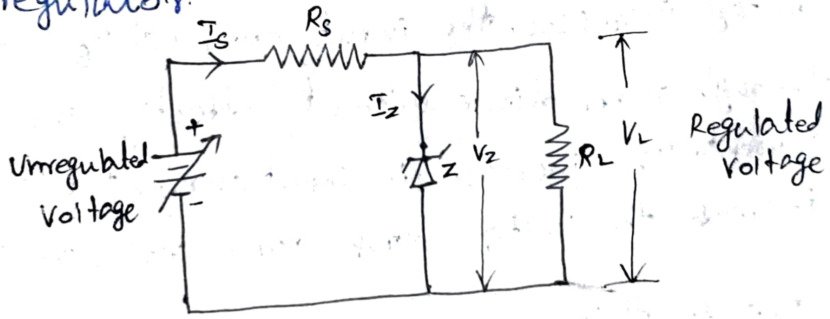
(i) Series voltage regulator
(ii) shunt voltage regulator

In the series voltage regulator, the control element is connected in series between input and output. In the shunt voltage regulator, the control element is connected in parallel with input and output.

Some important voltage regulators are
(i) zener diode shunt regulator
(ii) Transistor series voltage regulator
(iii) Transistor shunt regulator.

Zener diode shunt Regulator:

Here, a zener diode is connected in parallel with load. That is why it is known as shunt regulator.



A resistor R_s is connected in series with input. It is used to limit the input current. It is known as current limiting resistor. Here, zener diode is connected in the reverse biased. It operates in the breakdown region.

Apply KVL

$$V_S = I_S R_S + V_Z$$

$$I_S = \frac{V_S - V_Z}{R_S}$$

The practical zener diode should have a finite value of resistance called zener resistance. Because of the zener resistance, there is a voltage drop across it which is equal to $I_Z R_Z$.

Voltage across zener diode

$$V_L = V_Z + I_Z R_Z$$

If zener resistance is negligible, then the load voltage is equal to zener voltage.

$$V_L = V_Z$$

operation:

The output voltage is mainly varied due to the following two reasons

(i) Varying input voltage:

* Assume the load resistance is fixed. As the input voltage increases, the input current I_S also current through zener diode without affecting the load current. The increase in input current will also increase the voltage drop across series resistance.

* Due to this, raise in input voltage is dropped across the series resistance result in such a way that the load voltage is maintained constant.

* Suppose if the input voltage decreases, the source (or) input current also decreases. Due to this, the current through diode will also decreases. consequently voltage drop across R_S also decreased.

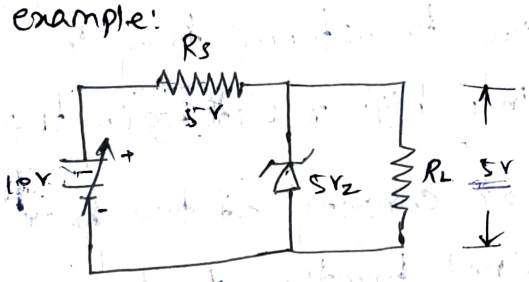
* Therefore the output voltage is maintained constant. In both cases the load current is not changed result in which the load (or) output load is maintained constant.

(ii) Varying load current:

Assume the input voltage is constant but the load current is varied by varying the load resistance. Here, the input current and voltage across R_s remains constant. When a load resistance decreases; the load current increases.

Due to this, zener current to decrease. Thus the load voltage remains constant.

For example:



Here the input voltage increased to 12V. Then the voltage drop across series resistance will be increased to 7V. Voltage across the load is 5V i.e the increased voltage is dropped in the Rs.

Disadvantages:

* Voltage regulation is very low.
* Power consumption in zenerdiode & Rs is higher than R_L.

Recall:

* What is Regulator, voltage regulation?
* why it is necessity?