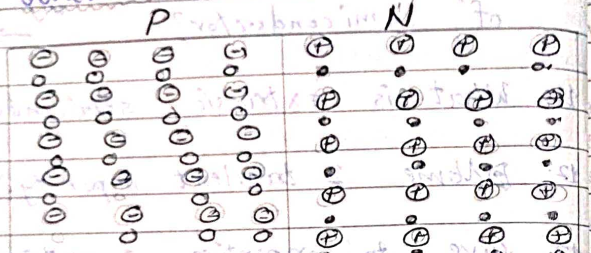
DIODES & THEIR APPLICATIONS

1

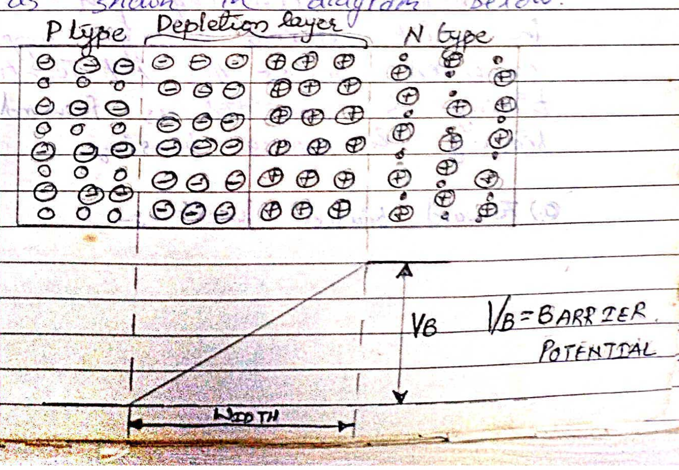
(1.) PN Junction



When P-type semiconductor & N-type semiconductors are jointed a PN Junction is formed. As soon a junction is formed due to intern- repulsion and difference in concentra the e^- from N-region diffuse int P-region and combine into holes. Similarly, holes from P-region diffuse into N-region and combine with e^-. Whenever a e^- combines with h in P region and positive immobile ion the N-region is left uncovered. Similarly, whenever a hole from P-reg combines with the e^- of N-region -ve ion in P-region is left uncovered. Thus a layer of +ve imm ions and -ve immobile ions is fo

on the either sides of the junction. Now the additional holes try to diffuse to into the N-region are repeled by the charge of +ve immobile ions. Similarly, the additional e^- trying to diffuse into P-region are repeled by the charge of -ve immobile ions. As a result of this, further the diffusion of e^- & holes across the junction is stopped.

The region containing immobile +ve and -ve ions is depleted of free e^- & free holes and hence is called depletion layer. This layer of ions acts as a barrier for further flow of e^- & holes across the junction as shown in diagram below.

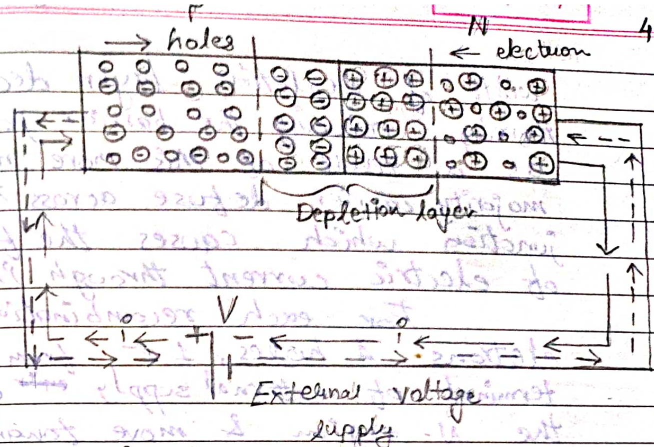


Since the depletion layer has immobile ions which are electrically charged, they possess electric field between them called barrier potential (V_B). The difference of potential from one side of the barrier to the other side is called barrier potential diff. With no ~~elect~~ external voltage applied the barrier potential for silicon PN Junction is 0·7 V and for germanium PN Junction it is 0·3 V.

(1·1) Biasing of PN Junction.

Whenever an ~~exert~~ external voltage supply is connected across PN Junction it is called biased PN Junction depending upon the way in which external voltage supply connected across the PN Junction biasing is classified as forward biasing & reverse biasing.

(a.) Forward biased junction:-



→ : direction of flow of current

- - → : direction of flow of electrons.

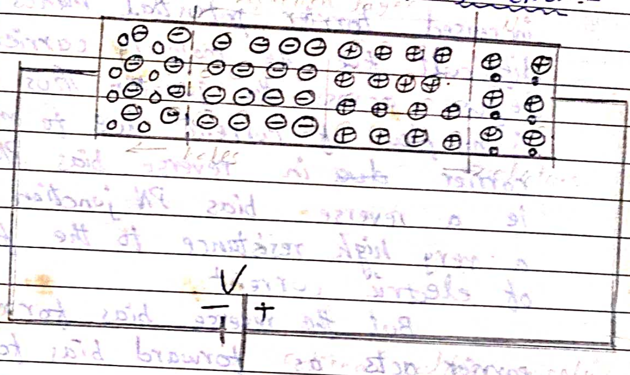
When P-type semiconductor is connected to the +ve terminal of external voltage supply and N-type semiconductor is connected to the −ve terminal of external voltage supply. then PN junction is said to be forward biased.

When PN-junction is forward. biasing the +vely charged holes of P-region are repeled by the +ve terminal of supply & move towards junctunction. Similarly −vely charged e⁻ of N-region are repeled by the −ve terminal of external supply and move towards the junction. Some of the e⁻ & holes acquire ~~d~~ sufficient energy from external supply & enter the depletion layer where ... charged ... N-region are attracted towards width of depletion layer decre[illegible] thereby reducing the barrier poten[illegible] as a result of this more no[illegible] majority carrier defuse across the junction which causes the flo[w] of electric current through PN[illegible]

For each recombination [illegible] electrons & holes, 1 e^- from [illegible] terminal of external supply ~~enter~~ en[ters] the N-region & move toward[s] junction. Similarly in P region near the +ve terminal and electron bre[aks] the coralent bond and enters th[e] positive terminal of the extern[al] supply. The current through external ~~circuit~~ circuit is due to the movem[ent] of e^- only. But current is th[e] ~~RH~~ within PN junction is the sum of e^- current in N-region & hole curre[nt] in P-region.

If further forward bias is increased by increasing the extern[al] voltage supply then at a ~~pa~~ particul[ar] voltage ie. ~~0.7~~ 0.7 V for Si & [illegible] for Ge the depletion layer is co[mpletely] vanished due to the opposite ele[ctric] field of external supply. Hence there [is] sudden rise in the current. From n[ow] onwards current goes on increasing with external supply but the voltage across junction remains constant which is 0.7 V for Si & 0.3 V for Ge.

(b) Reverse Biased PN junction:-



When a P type semiconductor is connected to the -ve terminal of external voltage supply and N-type semiconductor is connected to the +ve terminal PN Junction is said to be reversed bias.

When PN Junction is reversed bias the +vely charged holes of P-region are attracted towards the -ve terminal of voltage supply and -vely charged e^- of N-region are attracted towards the +ve terminal of voltage supply. As a result of this the majority carriers are driven away from the junction, due to this the width of depletion layer increases which in turn increases the barriers potential. The increased barrier potential makes it difficult for the majority carrier to defuse across the junction. Thus there is no flow of current due to majority carrier ~~due~~ in reverse bias PN Junction ie a reverse bias PN junction offers a very high resistance to the flow of electric current.

But the reverse bias for majority carrier acts as forward bias for minority carriers so as soon as minority carriers are generated, they are drifted away across the PN junction and hence a small amount of current flo[ws] through the reverse bias PN junction due [to] minority carriers. The generation of mini[rity] carriers depends upon the temperature & i[t] is independ of applied reverse voltage. Therefore the current due to movem[ent] of minority carrier remains fixed even if the reverse voltage is increased [or] decreased. [The] reverse current is

known as reverse saturated current. If the reverse bias is further increased to a larger value then at a particular voltage the crystal structure breaksdown due to which large number of minority carriers are available and hence the current increases suddenly. The voltage at which there is a sudden rise in reverse current is known as breakdown voltage.

(i) Reverse breakdown.

There two processes which cause the PN Junction to break down in reverse bias ~~condition~~ They are :-> (A) Zener breakdown.
(B) Avalanche breakdown.

(A) Zener breakdown.

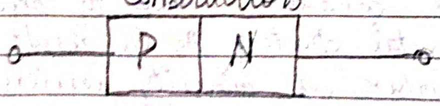
When reverse voltage is increased the depletion layer increases due to which the electric field across junction also increases. A strong electric field causes the covalent bonds to break from crystal structure. As a result of this large number of minority carriers are generated due to which a large amount of electric current flows through the junction.

(B.) Avalanche breakdown.

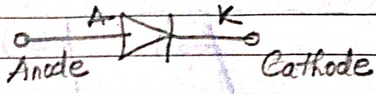
An increased reverse bias increases the amount of energy given to the minority carriers. If reverse bias is further increased the minority carriers aquire a large amount of energy and start moving with high velocities. In the process these carriers collide with semiconductor atoms and import sufficient energy to bring a covalent bond. As a result of this additional minority carriers are generated. These newly generated carriers pick up the energy from applied reverse ~~voltage and~~ generate still more minority carriers. Due to which the reverse current increases rapidly. This cumulative process of carrier generation is known as avalanche breakdown.

(2.) Diode.

Construction



construction.

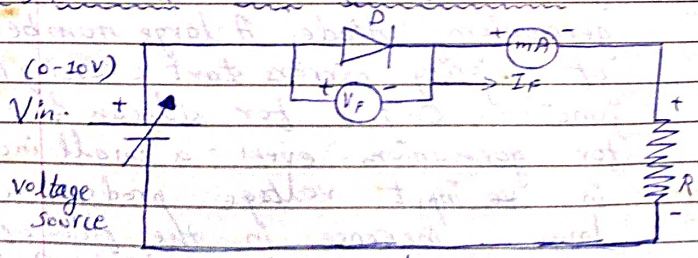


symbol.

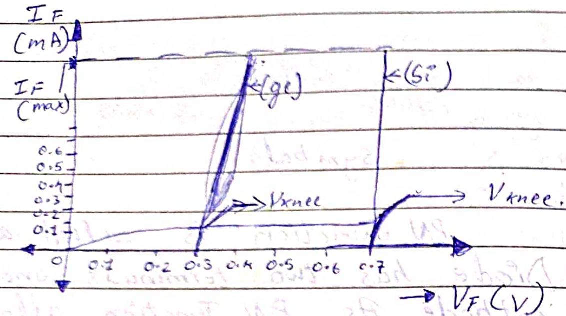
PN Junction is called as diode. Diode has two terminals anode and cathode. As PN Junction allows the current to flow only when it is forward biased. Hence the diode allows the current to flow only in one direction from anode to cathode. The arrow head in the symbol indicates direction of the flow of current.

V-I characteristics PN junction diode.

(a) Forward bias characteristics.



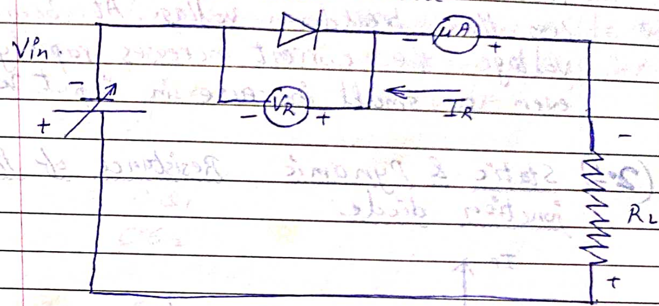
Circuit diagram.

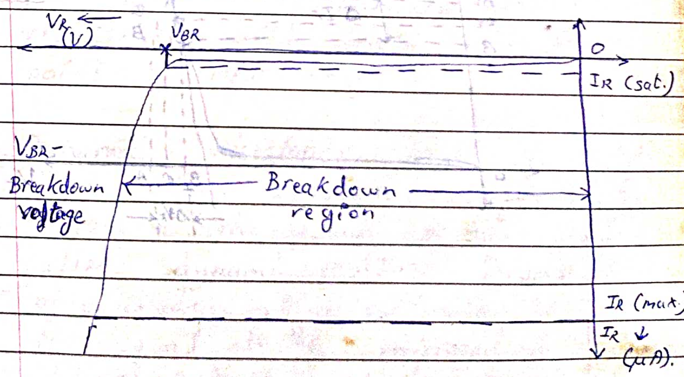


V knee :- / V cut in :-
for Si - 0.7 V
for Ge - 0.3 V.

When forward bias is applied across diode then for 1st few volts diode does not conduct a large current untill the external voltage overcomes potential barrier. As the external voltage approaches 0.7 V for silicon diode and 0.3 V for germanium diode. A large number of majority carriers start crossing the junction. 0.7 V for silicon & 0.3 V for germanium even a small increase in ve input voltage produces a large increase in the flow of current through the diode. But across voltage diode remains constant. The voltage at which the current starts increasing rapidly when diode is formed biasing is called knee voltage or cutin voltage.

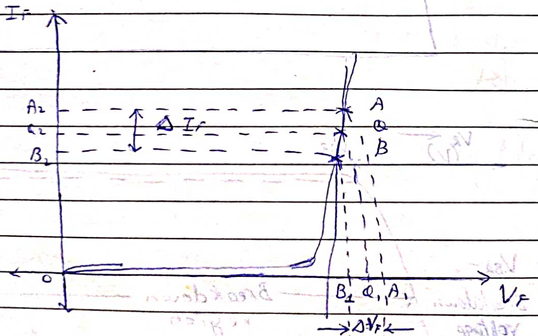
(b) Reverse bias characteristics.





In reverse bias condition the diode current is very small. It is in μAmp. for Germanium diode and ηAmp for silicon diode. It remains small and constant almost for reverse bias voltages. Less than breakdown voltage. At breakdown voltage the current increases rapidly for even a small increase in input voltage.

(2.1) Static & Dynamic Resistance of PNJ junction diode.



When forward bias diode offers a definite resistance to the flow of current. This resistance is known as static resistance. It is the ratio of DC voltage across the diode to DC current flowing through the diode. From the graph static resistance at point Q is given by ~~R = V/I~~

$$R = \frac{V}{I}$$

$$= \frac{OQ_1}{OQ_2}$$

Since the curve is non-linear the ratio OQ_1/OQ_2 i.e static resistance will vary with the point of measurement.

Dynamic resistance.

The resistance offered by diode to the flow of AC signal is called dynamic resistance. Dynamic resistance of a diode at a particular DC voltage is equal to the reciprocal of the slope of characteristic at a given point. ~~Dynamic~~ Dynamic resistance is the ratio of change in voltage across diode to the change in current flowing through diode. From the graph it is given by:-

$r_d = \frac{\Delta V}{\Delta I}$

$r_d = \frac{OA_1 - OB_1}{OA_2 - OB_2}$

Now,

Slope of curve $= \frac{y_2 - y_1}{x_2 - x_1}$

$\therefore S = \frac{\Delta I}{\Delta V}$

$\therefore r_d = \frac{\Delta V}{\Delta I}$

$\therefore r_d = \frac{1}{\Delta I / \Delta V}$

$\therefore \boxed{r_d = \frac{1}{S}}$

2.2) Specification of diode.

(1) PIV / PRV
(2) Average forward current.
(3) Forward surge current.
(4) Maximum forward voltage.
(5) Reverse current
(6) Power dissipation (liberation).
(7) Reverse Recovery time.

(1) PIV/PRV [Peak inverse voltage.]
[Peak reverse voltage.]

It is defined as the max. reverse voltage that can be applied to the diode without destruction.

(2) Average forward current.

It is defined as the forward current which a diode can pass continuously at room temperature.

(3) Forward surge current.

It is defined as large forward current which a diode can safely pass for a very short time (say 1 sec.)

(4) Maximum forward voltage.

It is defined as the max. voltage that can be applied to the diode without destruction when diode is forward biased.

(5) Reverse current.

It is defined as the max. reverse saturation current at a max. reverse voltage at given temperature.

(6.) Power dissipation

It is defined as the max. power that a diode can dissipate continuously without destruction at room temperature.

(7.) Reverse Recovery time.

It is defined as the time taken by the diode to switch from ON-state to OFF state it is in nanosecond.

(2.3) Applications of Diode.

(a) Electronic switch.
(b) Rectifier circuit
(c) Voltage Multiplier.
(d) Clipping circuit.

(3) Diode as Rectifier.

Rectifier is an electronic circuit which converts AC signal into DC signal.

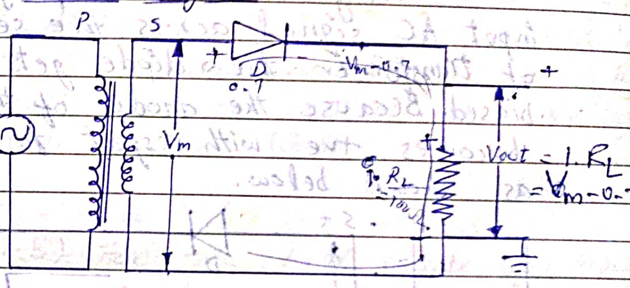
(3.1) Classification of Rectifier.

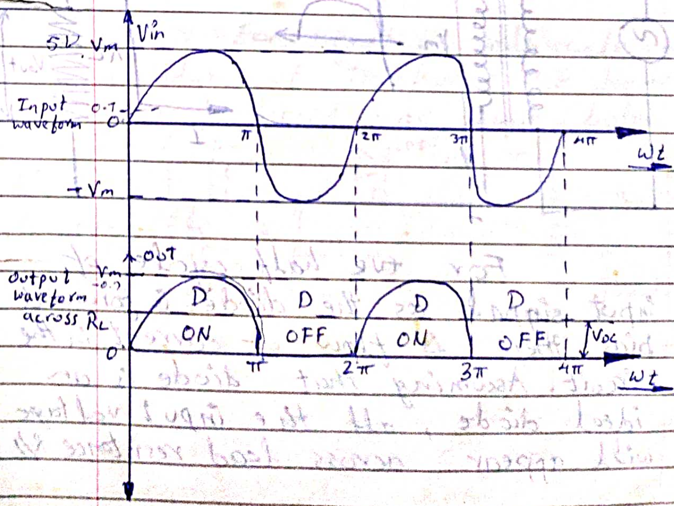
(a) Half wave rectifier (HWR).
(b) Full wave rectifier (FWR).

(i) Center tap FWR.
(ii) Bridge FWR.

[3.1.(a)] Half wave rectifier.

(i) Circuit diagram:-

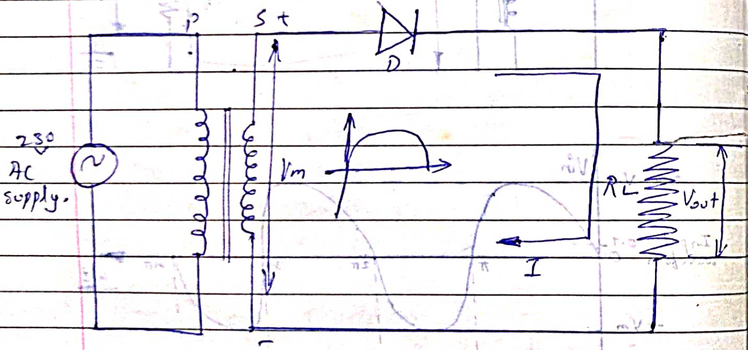




(ii) working of half wave rectifier.

(ii.a) For positive half cycle of input ac signal.

During the +ve half cycle of input AC signal across the secondary of transformer the diode gets forward biased. Because the anode of the diode becomes +ve with respect to cathode as shown below.



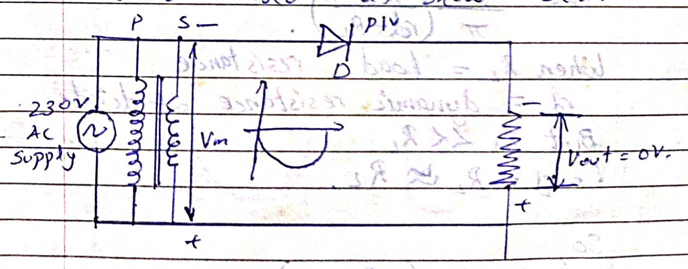
For +ve half cycle of input signal as the diode is forward bias there is flow of current in the circuit. Assuming that diode is an ideal diode, all the input voltage will appear across load resistance RL

$\therefore V_{out} \approx V_m$.

But practically no diode is an ideal diode i.e it offers some resistance when forward biased. So a small amount of voltage is dropped across the diode which is 0.7 V for Si diode & 0.3 V for Ge diode
$\therefore$ The output voltage is given by
$V_{out} = V_m - V_f$ where V_f is voltage drop across diode

(ii.b) For -ve half cycle of input ac signal.

For negative half cycle across secondary of transformer, the diode gets reversed biased as shown below:-



During -ve half cycle as the diode is reversed biased ideally no current flow into the circuit because a reversed bias diode offers high resistance to the flow of ~~of~~ current so all the input voltage drops across diode and there is no voltage at the output across R_L. The output waveform across R_L indicate that that output signal is unidirectional but ~~it~~ its magnitude keeps on changing and hence the output is called pulsating DC output. For half wave rectifier $PIV = V_m$.

Output DC voltage of HWR.

$$V_{DC} = \frac{V_m}{\pi}\left(\frac{R_L}{r_d + R_L}\right).$$

When R_L = load resistance
r_d = dynamic resistance of diode.
But $r_d << R_L$
$\therefore r_d + R_L \approx R_L$.

So,

$$V_{DC} = \frac{V_m}{\pi}\left(\frac{\cancel{R_L}}{\cancel{R_L}}\right)$$

$$\therefore \boxed{V_{DC} = \frac{V_m}{\pi}}$$

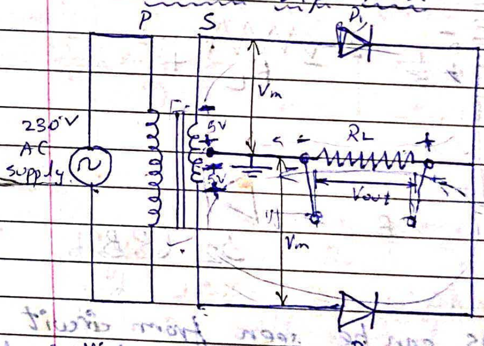
where V_m = max. input voltage.

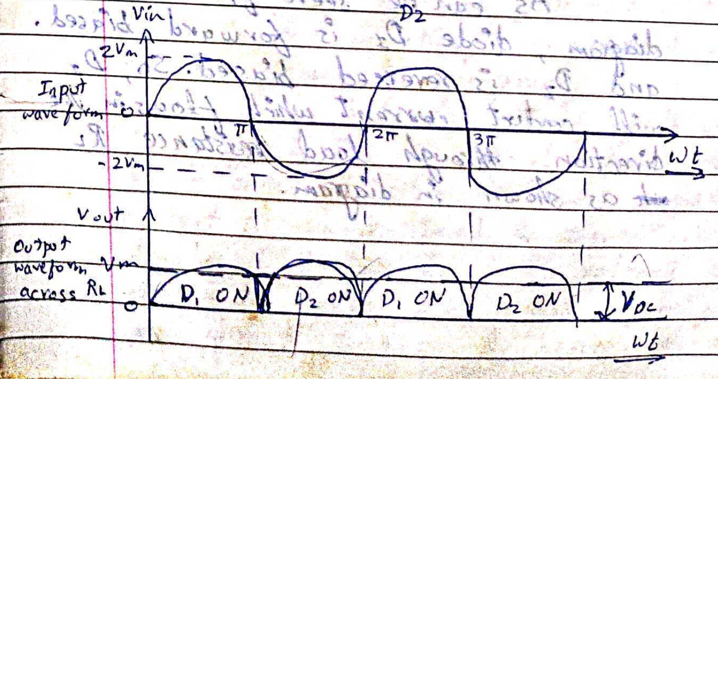
For HWR the frequency of output signal is equal to the frequency of input signal.

$$\therefore \boxed{f_{out} = f_{in}.}$$

[3.1 (b)] Full wave rectifier (FWR).
(i) Center-tap FWR.

circuit diagram

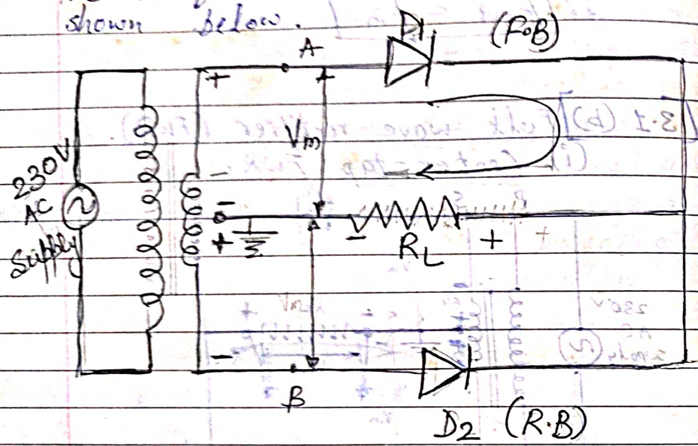




(3.1.) Working:-

@ For +ve half cycle of i/p ac signal.

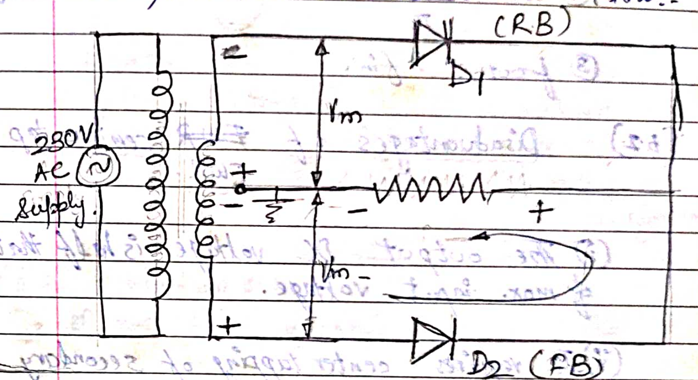
For +ve half cycle of input signal across the secondary half the transformer the polarities are as shown below.



As can be seen from circuit diagram, diode D_1 is forward biased. and D_2 is reversed biased. So, D_1 will conduct current which flows in the direction through load resistance R_L ~~at~~ as shown in diagram.

ⓑ For -ve half cycle of i/p ac signal

For -ve half cycle of input signal across the secondary of transformer the polarities are as shown below:-



As can be seen from circuit diagram, diode D_1 is reversed biased and diode D_2 is forward biased. So, diode D_2 will conduct current which flows in the direction through load resistance R_L as shown in diagram.

From both the half cycle of input signal the current flows through R_L in same direction. Hence the output current is unidirectional & the output voltage developed across R_L is DC voltage. Both the half cycle of input signal gives the output across R_L hence the name full wave rectifier.

* For center tap F.W.R.

① $PIV = 2V_m$

② $V_{dc} = \frac{2V_m}{\pi}$ —→ (V_m → max. I/P voltage)

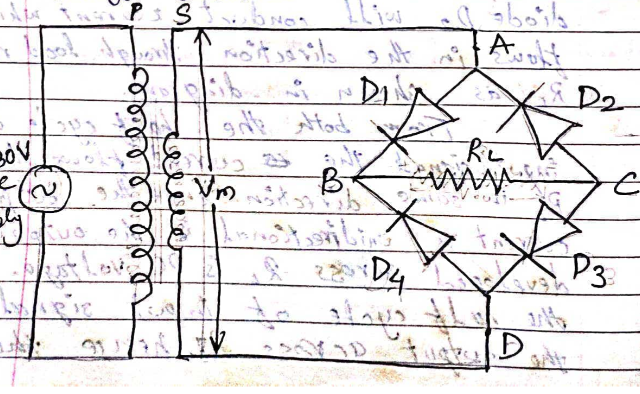
③ $f_{out} = 2 f_{in}$.

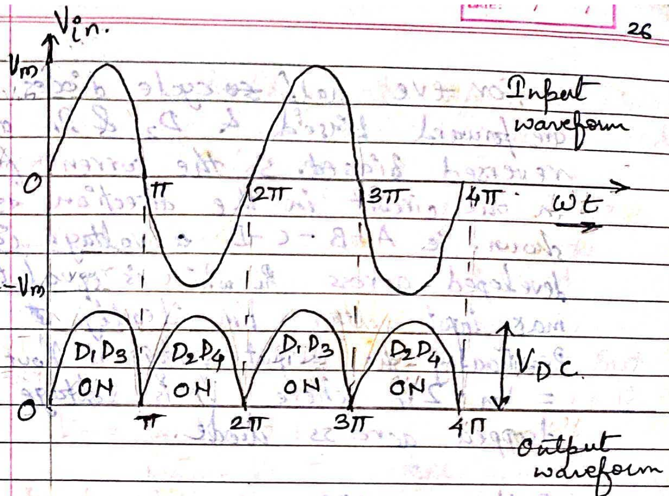
[6.2] Disadvantages of ~~FWR~~ center tap FWR.

(i) The output DC voltage is half that of max. input voltage.

(ii) It requires center tapping of secondary winding of transform which is not easy.

(ii) Bridge Rectifier.

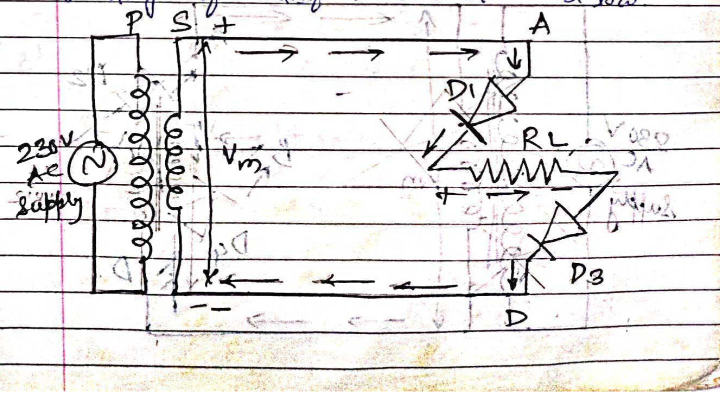




(ii.1) Working :-

ⓐ +ve half cycle:

For +ve half cycle of input signal the ~~potential~~ ~~across~~ polarities across secondary winding of transform is as shown below.

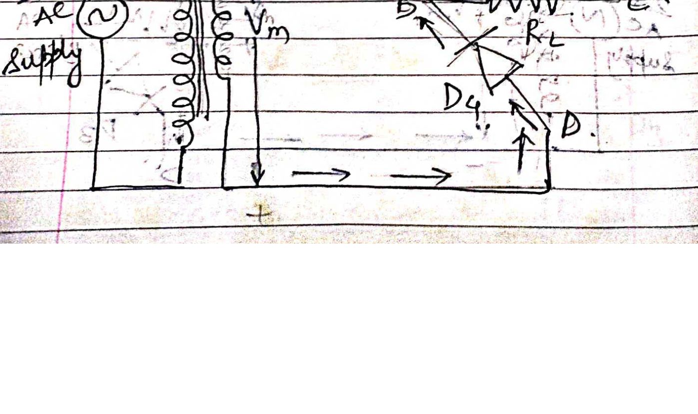


For +ve half ~~cy~~ cycle diodes D_1 & D_3 are forward biased & D_2 & D_4 are reversed biased. So the current flows in the circuit in the direction as shown. ie A-B-C-D a voltage is developed across R_L which is equal to max. input voltage V_m ideally. ~~B~~ Practically the output voltage is $V_{out} = V_m - 2V_F$ where V_F is voltage dropped across diode.

~~Bridge rectifier.~~

ⓑ For -ve half cycle of i/p ac signal.

for -ve half cycle the polarities across secondary ~~hat~~ winding of transformer are as shown.



For -ve half cycle of input signal diodes D_2 & D_4 are forward biased whereas diodes D_1 & D_3 are reversed biased. So the current flows through the circuit in the direction as shown. ie D-B-C-A voltage is developed across R_L which is equal to V_m ideally But practically the output voltage is

$V_{out} = V_m - 2V_F$

where V_F is voltage across diode

As for both the half cycles of input signal, the current flows through R_L in same direction. Hence the current is unidirectional & the output voltage across R_L is DC voltage.

~~For~~

(ii. 2). For Bridge Rectifier :-

ⓐ $PIV = V_m$

ⓑ $V_{dc} = \frac{2V_m}{\pi}$

ⓒ $F_{out} = 2F_{in}$

(ii.3) Advantages of Bride Rectifier.

(a) Center taping of secondary winding of transformer is not required. ~~The~~

(b) The output voltage is twice as compared to output voltage of center tap rectifier for same amount of input voltage.

(c) PIV is less as compared to center tap rectifier.

(ii.4) Disadvantages :-

(a) It requires 4 diodes for its operation.

(ii.5) Specifications of Rectifier.

(1) Rectifier Efficiency (η)

(2) Ripple factor (r).

(1) Rectifier Efficiency (η)

It is defined as the ratio of output DC power to the applied input AC power. It is given as

$$\eta = \frac{O/p\ dc\ power}{i/p\ ac\ power}$$

i.e. $$\boxed{\eta = \frac{P_{dc}}{P_{ac}}}$$

Formulae.

$$P_{dc} = I^2_{dc} \times R_L$$

$$P_{ac} = I^2_{rms} \times (r_d + R_L)$$

$$\therefore \eta = \frac{P_{dc}}{P_{ac}}$$

$$\therefore \eta = \frac{I^2_{dc} \times R_L}{I^2_{rms} \times (r_d + R_L)}$$

But ideally $r_d \ll R_L$

$$\therefore r_d + R_L \approx R_L$$

$$\therefore \eta = \frac{I^2_{dc}}{I^2_{rms}} \times \frac{R_L}{R_L}$$

$$\therefore \boxed{\eta = \frac{I^2_{dc}}{I^2_{rms}}} \rightarrow (A)$$

(a) For HWR

$$I_{dc} = \frac{I_m}{\pi} \rightarrow (1)$$

$$I_{rms} = \frac{I_m}{2} \rightarrow (2)$$

$\therefore$ substituting eqn (1) & (2) in eqn (A)

$$\therefore \eta = \frac{I^2_{dc}}{I^2_{rms}} = \frac{(I_m/\pi)^2}{(I_m/2)^2}$$

$$\therefore \eta = \frac{I_m^2}{\pi^2} \times \frac{4}{I_m^2}$$

$$\therefore \eta = \frac{4}{\pi^2} = 0.405.$$

$\therefore \% \eta = \eta \times 100$

$\therefore \% \eta = 0.405 \times 100$

$\therefore$ For HWR,

$\% \eta = 40.5\%$

For HWR, 40.5% of ~~outp~~ input AC power is converted into DC supply.

(b) For FWR,

$I_{dc} = \frac{2 I_m}{\pi} \rightarrow (1)$

$I_{rms} = \frac{I_m}{\sqrt{2}} \rightarrow (2)$

$\therefore$ Substituting eqn (1) & (2) in eqn (A).

$\therefore \eta = \frac{4 I_m^2 / \pi^2}{I_m^2 / 2}$

$\therefore \eta = \frac{4 \cancel{I_m^2}}{\pi^2} \times \frac{2}{\cancel{I_m^2}}$

$\therefore \eta = \frac{8}{\pi^2} = 0.811$

$\therefore \% \eta = 0.811 \times 100$

$\therefore \% \eta = 81.1\%$

For FWR 81.1% of input ac power is converted into output DC power. So FWR is more efficient than HWR.

(2) Ripple factor

The output of rectifier consists of dc components and ac components. These ac components cause the pulsation in the output of rectifier and are called ripples, so the smaller the ac components more pure is rectifier output.

Defin:- It is defined as the ratio of 'rms' value of AC components at the output to the average value of dc components at the output. It is given as

$r = \frac{\text{rms values of ac components at o/p}}{\text{avg. value of dc components at o/p.}}$

ie. $r = \frac{I_{ac}}{I_{dc}}$

$I_{rms} = \sqrt{I^2_{ac} + I^2_{dc}}$

where

I_{rms} = i/p ac signal.

I_{ac} = rms value of ac component at o/p

I_{dc} = avg. value of dc component at o/p.

$I_{ac} = \sqrt{I^2_{rms} - I^2_{dc}}$

$\therefore \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I^2_{rms} - I^2_{dc}}}{I_{dc}}$

$\therefore \frac{I_{ac}}{I_{dc}} = \sqrt{\frac{I^2_{rms} - I^2_{dc}}{I^2_{dc}}}$

ie

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

ie

$\boxed{r = \sqrt{\frac{I^2_{rms}}{I^2_{dc}} - 1}} \longrightarrow$ (A.)

* For HWR

$I_{rms} = \frac{I_m}{2}$ — (1)

$I_{dc} = \frac{I_m}{\pi}$ — (2)

Substituting eqn. (1) & (2) in (A).

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

$r = \sqrt{\frac{\cancel{I^2_m} \times \pi^2}{\cancel{I^2_m} \times 4} - 1}$

$\boxed{r = 1.21}$ for HWR

* For FWR,

$I_{rms} = \frac{I_m}{\sqrt{2}}$ — (1)

$I_{dc} = \frac{2I_m}{\pi}$ — (2)

Substituting eqn. (1) & (2) in (A), we get

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

$r = \sqrt{\left(\frac{\cancel{I^2_m} \times \pi^2}{2 \times 4\cancel{I^2_m}}\right) - 1}$

$r = \sqrt{\frac{\pi^2}{8} - 1}$

$\boxed{r = 0.48}$ for FWR

Question Bank:-

2 marks -

1.) Why conductivity of Ge is more than that of Si at room temperature?

2.) Define term - (a) Rectifier efficiency.
(b) Ripple factor.

3.) Define dynamic resistance of diode?

4.) State PIV rating of diode in center tap FWR?

5.) Name two pentavalent impurities?

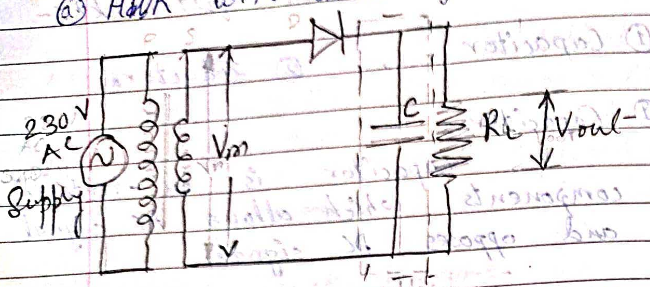
6.) Give cutting/knee voltage in Si & Ge diode?

7.) Define PIV rating of diode?

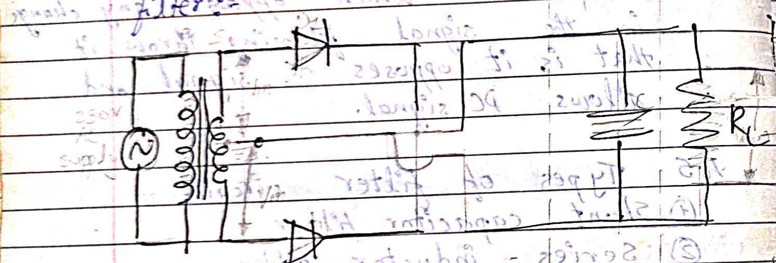
8.) Define intrinsic semicondor. & Give its two example?

9.) What is extrinsic semicondar & Give its 2 example?

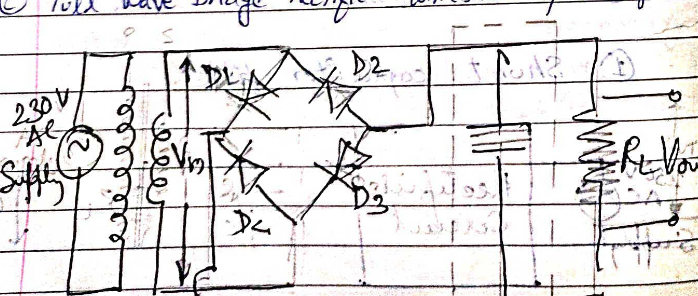
(a) HWR with Shunt capacitor filter:-



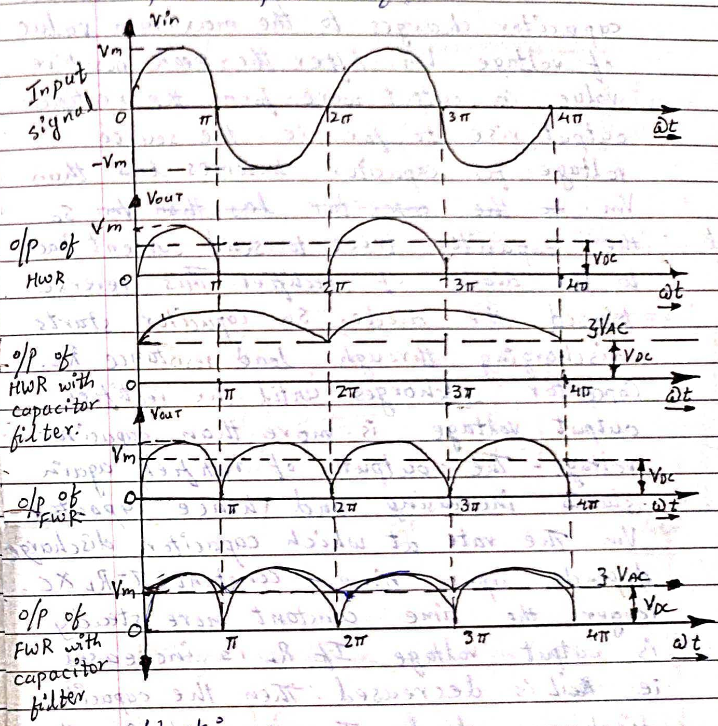
(b) FWR with centre tap with shunt capacitor filter:-



(c) Full Wave Bridge Rectifier with shunt capacitor filter.



Input, output waveform

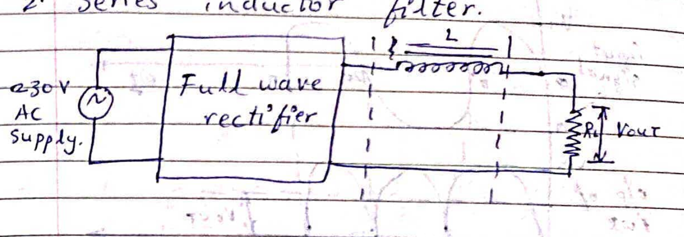


Working:-

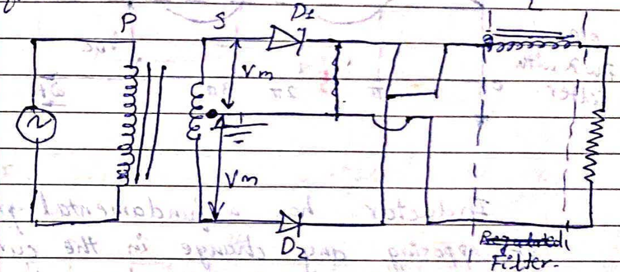
Whenever output of rectifier is given to the capacitor of the filter the AC components of rectifier output are by passed through capacitor and DC components passed through load resistance R_L. There by producing more improved out DC voltage.

When rectifier output increases the capacitor charges to the maximum value of voltage V_m. After the peak positive value in output wave form the rectifier output rise to far. ie. the source voltage for capacitor becomes less than V_m. ~~So the capacitor less than V_m~~ So the capacitor tries to send current back to the diode of rectifier. This reverse biased the diode. So capacitor starts discharging through load resistance. R_L. Capacitor discharges until the rectifier output voltage is more than capacitor voltage. The output of rectifier again starts increasing and hence capacitor V_m. The rate at which capacitor discharges depends upon time constant $T = R_L \times C$. longer the time constant more steady is output voltage. If R_L is increased ie i_L is decreased. Then the capacitor discharges slowly. There by reducing the ripples. But if R_L is decreased ie i_L is increased. Then the capacitor discharges rapidly there are increasing the ripples.

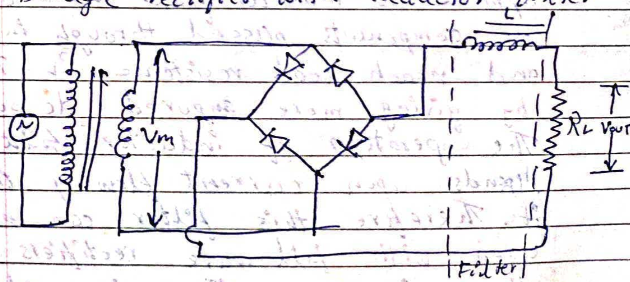
2. Series inductor filter.

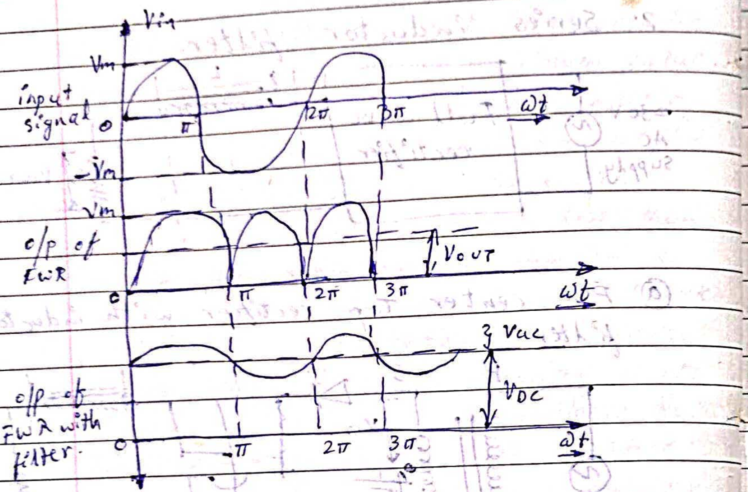


(a) FW center Tap rectifier with inductor filter.



(b) Bridge rectifier with inductor filter

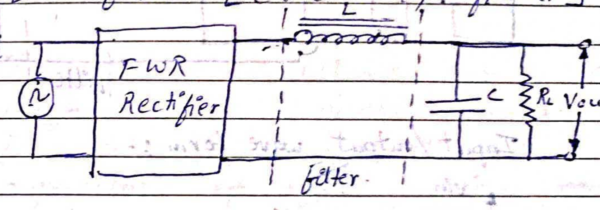




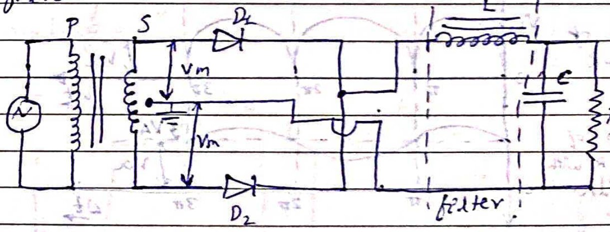
Inductor has a fundamental property of opposing any change in the current flowing through it. Therefore when pulsating DC output of rectifier is applied to inductor filter than only the dc components passed through inductor and reach load resistance, R_L. There by giving more impured dc output. The operation of inductor filter depends upon current flowing through it. Therefore this filter can only be used with full wave rectifiers because it requires a continuously flow of current. Higher the current

flowing through it better is the filtering action. Therefore increase in load current I_L decreases ripples.

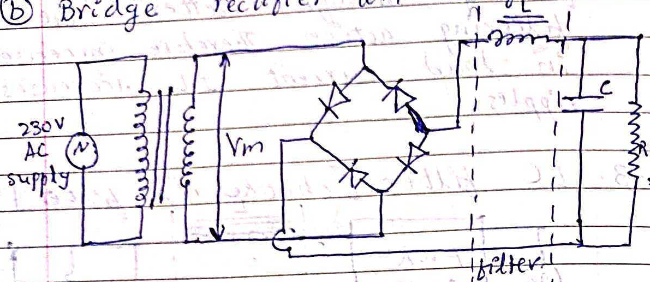
3. LC filter [chocke i/p filter].



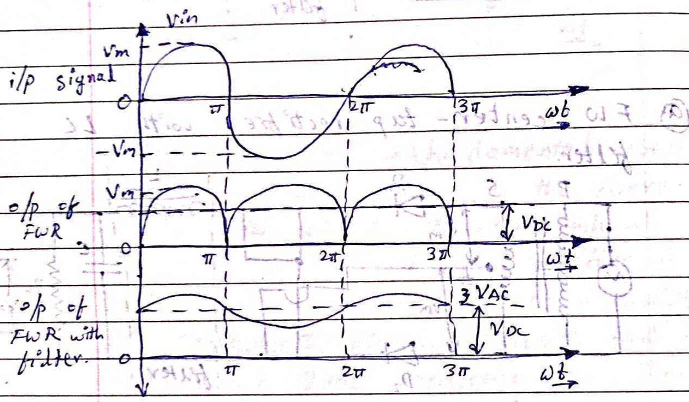
(a) FW center-tap rectifier with LC filter.



(5) Bridge rectifier with LC filter.



Input/output wave form :-

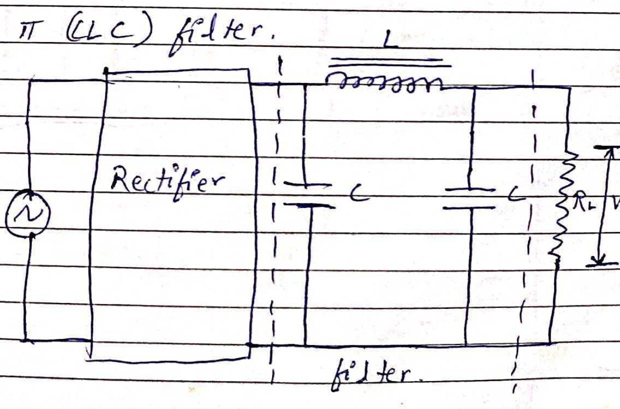


A series inductor filter has property of decreasing ripple when load current I_L increased. Where as shunt capacitor filter has the property of increasing ripples. when load current I_L is

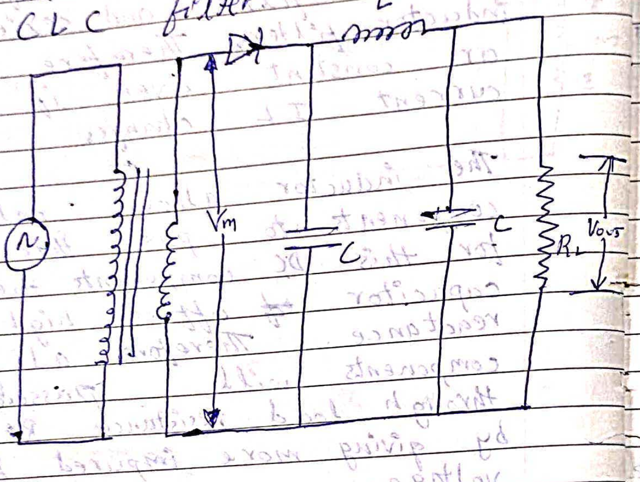
increased and LC filter combines the features of shunt capacitor filter and series ~~induc~~ inductor filter. Therefore ripples are constant even if load current I_L changes.

The inductor allows only dc components to pass through it for this DC components the capacitor ~~of~~ offers high ~~rea~~ reactance. Therefore all DC components will passed through load resistance R_L. There by giving more ~~im~~pured DC out voltage.

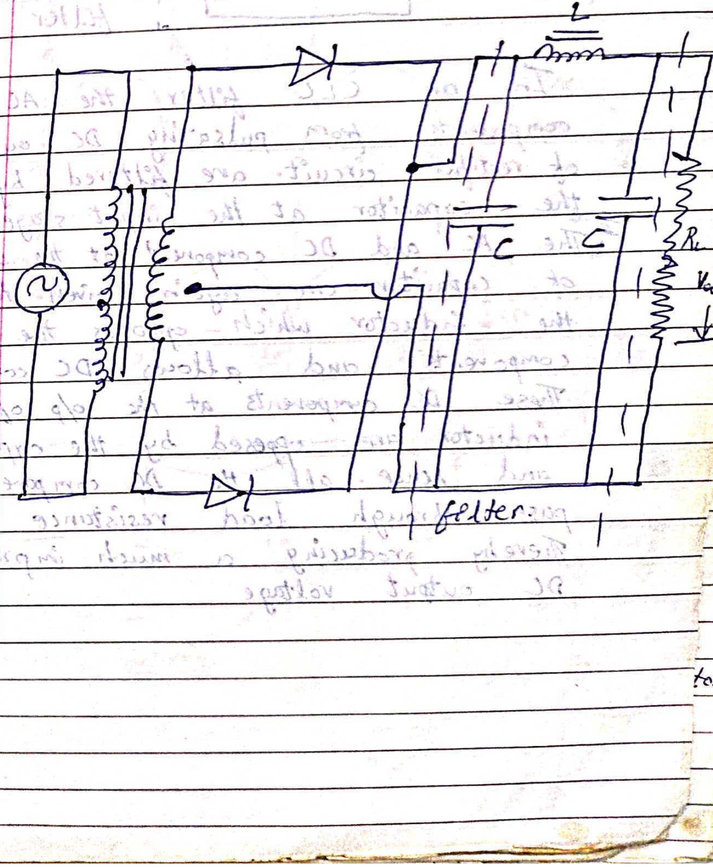
4. π (CLC) filter.



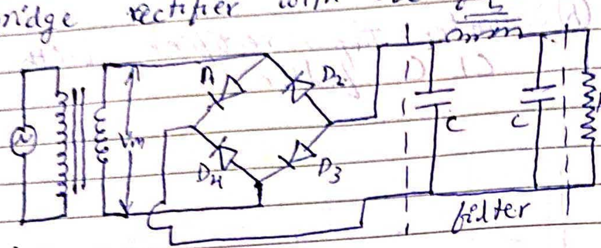
(a) Full wave rectifier with CLC filter



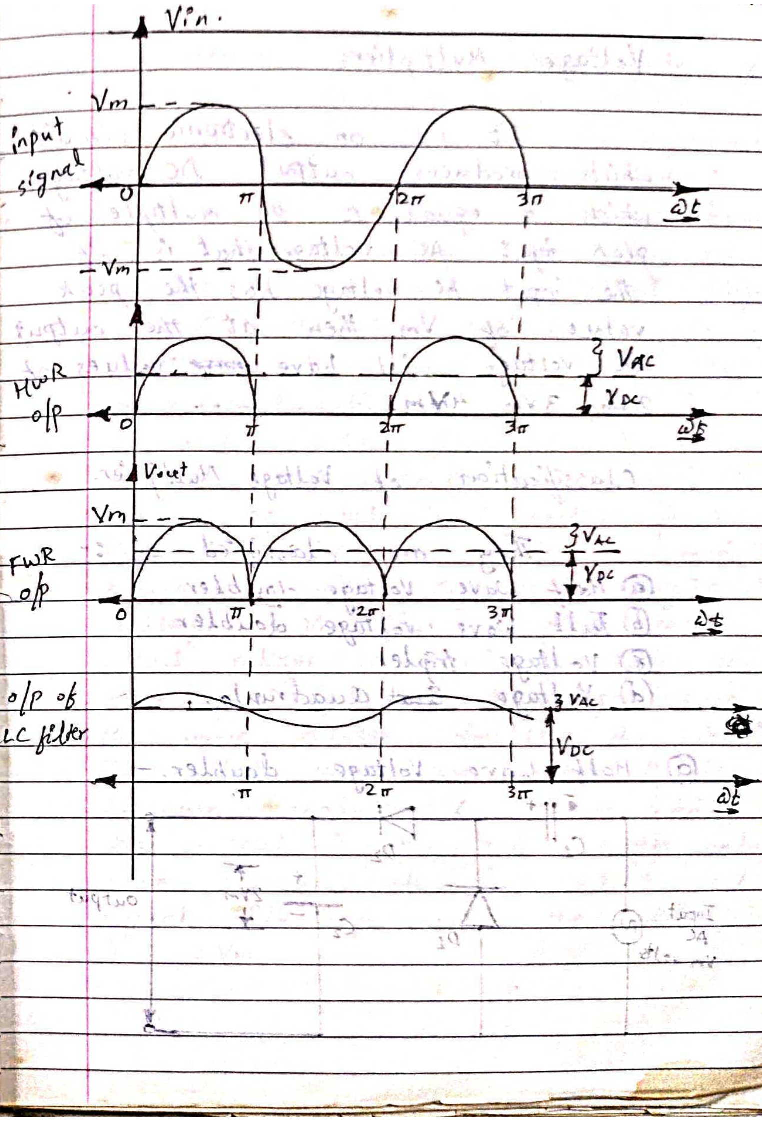
(b) Center-Tap rectifier with CLC filter.



(c) Bridge rectifier with CLC filter



In an CLC filter the AC components from pulsating DC output of rectifier circuit are filtered by the capacitor at the input stage. The AC and DC component at the output of capacitor are again given to the inductor which opposes the AC components and allows DC components. These DC components at the o/p of inductor are opposed by the capacitor and hence all the DC components pass through load resistance R_L. Thereby producing a much improved DC output voltage.



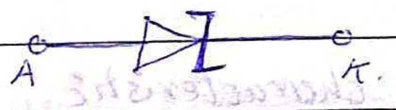
CHAPTER 5.

Zener diode & its applications.

[5.1] Definition of Zener diode

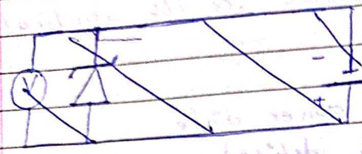
It is defined as the properly doped crystal diode which has ~~tar~~ sharp breakdown voltage.

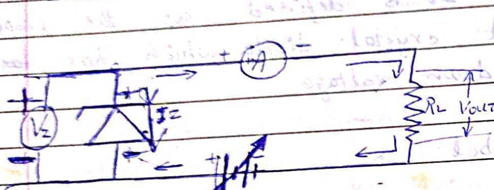
Symbol



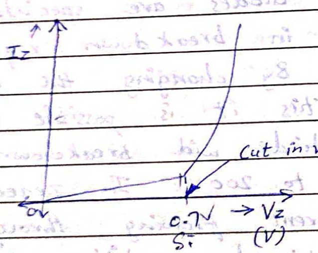
Zener diodes are specially designed to operate in breakdown region widout destruction. By changing the concentration of impurities it is possible to produce zener diode wid breakdown voltage from 2V to 200V. In zener diode the current flowing through it in reverse biased condition is not destructive as its value is limited by controlling doping level.

[5.2] V-I characteristics of zener diode.



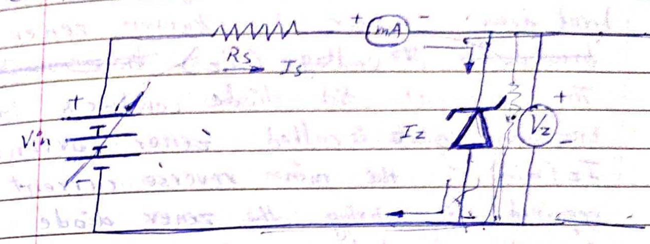


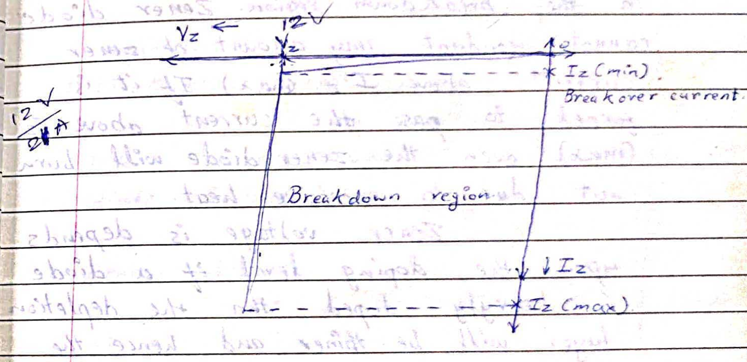
(a) Forward biased characteristic.



When forward biased zener diode operates as ordinary PN Junction diode. For first few volts. As the i/p voltage increases the current also increases. After a particular voltage called cut voltage the current increases suddenly keeping the voltage across diode constant

(b) Reverse biased characteristics.





In R.B condition for first few volts as input voltage increases the depletion layer also increases hence a small reverse current flows through the diode due to minorities carriers. At a particular value of input voltage the crystal structure breaks down and large amount of current flows through the diode keeping the voltage across the diode constant. After this even if the i/p voltage increases the voltage across diode remains constant but current increase. The voltage at which break down occur is known zener ~~breakdown~~ voltage (V_z)

The current the diode conducts in breakdown region is called zener current. I_z (min) is the min. reverse current required to bring the zener diode in the breakdown region. Zener diode cannot conduct any amount of zener current above I_z (max.) If it is forced to pass the current above I_z (max) even the zener diode will burn out due to excessive heat.

Zener voltage is depends upon the doping level if a diode is heavyly doped then the depletion layer will be thiner and hence the breakdown will occur at smaller reverse voltage. If a diode is light doped the depletion layer is wider and breakdown occurs at higher voltages.

For the breakdown voltages less than 4 V, Zener breakdown takes place And for breakdown voltages ~~great~~ more than 6V, Avalanche breakdown occur. For voltages between 4V and 6V both Kinds of breakdown may occur.

[5.3] Specification of Zener diode :-

(1) Break over Current. I_z (min) —
(2) Zener Voltage (V_z) —
(3) Power dissipation (P_z) —
(4) Dynamic resistance (rd) —
(5) Max. zener current I_z (max) —

Definition :-

(1) Breakover current I_z (min) :

It is defined as the min. reverse current required to bring zener diode in breakdown region.

(2) Zener voltage (V_z) :

It is defined as the voltage at which breakdown occurs in zener diode. At this voltage there is a sudden rise in zener current and the internal resist. of diode decreases from several k-Ω to few ohms. The commercial value of V_z for various zener diode are available from 2V to 200V.

(3) Power dissipation (P_z) :-

The max. amt. of power dissipated by zener diode safely is called power dissipation. It is given by $P_Z = V_Z \times I_Z$. Its value ranges from 150 m Watt to 50 Watt.

(4) Dynamic resistance (rd):- It is defined as the ratio of change in zener voltage to change in zener current. It is given by $rd = \frac{\Delta V_Z}{\Delta I_Z}$

(5) Max. Zener current I_Z (max.):- It is defined as the max. amt. of current that can be allowed to flow through zener diode without destruction.

[5.5] Zener diode as Voltage Regulator:-

(a) Voltage regulation -

Def:- It is the ability of a power supply to maintain constant output voltage inspite of fluctuation in i/p voltage and changes in load resistance R_L. Mathematically voltage regulation is given by

$-V_{in} + I_S R_S + V_Z = 0$

$\therefore I_S = \frac{V_{in} - V_Z}{R_S}$

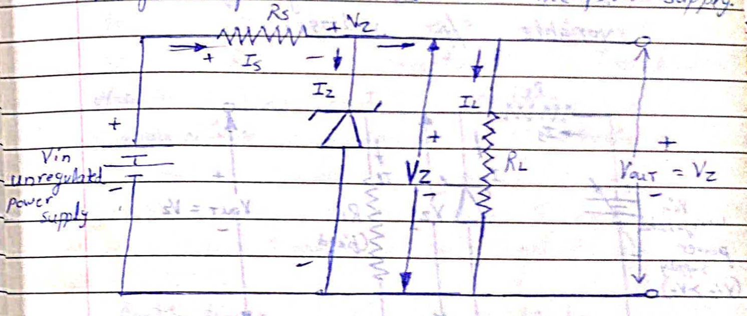
% voltage regulation = $\frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$

where,

V_{NL} = No load voltage

V_{FL} = Full load voltage.

Smaller the value of percentage voltage regulation better is the power supply.



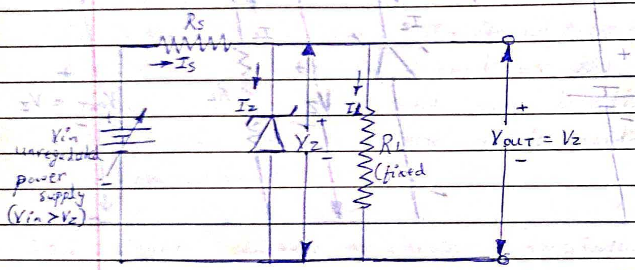
From circuit,

$I_S = I_Z + I_L$

$\therefore \frac{V_{in} - V_Z}{R_S} = I_Z + \frac{V_Z}{R_L}$ → (∵ zener diode is in // with R_L, $V_{OUT} = V_Z$).

Zener diode can act as voltage regulator so as to provide a constant output voltage from unregulated power supply. Zener diode is connected in // with load resis. R_L. A series resist R_S is connected in series to limit the zener current. The o/p voltage V_{OUT} is taken across load resis. R_L. zener diode maintain a constant voltage V_Z across itself as long as i/p voltage does not fall below V_Z

(a.1) Zener diode as voltage regulator wid variable i/p voltage:



In this ckt., resistance R_L is kept fixed and i/p voltage ~~vo~~ supply is variable. When the i/p voltage increases then i/p current I_S will increases due to this the current through zener diode will increase so as to keep current flowing through resistance R_L constant. ie if i/p current 'I_S' increases zener diode will conduct extra current so that current flowing through load resistance R_L remains constant thereby keeping the voltage across R_L constant. If i/p voltage is decreased the ~~R_S~~ ~~constant~~ current I_S will decrease as a result of this zener diode will conduct less current so as to keep the current to R_L constant. Therefore the output voltage remains constant.

Applications of zener diode.

(1) As a voltage regulator.
(2) As a fixed reference voltage source
(3) In battery charges.

Limitations of zener diode.

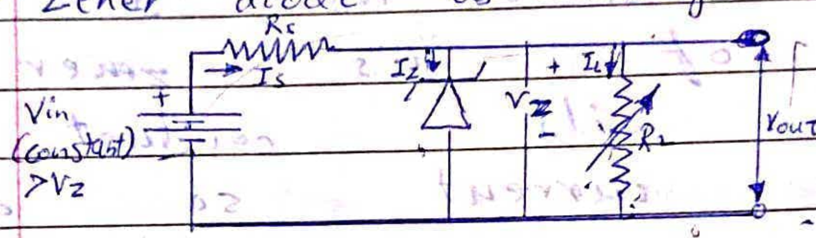
(1.) It is not a current regulator.
(2.) The max. load current I_L which can be supplied to load resistance R_L is limited to the value.

$I_L = I_S - I_Z$

which is few milliamps only.

(3.) It is not suitable for all values of R_L

(a.2) Zener diode as voltage regulator for variable load



In dis ckt. diag. i/p voltage is kept cons and load resist. R_L is variable. If R_L decreases, dis increase in load current I_L so tht voltage across R_L remains constant. The extra current which is requ. to through R_L cannot come from supply as i/p voltage is Hence zener diode will conduct less current so as to supply extra current through load resist R_L.

If R_L increases dis requires decrease in load current I_L, In order to maintain const voltage across R_L. So the extra current is taken by diode so it will conduct more current there keeping ~~volt~~ the voltage across load resistance R_L constant.