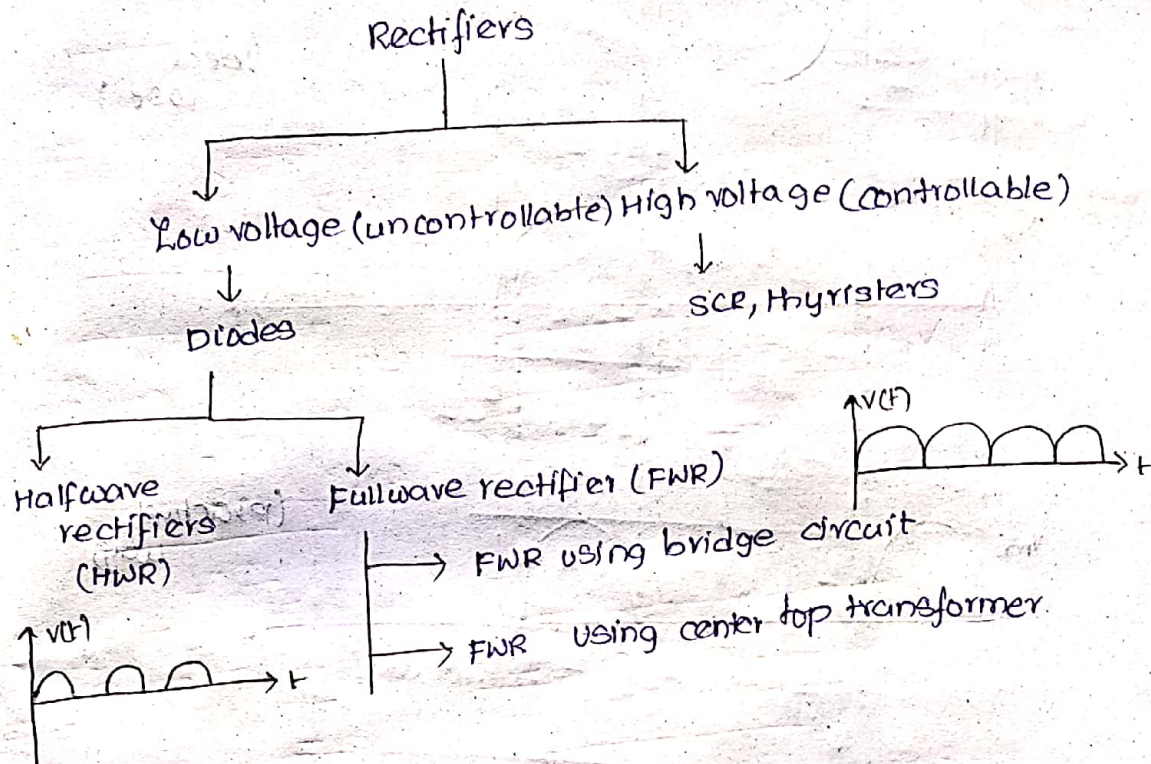


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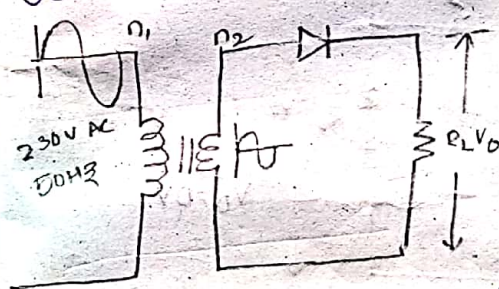
Rectifiers

* Rectifiers are electronic circuit which convert ac to dc.
(pulsating dc)

* Rectifiers with diodes is called uncontrollable rectifiers.



Half wave rectifier:-



$$\frac{V_1}{V_2} = \frac{n_1}{n_2} \Rightarrow V_2 = \frac{V_1 n_2}{n_1}$$

$$V_2 < V_1$$

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

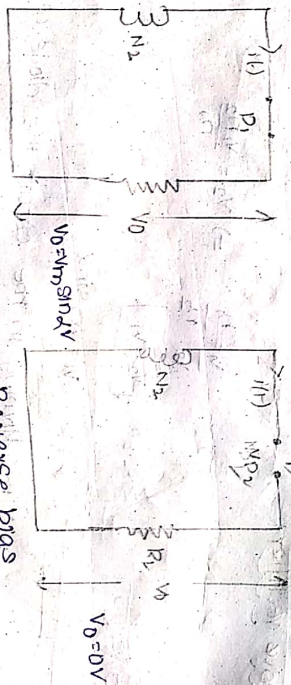
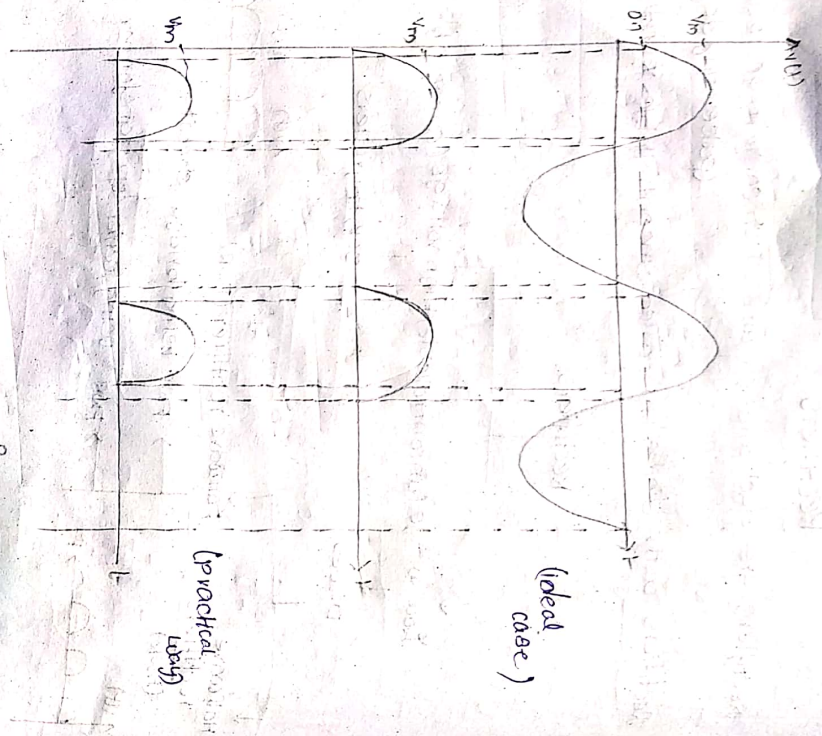
* When +ve pulse is flowing in the circuit the diode will act as forward bias and produce output V_0

where $V_0 = V_i = V_m \sin \omega t$ $0 < \omega t < \pi$

* When -ve pulse is flowing the diode will act as reverse bias and the current inside it "0". The output voltage V_0 is

$$V_0 = 0$$

$$\pi < \omega t < 2\pi$$



Analysis of Halfwave rectifier

Forward bias:-

$$V_D = V_m \sin \omega t$$

$$(0 \leq \omega t \leq \pi)$$

$$i = \frac{V_m \sin \omega t}{R_L} \quad \text{or} \quad i = \frac{V_m \sin \omega t}{R_L + R_f}$$

Reverse biased:-
 $V_b = V_i$ but $i = 0$

Parameters of Half wave Rectifier:-

$$I_{avg} = \frac{1}{T} \int_0^T i(\alpha) d\alpha$$

$$I_{avg} = I_m \cdot Idc$$

$$= \frac{1}{2\pi} \int_0^\pi I_m \sin \alpha d\alpha + \int_\pi^{2\pi} 0 d\alpha$$

$$= \frac{I_m}{2\pi} (-\cos \alpha)_0^\pi$$

$$= \frac{I_m}{2\pi} (-(-1) + 1)$$

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

$$\text{and } V_{avg} = \frac{V_m}{\pi}$$

$$V_{avg} = \frac{1}{T} \int_0^T v(\alpha) d\alpha$$

$$= \frac{1}{2\pi} \int_0^\pi V_m \sin \alpha d\alpha + \int_\pi^{2\pi} 0 d\alpha$$

$$= \frac{V_m}{2\pi} (-\cos \alpha)_0^\pi$$

$$= \frac{V_m}{2\pi} (-2)$$

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

Rms of o/p signal (I_{rms})

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T i^2(\alpha) d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^\pi (I_m \sin \alpha)^2 d\alpha + \int_\pi^{2\pi} 0 d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \times I_m^2 \int_0^\pi \sin^2 \alpha d\alpha}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \int_0^\pi \frac{1 - \cos 2\alpha}{2} d\alpha}$$

$$= \sqrt{\frac{I_m^2}{4\pi} \left[\alpha - \frac{\sin 2\alpha}{2} \right]_0^\pi}$$

$$= \sqrt{\frac{I_m^2}{4\pi} [\pi]} = \frac{I_m}{2}$$

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

Rms of AC o/p signal (I_{rms}):-

$$I = I_{AC} + I_{DC} \Rightarrow i = i_{AC} + I_{DC}$$

$$I_{AC} = I - I_{DC} \quad i_{AC} = i - I_{DC}$$

$$I_{AC(rms)} = \sqrt{\frac{1}{T} \int_0^T (i - I_{DC})^2 d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (i - I_{DC})^2 d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (i^2 + I_{DC}^2 - 2iI_{DC}) d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \left[\int_0^{2\pi} i^2 d\alpha + \int_0^{2\pi} I_{DC}^2 d\alpha - 2 \int_0^{2\pi} iI_{DC} d\alpha \right]}$$

$$= \sqrt{I_{rms}^2 + \frac{I_{DC}^2}{2\pi} \int_0^{2\pi} d\alpha - \frac{2I_{DC}}{2\pi} \int_0^{2\pi} i d\alpha}$$

$$= \sqrt{I_{rms}^2 + \frac{I_{DC}^2}{2\pi} [\alpha]_0^{2\pi} - \frac{2I_{DC}}{2\pi} (I_{DC})}$$

$$= \sqrt{I_{rms}^2 + I_{DC}^2 - 2I_{DC}^2}$$

$$= \sqrt{I_{rms}^2 - I_{DC}^2}$$

$$\boxed{I'_{rms} = \sqrt{I_{rms}^2 - I_{DC}^2}}$$

Ripple factor (γ):-

$$\gamma = \frac{V_{ac}}{V_{dc}} = \frac{I_{ac}}{I_{dc}} = \frac{I_{rms}}{I_{dc}}$$

$$\gamma = \frac{I_{rms}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$\gamma = \sqrt{\frac{(I_{rms})^2}{(I_{dc})^2} - 1} = \sqrt{\frac{\left(\frac{I_m}{2}\right)^2}{\left(\frac{I_m}{\pi}\right)^2} - 1} = 1.21 //$$

Input power (P_i):-

$$P_i = \text{avg of } VI$$

$$= \frac{1}{T} \int_0^T v \cdot i$$

$$= \frac{1}{T} \int_0^\pi v i d\alpha + \int_\pi^{2\pi} v i d\alpha$$

$$= \frac{1}{T} \int_0^\pi (V_m \sin \alpha) (I_m \sin \alpha) d\alpha$$

$$= \frac{1}{T} \int_0^\pi I_m (R_F + R_L) I_m \sin^2 \alpha d\alpha$$

$$= \frac{1}{T} \int_0^\pi I_m^2 (R_F + R_L) \sin^2 \alpha d\alpha$$

$$= \frac{R_F + R_L}{T} \int_0^\pi (I_m \sin \alpha)^2 d\alpha$$

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

Efficiency (η):-

$$\eta \% = \frac{\text{o/p DC power}}{\text{i/p AC power}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100\%$$

$$\eta \% = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{2}\right)^2 (R_F + R_L)} \times 100\% = 40.5 \times \frac{R_L}{R_F + R_L} //$$

Diode DC Voltage:-

* In F.B the voltage across the diode is "0". ($0 < \alpha < \pi$)

* In Reverse bias the voltage across the diode is

$$V_D = V_m \sin \alpha \quad (\pi < \alpha < 2\pi)$$

$$V_{Davg} = \frac{1}{T} \int_0^T v_m \sin \alpha d\alpha$$

$$= \frac{1}{2\pi} \int_0^\pi 0 d\alpha + \int_\pi^{2\pi} v_m \sin \alpha d\alpha$$

$$= \frac{V_m}{2\pi} (-\cos \alpha) \Big|_\pi^{2\pi}$$

$$= -\frac{V_m}{2\pi} [1 + 1]$$

$$V_{Davg} = -\frac{V_m}{\pi}$$

PIV (Peak Inverse Voltage) :-

* Maximum Reverse bias voltage across a diode is going to handle is "PIV".

Tag & I_{rms} For Triangle wave:-

$$\Rightarrow 0 < \alpha < \pi/2$$

slope (0,0), ($\pi/2, I_m$)

$$m = \frac{I_m - 0}{\pi/2 - 0} = \frac{2I_m}{\pi}$$

$$i(\alpha) = \frac{2I_m}{\pi} \alpha$$

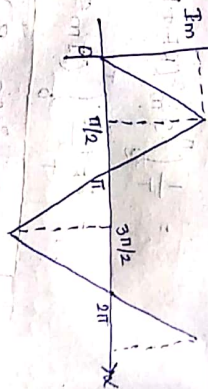
$$I_{rms}^2 = \frac{1}{\pi/2} \int_0^{\pi/2} i^2(\alpha) d\alpha$$

$$= \frac{2}{\pi} \int_0^{\pi/2} \left(\frac{2I_m}{\pi} \alpha \right)^2 d\alpha$$

$$= \frac{2}{\pi} \int_0^{\pi/2} \frac{4I_m^2}{\pi^2} \alpha^2 d\alpha$$

$$= \frac{8I_m^2}{\pi^3} \left[\frac{\alpha^3}{3} \right]_0^{\pi/2} = \frac{8I_m^2}{\pi^3} \left[\frac{\pi^3}{8 \times 3} \right] = \frac{I_m^2}{3}$$

$$I_{rms} = \frac{I_m}{\sqrt{3}}$$



Avg value:

$$I_{avg} = \frac{1}{T} \int_0^T i(\alpha) d\alpha$$

$$= \frac{2}{\pi} \int_0^{\pi/2} \frac{2I_m}{\pi} \alpha d\alpha$$

$$= \frac{4I_m}{\pi^2} \left[\frac{\alpha^2}{2} \right]_0^{\pi/2}$$

$$= \frac{2I_m}{\pi^2} \left[\frac{\pi^2}{4} \right]$$

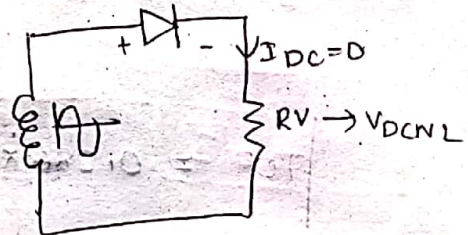
$$I_{avg} = I_m/2$$

No Load DC voltage: (V_{DCNL})

$$0 - V_{diode, DC} - V_D = 0$$

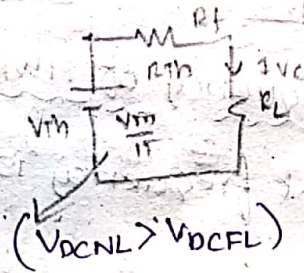
$$V_{DCNL} = -V_{diode, DC}$$

$$= -\left(-\frac{V_m}{\pi}\right) = \frac{V_m}{\pi}$$



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

Full load DC voltage: (V_{DCFL})

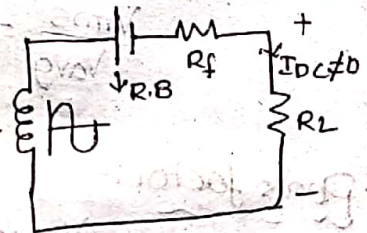


$$V_{DCFL} = -V_{diode, D} - I_{DC} R_f$$

$$V_{DCFL} = \frac{V_m}{\pi} - I_{DC} (R_f + R_{sw})$$

$$V_{DCFL} = I_{DC} R_L$$

$$V_{DCFL} = \frac{V_m}{\pi} - I_{DC} R_f$$



% Load Regulation :-

$$\% L.R = \frac{V_{DCNL} - V_{DCFL}}{V_{DCFL}} \times 100\%$$

$$= \frac{V_{DCNL} - V_{DCFL} + I_{DC} R_f}{V_{DCFL}}$$

$$\% L.R = \frac{I_{DC} R_f}{V_{DCFL}} \times 100\%$$

$$\frac{V_{DCNL} - V_{DCFL}}{V_{DCFL}} \times 100$$

TUF:- (transformer utilization factor)

$$TUF = \frac{\text{DC o/p Power}}{\text{AC rating of transformer}}$$

$$= \frac{I_{pc}^2 R_L}{V_{rms} I_{rms}}$$

$$= \frac{I_{pc}^2 R_L}{\left(\frac{V_m}{\sqrt{2}}\right) \left(\frac{I_m}{2}\right)} = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{2}}$$

$$= \frac{\frac{I_m^2}{\pi^2} \times R_L}{\frac{V_m I_m^2}{2\sqrt{2}} (R_F + R_L)}$$

$$\Rightarrow \frac{V_m I_m^2 (R_F + R_L)}{2\sqrt{2}}$$

$$TUF = 0.286 \times \frac{R_L}{R_F + R_L}$$

O/p frequency of HWR:-

Input frequency is equal to output frequency.

Form factor:-

$$\frac{V_{rms}}{V_{avg}} = \frac{\frac{V_m}{2}}{\frac{V_m}{\pi}} = 1.57 //$$

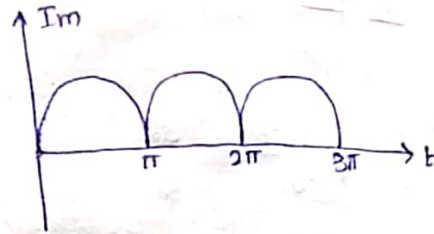
Peak factor:-

$$= \frac{V(\text{peak})}{V_{rms}} = \frac{\frac{V_m}{2}}{\frac{V_m}{2}} = 2 //$$

I_{avg} - I_{rms} of Full wave Rectifier and Sinusoidal wave

I_{avg} - I_{DC} :-

$$I_{avg} = \frac{1}{T} \int_0^T i(\alpha) d\alpha$$



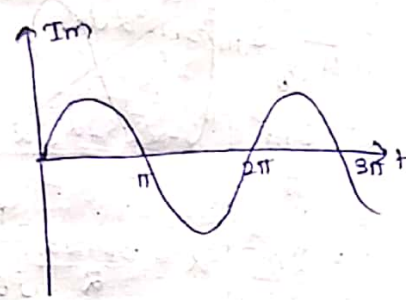
$$= \frac{1}{2\pi} \left[\int_0^{\pi} I_m \sin \alpha d\alpha + \int_{\pi}^{2\pi} I_m \sin \alpha d\alpha \right]$$

$$= \frac{I_m}{2\pi} \left[\int_0^{\pi} \sin \alpha d\alpha + \int_{\pi}^{2\pi} \sin \alpha d\alpha \right]$$

$$= \frac{I_m}{2\pi} \left[[-\cos \alpha]_0^{\pi} + [-\cos \alpha]_{\pi}^{2\pi} \right]$$

$$= \frac{I_m}{2\pi} \left[-(-1-1) + [1+1] \right]$$

$$= \frac{I_m}{2\pi} [4] = \frac{2I_m}{\pi}$$



$$\boxed{I_{avg} = \frac{2I_m}{\pi}} \text{ and } \boxed{V_{avg} = \frac{2V_m}{\pi}}$$

I_{rms} value :-

$$I_{rms}^2 = \frac{1}{T} \int_0^T I^2(\alpha) d\alpha$$

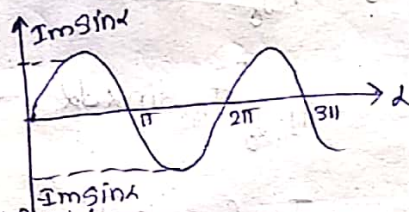
$$= \frac{1}{2\pi} \left[\int_0^{\pi} I_m^2 \sin^2 \alpha d\alpha + \int_{\pi}^{2\pi} I_m^2 \sin^2 \alpha d\alpha \right]$$

$$= \frac{I_m^2}{2\pi} \left[\int_0^{\pi} \frac{1-\cos 2\alpha}{2} d\alpha + \int_{\pi}^{2\pi} \frac{1-\cos 2\alpha}{2} d\alpha \right]$$

$$= \frac{I_m^2}{4\pi} \left[\left[\alpha - \frac{\sin 2\alpha}{2} \right]_0^{\pi} + \left[\alpha - \frac{\sin 2\alpha}{2} \right]_{\pi}^{2\pi} \right]$$

$$= \frac{I_m^2}{4\pi} [\pi + \pi] = \frac{I_m^2}{4\pi} (2\pi)$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \text{ and } \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$



I_{rms} of FWR :-

$$I_{rms}^2 = \frac{1}{T} \int_0^T I^2(\alpha) d\alpha$$

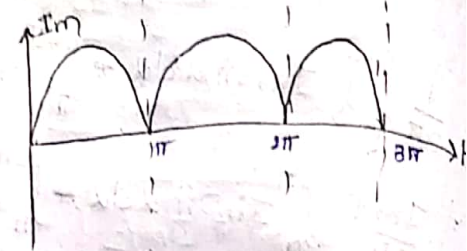
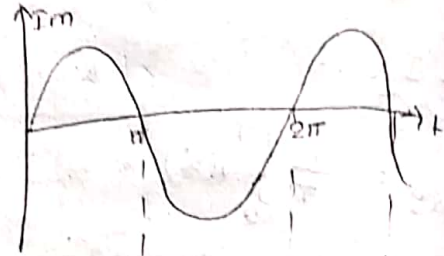
$$= \frac{1}{\pi} \int_0^{\pi} I_m^2 \sin^2 \alpha d\alpha$$

$$= \frac{I_m^2}{\pi} \int_0^{\pi} \frac{1 - \cos 2\alpha}{2} d\alpha$$

$$= \frac{I_m^2}{2\pi} \left[\alpha - \frac{\sin 2\alpha}{2} \right]_0^{\pi}$$

$$= \frac{I_m^2}{2\pi} [\pi]$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \text{ and } \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$



I_{avg} of FWR :-

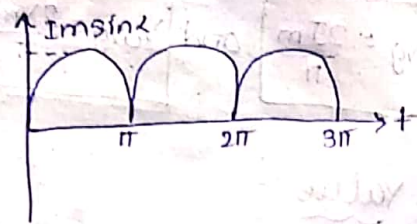
$$I_{avg} = \frac{1}{T} \int_0^T I(\alpha) d\alpha$$

$$= \frac{1}{\pi} \int_0^{\pi} I_m \sin \alpha d\alpha$$

$$= \frac{I_m}{\pi} [-\cos \alpha]_0^{\pi}$$

$$= \frac{I_m}{\pi} [-(-1 - 1)]$$

$$\boxed{I_{avg} = \frac{2I_m}{\pi}}$$



Peak factor of FWR :-

$$= \frac{V_{peak}}{V_{rms}} = \frac{V_m}{\frac{V_m}{\sqrt{2}}} = 1.414$$

Form factor of FWR:-

$$\Rightarrow \frac{V_{rms}}{V_{avg}} = \frac{\frac{V_m}{\sqrt{2}}}{\frac{2V_m}{\pi}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

Rms of AC o/p signal (I'_{rms})

$$i = i_{AC} + I_{dc}$$

$$i_{AC} = i - I_{dc}$$

$$I_{AC}^2(rms) = \frac{1}{T} \int_0^T (i - I_{dc})^2 d\alpha$$

$$= \frac{1}{\pi} \int_0^\pi (i^2 + I_{dc}^2 - 2iI_{dc}) d\alpha$$

$$= \frac{1}{\pi} \left[\int_0^\pi i^2 d\alpha + \int_0^\pi I_{dc}^2 d\alpha - 2 \int_0^\pi i I_{dc} d\alpha \right]$$

$$= \frac{1}{\pi} \left[I_{rms}^2 + \frac{I_{dc}^2}{\pi} \int_0^\pi d\alpha - \frac{2I_{dc}}{\pi} \int_0^\pi i d\alpha \right]$$

$$= I_{rms}^2 + \frac{I_{dc}^2}{\pi} [\pi] - 2I_{dc}$$

$$= I_{rms}^2 - I_{dc}^2$$

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

Ripple factor of FWR:-

$$\gamma = \frac{V_{ac}}{V_{dc}} = \frac{I_{ac}}{I_{dc}} = \frac{I'_{rms}}{I_{dc}}$$

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

$$= \sqrt{\frac{\frac{1}{2}}{\frac{4}{\pi^2}} - 1}$$

$$= 0.481$$

Input power (P_i):-

$$P_i = \frac{1}{T} \int_0^T v_i i d\alpha$$

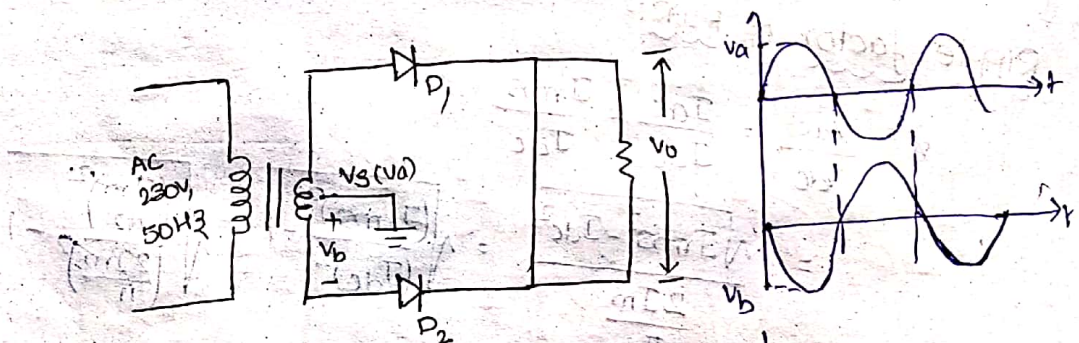
$$\begin{aligned}
 &= \frac{1}{2\pi} \int_0^{\pi} (V_m \sin \alpha) (I_m \sin \alpha) d\alpha + \int_{\pi}^{2\pi} (-\sin \alpha V_m) (-I_m \sin \alpha) d\alpha \\
 &= \frac{1}{2\pi} \int_0^{2\pi} I_m (R_F + R_L) I_m \sin^2 \alpha d\alpha \\
 &= (R_F + R_L) \frac{I_m^2}{2\pi} \int_0^{\pi} \sin^2 \alpha d\alpha \\
 &= \frac{I_m^2 (R_F + R_L)}{2\pi} [\alpha - 0] \\
 &\boxed{P_i = I_{rms}^2 (R_F + R_L)}
 \end{aligned}$$

Efficiency (η):

$$\begin{aligned}
 \eta \% &= \frac{\text{o/p DC power}}{\text{o/p AC power}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100\% \\
 &= \frac{\left(\frac{2V_m}{\pi}\right)^2 R_L}{\left(\frac{V_m}{\sqrt{2}}\right)^2 (R_F + R_L)}
 \end{aligned}$$

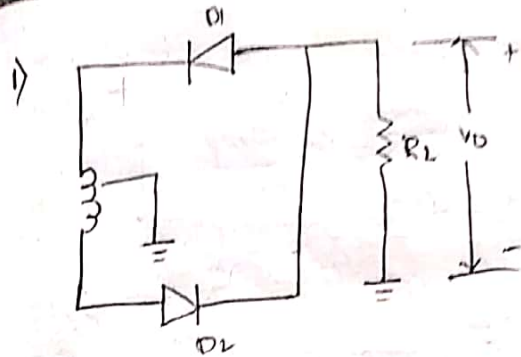
$$\boxed{\eta \% = 81.0 \frac{R_L}{R_F + R_L}}$$

Full wave Rectifier using center tap



$$\begin{aligned}
 V_a &= V_m \sin \alpha, \quad 0 < \alpha < 2\pi \\
 V_b &= -V_m \sin \alpha \quad (0 < \alpha < 2\pi)
 \end{aligned}$$

- At first the \$D_1\$ diodes acts in F.B and then \$D_2\$ is considered as R.B. (+ve signal)
- when the \$D_1\$ is in reverse bias then \$D_2\$ acts as first forward bias. So, both +ve and -ve cycle is get rectified. (-ve signal)

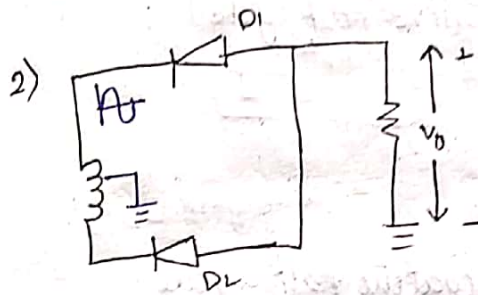


For +ve signal

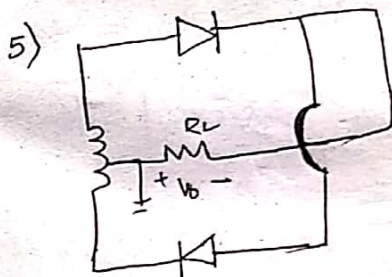
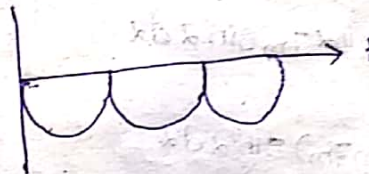
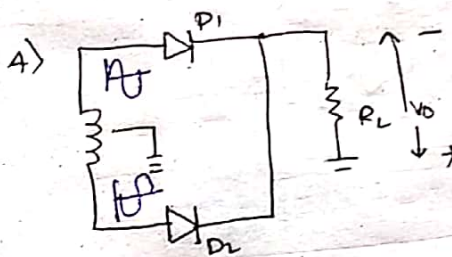
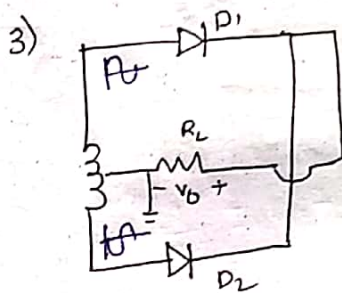
$$V_0 = 0$$

For -ve signal

$$V_0 = 0$$

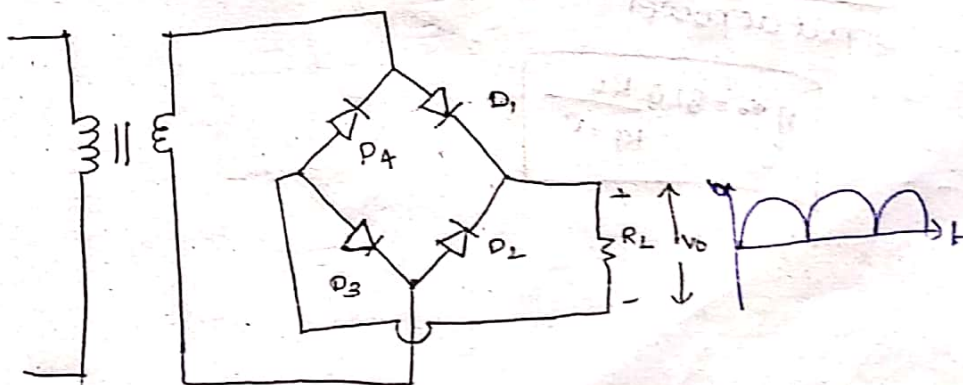


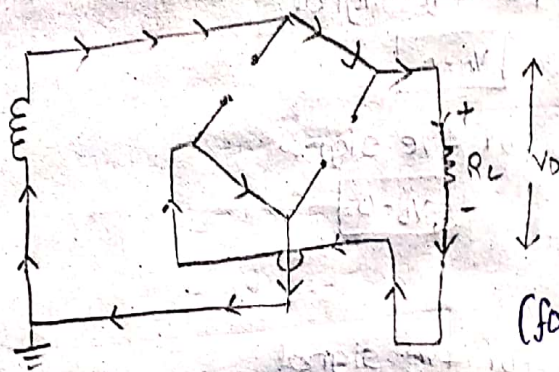
For +ve signal



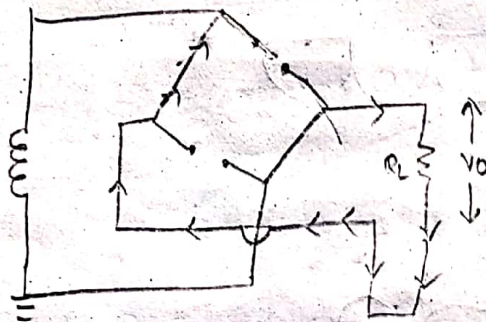
$$V_0 = 0V$$

FWR with using Bridge circuit





(for positive half cycle)



(for negative half cycle)

Input Average power (P_i):-

$$= \frac{1}{T} \int_0^T v \cdot I_{dd} d\alpha$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_m \sin \alpha I_m \sin \alpha d\alpha$$

$$= \frac{1}{2\pi} \int_0^{2\pi} (V_m I_m) \sin^2 \alpha d\alpha$$

$$= \frac{1}{2\pi} \int_0^{2\pi} I_m^2 (R_F + R_L) \sin^2 \alpha d\alpha$$

$$= \frac{I_{rms}^2}{2\pi} (R_F + R_L) [2\pi]$$

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

Efficiency (η):-

$$\eta\% = \frac{\text{output DC power}}{\text{Input ac power}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100\%$$

$$\eta\% = 81.0 \frac{R_L}{R_F + R_L}$$

Peak Inverse Voltage (PIV) FWR

$$V_a = V_m \sin \alpha$$

$$V_b = -V_m \sin \alpha$$

$$-V_a + V_D + V_b = 0$$

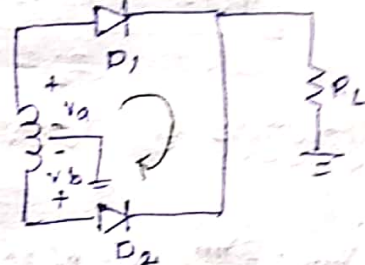
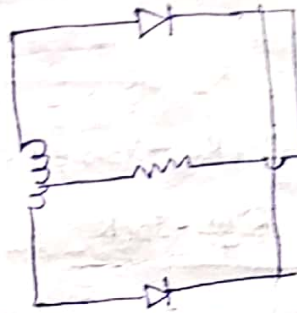
$$V_D = V_a - V_b$$

$$V_D = V_m \sin \alpha - (-V_m \sin \alpha)$$

$$V_D = 2V_m \sin \alpha$$

$$\text{PIV} = |2V_m \sin \alpha|_{\text{max}}$$

$$\text{PIV} = 2V_m$$



V_{Diode} DC (FWR) :-

$$V_{D \text{ avg}} = \frac{1}{T} \int_0^T 2V_m \sin \alpha \, d\alpha$$

$$= \frac{1}{2\pi} \left[\int_0^{\pi} 2V_m \sin \alpha \, d\alpha + \int_{\pi}^{2\pi} 2V_m \sin \alpha \, d\alpha \right]$$

$$= \frac{-1}{2\pi} \left[2V_m [\cos \alpha]_{\pi}^{2\pi} \right]$$

$$= -\frac{V_m}{\pi} [1 - (-1)] = -\frac{2V_m}{\pi}$$

$$V_{D \text{ avg}} = -\frac{2V_m}{\pi}$$

$$V_{Diode} = 0, 0 < \alpha < \pi$$

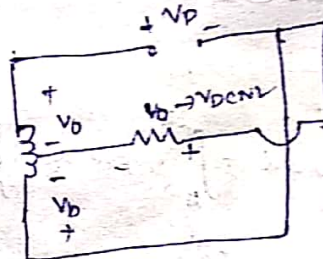
$$V_D = 2V_m \sin \alpha, \pi < \alpha < 2\pi$$

No load DC voltage (FWR) :-

$$V_{Diode} = -V_{DCNL}$$

$$= -\left(\frac{2V_m}{\pi}\right)$$

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

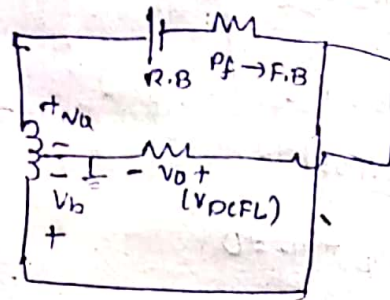


Full load DC voltage (FLVR):-

$$\begin{aligned} V_{PCFL} &= I_{DC} R_L \\ &= -I_{DC} R_f - V_{diode, DC} \\ &= \frac{2V_m}{\pi} - I_{DC} R \end{aligned}$$

$$\boxed{V_{PCFL} = V_{PCNL} - I_{DC} R}$$

$$\frac{2V_m}{\pi} - I_{DC} R_L$$

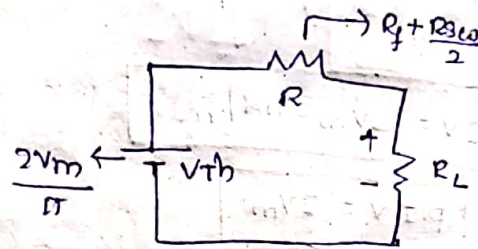


$$\boxed{R = R_f + \frac{R_{sw}}{2}}$$

Thevenin's equivalent circuit:-

$$V_{th} = \frac{2V_m}{\pi}, R = R_f + \frac{R_{sw}}{2}$$

and $R_L = \text{load}$

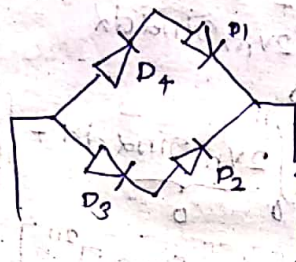


PIV voltage (Bridge)

$$D_1, D_3 \Rightarrow 0, 0 < \alpha < \pi$$

$$\Rightarrow V_m \sin \alpha, \pi < \alpha < 2\pi$$

$$\begin{aligned} D_2, D_4 &\Rightarrow -V_m \sin \alpha, 0 < \alpha < \pi \\ &0, \pi < \alpha < 2\pi \end{aligned}$$



$$PIV = |V_{diode}|_{\max} = |V_m \sin \alpha|$$

$$= V_m$$

V_{diode DC} (Bridge):-

For D_1, D_3

$$= \frac{1}{2\pi} \left[\int_0^\pi 0 d\alpha + \int_\pi^{2\pi} V_m \sin \alpha d\alpha \right]$$

$$= -\frac{V_m}{2\pi} [\cos \alpha]_\pi^{2\pi}$$

$$= -\frac{V_m}{2\pi} [1 - (-1)] = -\frac{V_m}{\pi}$$

FOR D_1, D_2

$$= \frac{1}{2\pi} \left[\int_0^{\pi} -V_m \sin \alpha d\alpha + \int_{\pi}^{2\pi} 0 d\alpha \right]$$

$$= + \frac{V_m}{2\pi} [\cos \alpha]_0^{\pi}$$

$$= \frac{V_m}{2\pi} [-1 - (1)] = -\frac{V_m}{\pi} //$$

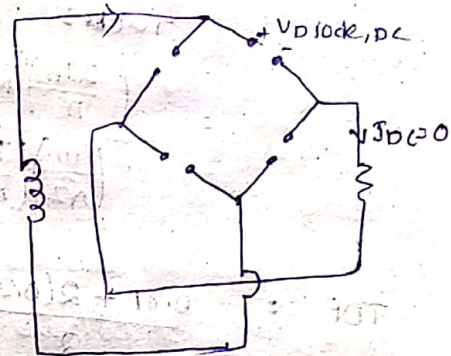
V_{DCNL} (Bridge):-

$$-V_0 - V_{diode, DC} - V_{DCNL} = 0$$

$$V_{DCNL} = -V_{diode, DC} - V_{diode, DC}$$

$$= -2 \left(-\frac{V_m}{\pi} \right)$$

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



V_{DCFL} (Bridge):-

$$V_{DCFL} = I_{DC} R_L$$

$$V_{DCFL} = V_{DCNL} - I_{DC} R$$

$$V_{DCFL} = -V_{diode, DC} - I_{DC} R$$

$$V_{DCFL} = \frac{2V_m}{\pi} - I_{DC} R$$

$$R = R_F + R_{SW}$$

TUF (Bridge):-

$$TUF = \frac{DC \text{ o/p power}}{AC \text{ rating of transformer}}$$

$$= \frac{I_{DC}^2 R_L}{V_{rms} I_{rms}}$$

$$= \frac{I_{DC}^2 R_L}{\left(\frac{V_m}{\sqrt{2}} \right) \left(\frac{I_m}{\sqrt{2}} \right)} = \frac{\left(\frac{2V_m}{\pi} \right)^2 R_L}{\frac{V_m I_m}{2}}$$

$$= \frac{4I_m^2}{\pi^2} \times R_L \times \frac{2}{V_m I_m} = \frac{0.81 R_L}{R_L + R_F} //$$

TUF (center tap):

$$TUF = \frac{TUF_{Primary} + TUF_{Secondary}}{2}$$

$$TUF_{sec} = 2(TUF)_{HWR}$$

$$TUF = 1.2 < 0.286$$

$$TUF_{pn} = \frac{\text{DC o/p power}}{\text{AC rating of transformer}}$$

$$= \frac{(I_{DC})^2 R_L}{V_{rms} I_{rms}}$$

$$= \frac{\left(\frac{2I_m}{\pi}\right)^2 R_L}{\left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)} = \frac{0.81 R_L}{R_L + R_F}$$

$$TUF = \frac{0.81 + 2(0.286)}{2} \times \frac{R_L}{R_L + R_F} = 0.693 \frac{R_L}{R_L + R_F}$$

Parameters	HWR	FWR (CT)	FWR (Bridge)
I_{avg}	I_m/π	$2I_m/\pi$	$2I_m/\pi$
V_{avg}	V_m/π	$2V_m/\pi$	$2V_m/\pi$
$V_{rms} (O/P)$	$V_m/2$	$V_m/\sqrt{2}$	$V_m/\sqrt{2}$
$I_{rms} (O/P)$	$I_m/2$	$I_m/\sqrt{2}$	$I_m/\sqrt{2}$
$V'_{rms} (O/P)$	$\sqrt{V_{rms}^2 - V_{DC}^2}$	$\sqrt{V_{rms}^2 - V_{DC}^2}$	$\sqrt{V_{rms}^2 - V_{DC}^2}$
$I'_{rms} (O/P)$	$\sqrt{I_{rms}^2 - I_{DC}^2}$	$\sqrt{I_{rms}^2 - I_{DC}^2}$	$\sqrt{I_{rms}^2 - I_{DC}^2}$
Ripple factor (%)	1.21	0.48	0.48
Input power (P)	$I_{rms}^2 (R_F + R_L)$	$I_{rms}^2 (R_F + R_L)$	$I_{rms}^2 (R_F + R_L)$
Efficiency (%)	$40.5 \times \frac{R_L}{R_F + R_L}$	$81.0 \times \frac{R_L}{R_F + R_L}$	$81.0 \times \frac{R_L}{2R_F + R_L}$
$V_{pide, DC}$	$-V_m/\pi$	$-2V_m/\pi$	$-V_m/\pi$
PIV	V_m	$2V_m$	V_m
Form factor	1.57	1.11	1.11
Peak factor	2	1.414	1.414
V_{DCNL}	V_m/π	$2V_m/\pi$	$2V_m/\pi$
V_{DCFL}	$\frac{V_m}{\pi} - I_{DC} R_f$	$\frac{2V_m}{\pi} - I_{DC} R$	$\frac{2V_m}{\pi} - I_{DC} R$
TUF	$0.286 \times \frac{R_L}{R_F + R_L}$	$0.693 \times \frac{R_L}{R_F + R_L}$	$0.81 \times \frac{R_L}{2R_F + R_L}$
Load Regulation	$\frac{I_{DC} R_f}{V_{DCFL}} \times 100\%$		

$X_C = 0$ (which allows ac signal)

$X_L = \infty$ (which doesn't allow ac signal)

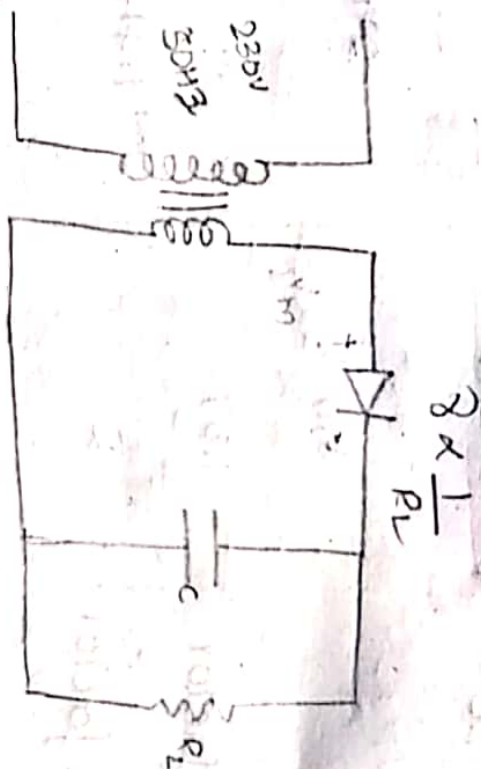
C-Filter:-

* During +ve cycle the diode acts as short circuit and allows ac and dc signal.

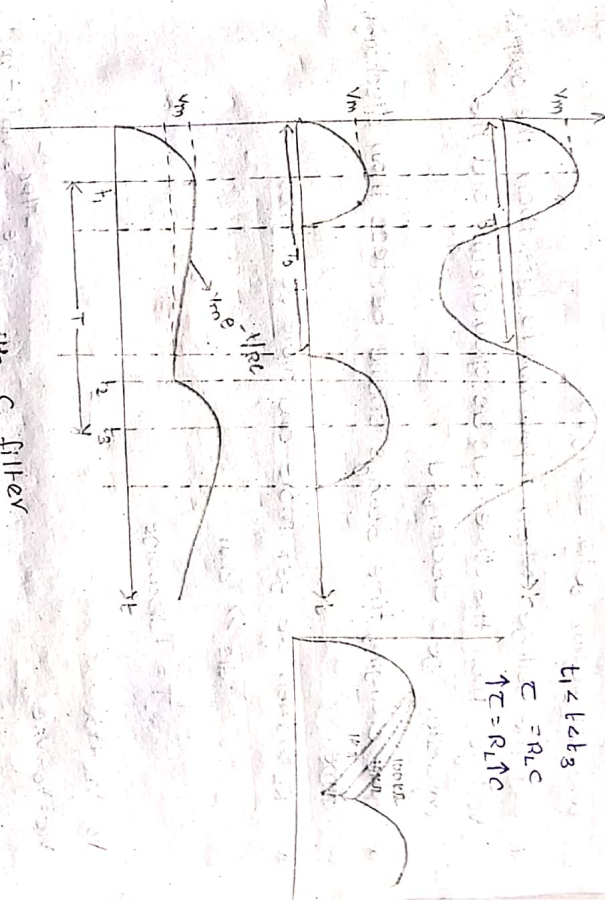
* During half of the +ve cycle the capacitor gets charged and next half of the +ve signal the diode acts as open circuit and the capacitor gets discharged.

* The charging time always should be less than discharging time.

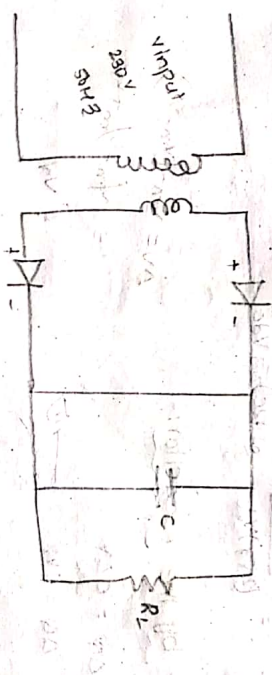
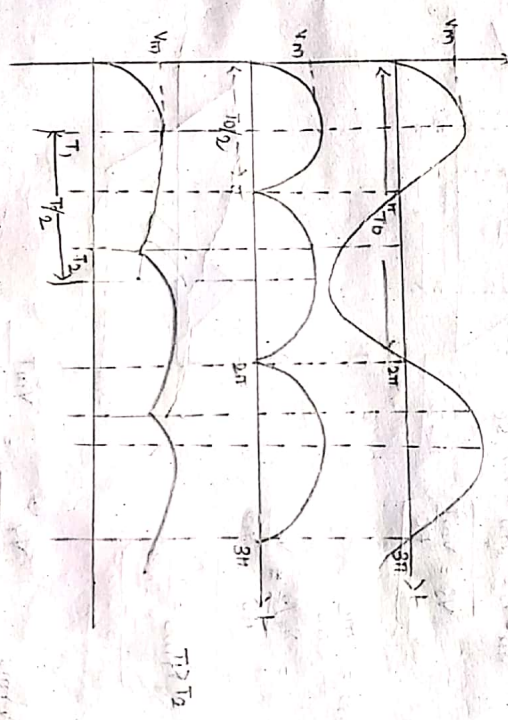
* If R_L is more the discharging time is more. that means discharging time depends on R_L .



Full wave Rectifier with C filter



$t_1 < t < t_3$
 $C = R_L C$
 $T = R_L / \omega$



* During the +ve half cycle the diode acts as short circuit and capacitor gets charged.

* But the voltage when input (V_m) is less than the output voltage then the diode acts as open circuit and the capacitor gets discharged.

* The charging time always should be less than discharge time.

* $R_L \gg$ then we get more and more dc signal.

$$T_{dis} \gg T_{char}$$

$$T = T_{discharge}$$

$$V_0 = V_{AC} + V_{DC}$$

$$V_{DC} = V_0 - V_{AC}$$

$$V_m - V_2 = V_m(1 - T/RC)$$

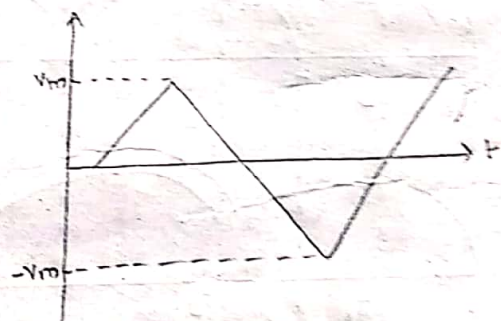
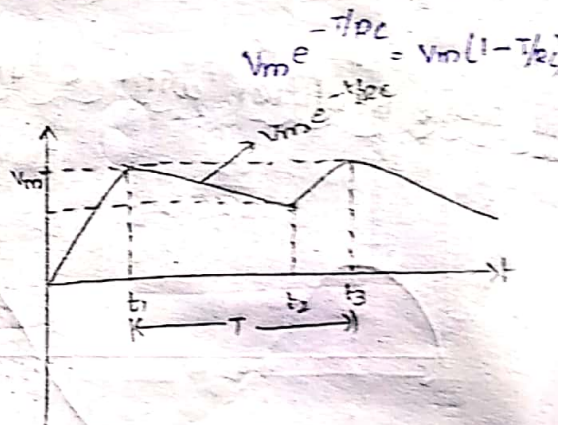
$$V_m - V_2 = V_m - V_m T/RC$$

$$V_2 = \frac{V_m T}{RC}$$

$$V'_{rms} = \frac{V_m}{\sqrt{3}}$$

$$= \frac{V_2/2}{\sqrt{3}} = \frac{V_2}{2\sqrt{3}}$$

$$V'_{rms} = \frac{V_2}{2\sqrt{3}}$$



$$\gamma = \frac{V'_{rms}}{V_{dc}} = \frac{V_2}{(2\sqrt{3})V_{dc}} = \frac{V_m T}{2(RC)\sqrt{3}V_{dc}}$$

Charge lost by the capacitor:-

$$\Delta Q = C \Delta V$$

$$\Delta Q = C V_2 \rightarrow \text{①}$$

$$\begin{aligned} \Delta V &= V_m - (V_m - V_2) \\ &= V_m - V_m + V_2 \\ &= V_2 \end{aligned}$$

charge gained by Resistor:-

$$\Delta Q = I_{DC} \Delta T$$

$$\Delta Q = I_{DC} T \quad \rightarrow (2)$$

From (1) and (2)

$$CV\gamma = I_{DC} T$$

$$V\gamma = \frac{I_{DC}}{fC} \quad \rightarrow (3)$$

$$\begin{aligned} \gamma &= \frac{V_{rms}}{V_{DC}} = \frac{V\gamma}{(2\sqrt{3})V_{DC}} \\ &= \frac{I_{DC}}{fC(2\sqrt{3})V_{DC}} \end{aligned}$$

$$V_{DC} = I_{DC} R_L$$

$$\gamma = \frac{1}{(2\sqrt{3})fC R_L}$$

Full wave rectifier:-

charge lost by capacitor

$$\Delta Q = C \Delta V$$

$$\Delta Q = CV\gamma \quad \rightarrow (1)$$

charge gained by resistor:-

$$\Delta Q = I_{DC} \Delta T$$

$$P_{positive} \quad \Delta Q = \frac{I_{DC} T}{2} \quad \rightarrow (2)$$

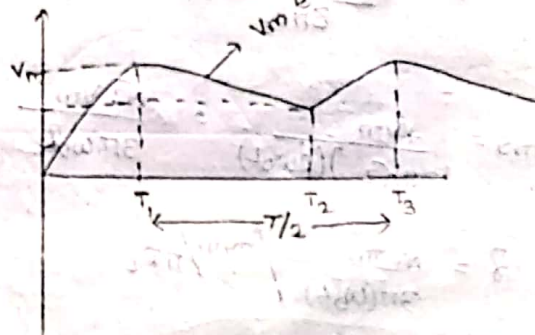
From (1) and (2), we get

$$CV\gamma = \frac{I_{DC} T}{2}$$

$$V\gamma = \frac{I_{DC} T}{2C} \quad \rightarrow (3)$$

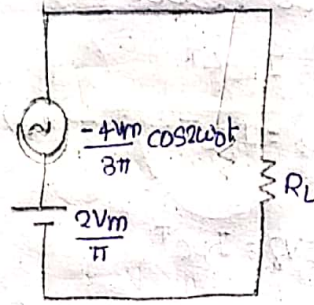
$$\gamma = \frac{V_{rms}}{V_{DC}} = \frac{V\gamma}{2\sqrt{3}V_{DC}} = \frac{I_{DC} T}{(2\sqrt{3})C I_{DC} R_L}$$

$$\gamma = \frac{1}{4\sqrt{3}fC R_L}$$



$$x(t) = \underbrace{\frac{2V_m}{\pi}}_{DC} - \underbrace{\frac{4V_m}{\pi} \sum_{k=1}^{\infty} \frac{\cos k\omega t}{(k+1)(k-1)}}_{AC}$$

$$V_0 = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi} \cos 2\omega t$$



L-filter (Full wave)

When DC voltage acting alone

$$I_{dc} = \frac{2V_m}{\pi R_L}$$

when AC voltage acting alone

$$I_{ac} = \frac{V_{ac}}{R_L + X_L} = \frac{V_{ac}}{X_L}$$

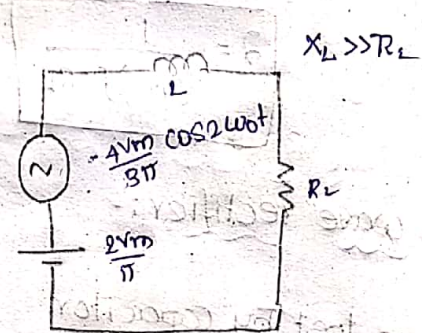
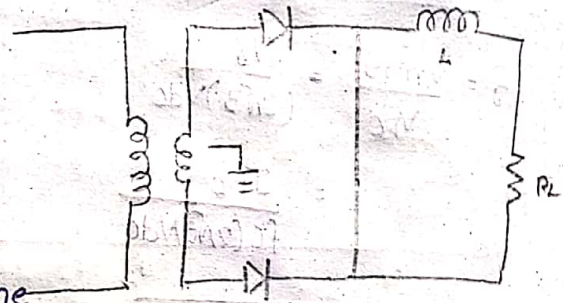
$$= \frac{-4V_m \cos 2\omega t}{3\pi X_L}$$

$$I_{rms} = \frac{4V_m}{(3\pi\sqrt{2})(\omega L)} = \frac{\sqrt{2}V_m}{3\pi\omega L}$$

$$\eta = \frac{\sqrt{2}V_m}{3\pi(\omega L)} \div \frac{2V_m}{\pi R_L}$$

$$\eta = \frac{\sqrt{2}R_L}{3\pi(\omega L)}$$

$$\boxed{\eta = \frac{R_L}{3\sqrt{2}\omega L}}$$



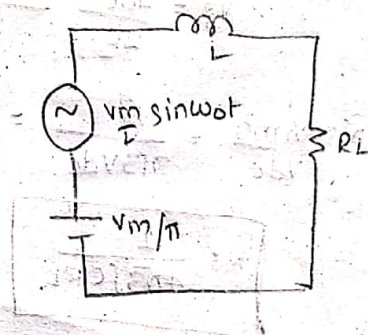
Half wave rectifier with filter using L filter

when DC voltage acting alone

$$I_{dc} = \frac{V_m}{\pi R_L}$$

when AC voltage acting alone

$$I_{ac} = \frac{V_{ac}}{X_L + R_L} = \frac{V_{ac}}{X_L}$$



$$I_{ac} = \frac{V_m \sin \omega t}{2X_L}$$

$$I_{ac} = \frac{V_m \sin \omega t}{2X_L}$$

$$I_{rms} = \frac{V_m}{2\sqrt{2}X_L} = \frac{V_m}{2\sqrt{2}\omega L} = \frac{V_m}{\sqrt{2}\omega L}$$

$$\eta = \frac{I_{rms}}{I_{dc}} = \frac{\frac{V_m}{\sqrt{2}\omega L}}{\frac{V_m}{\pi R_L}} = \frac{\pi R_L}{\sqrt{2}\omega L}$$

$$\boxed{\eta = \frac{\pi R_L}{\sqrt{2}\omega L}}$$

L-C Filter

when ac voltage get shorted

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

$$V_{ac} = \frac{(V_1)(X_C || R_L)}{X_L + (X_C || R_L)}$$

$$V_{ac} = \frac{V_1(X_C)}{X_L + X_C} = \frac{V_1 X_C}{X_L}$$

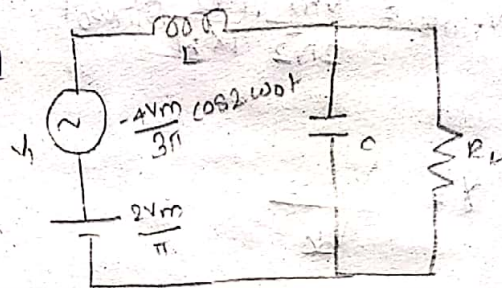
$$V_{ac} = \frac{4V_m \cos 2\omega t}{3\pi} \times \frac{X_C}{X_L}$$

$$V'_{rms} = \frac{4V_m}{3\pi\sqrt{2}} \times \frac{X_C}{X_L}$$

$$\eta = \frac{V'_{rms}}{V_{dc}} = \frac{\frac{4V_m X_C}{3\pi\sqrt{2}X_L}}{\frac{2V_m}{\pi}} = \frac{2X_C}{\sqrt{2}X_L}$$

$$\eta = \frac{2X_C}{\sqrt{2}X_L} \times \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}X_C}{X_L}$$

$$\boxed{\eta = \frac{\sqrt{2}X_C}{X_L}}$$



$$X_C \ll R_L$$

$$X_L \gg X_C$$

LC Filter For Half wave

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

$$V_{ac} = \frac{V_1 \times (X_C \parallel R_L)}{X_L + (X_C \parallel R_L)}$$

$$V_{ac} = \frac{V_1 \times X_C}{X_L + X_C} = \frac{V_1 |X_C|}{|X_L|}$$

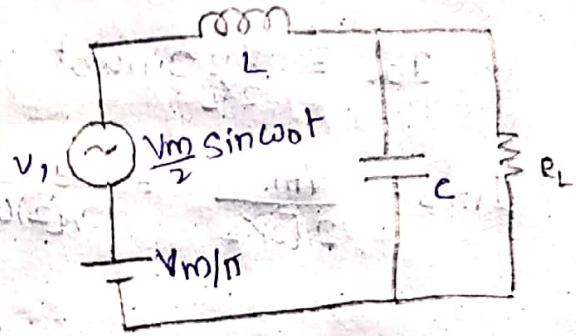
$$V_{ac} = \frac{V_m |X_C| \sin \omega t}{2 X_L}$$

$$V'_{rms} = \frac{V_m}{2\sqrt{2}} \cdot \frac{|X_C|}{|X_L|} \sin \omega t$$

$$\gamma = \frac{V'_{rms}}{V_{dc}}$$

$$= \frac{V_m}{2\sqrt{2}} \times \frac{|X_C|}{|X_L|} \times \frac{\pi}{V_m}$$

$$\gamma = \frac{\pi}{2\sqrt{2}} \times \frac{|X_C|}{|X_L|}$$



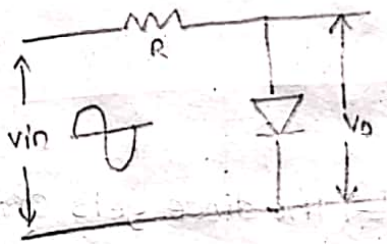
Clippers

* Clipper means removing a part from the signal.

there are two types of clippers. They are:-

1. Shunt clippers
2. Series clippers

Shunt clipper:-

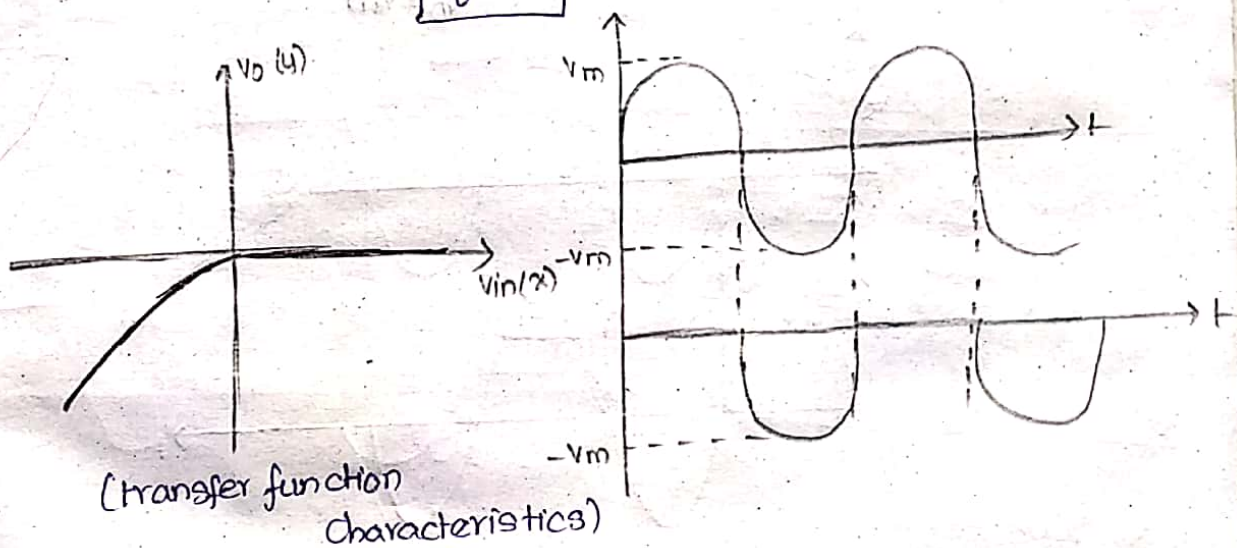


* For the first half cycle the diode acts as short circuit and the output voltage.

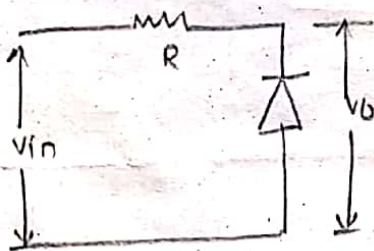
$$V_o = 0V$$

* For the -ve half cycle the diode acts as reverse bias and the output voltage:

$$V_o = v_{in}$$



Shunt clipper:-

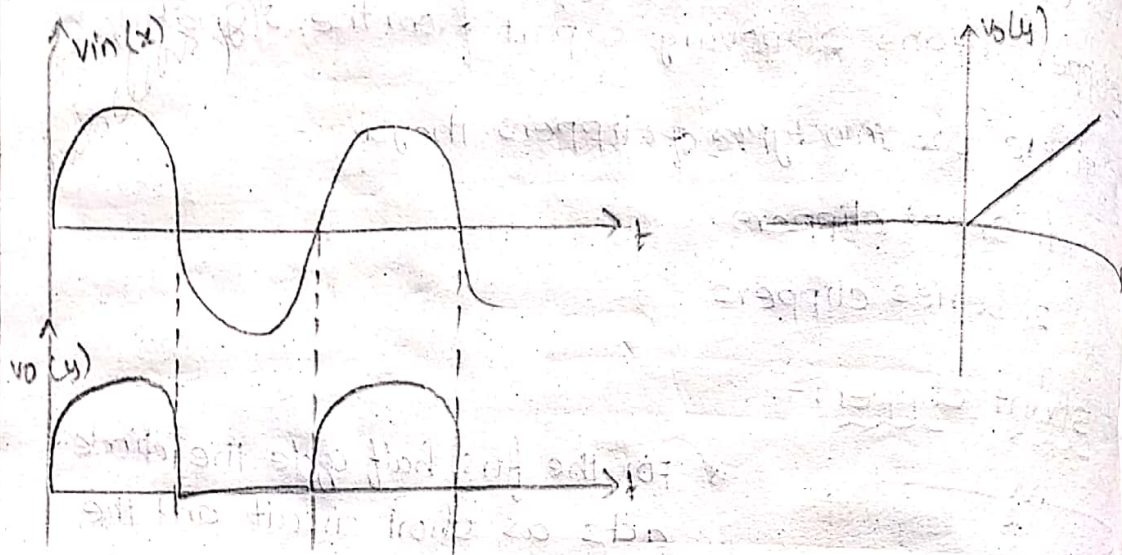


* for the +ve cycle the diode acts as open circuit and the

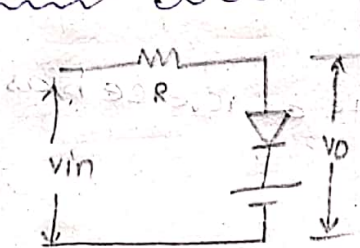
$$V_o = v_{in}$$

* for the -ve cycle the diode acts as short circuit then the

$$V_o = 0V$$



Biased condition:-

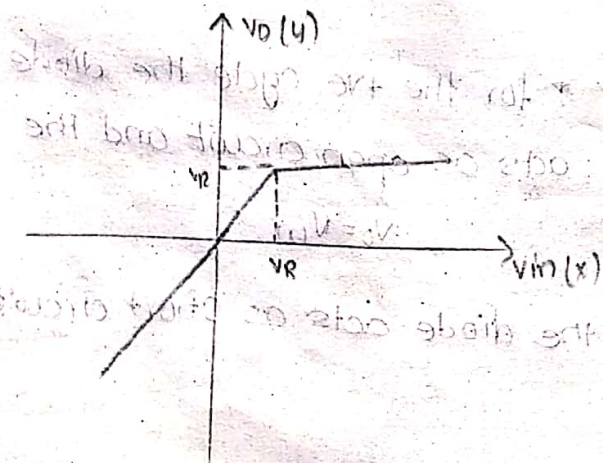
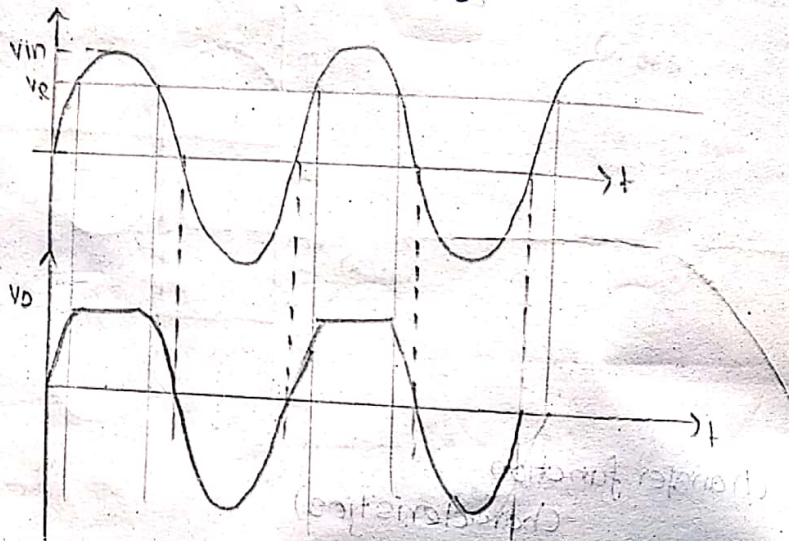


When $v_{in} > V_R \Rightarrow$ the diode gets S_{on}

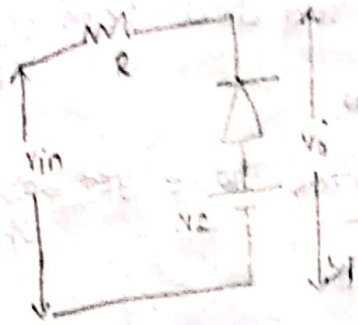
$$V_D = V_R$$

When $v_{in} < V_R \Rightarrow$ the diode gets open

$$V_D = v_{in}$$



$$V_D = V_R$$

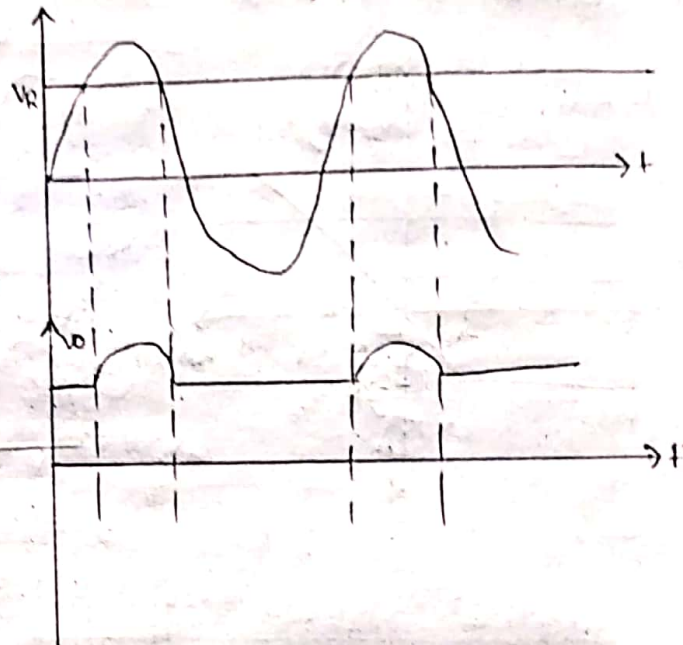
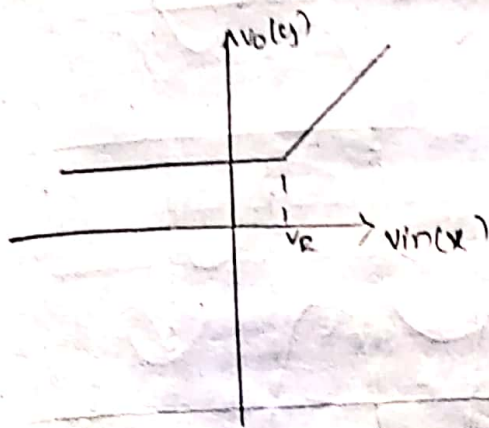


when $v_{in} > V_R \Rightarrow$ the diode gets open

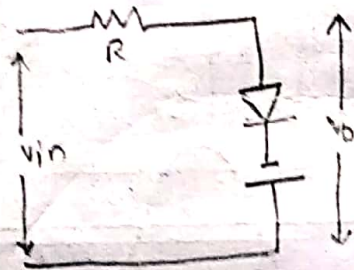
$$V_o = V_{in}$$

when $v_{in} < V_R \Rightarrow$ the diode gets short

$$V_o = V_R$$



iii)

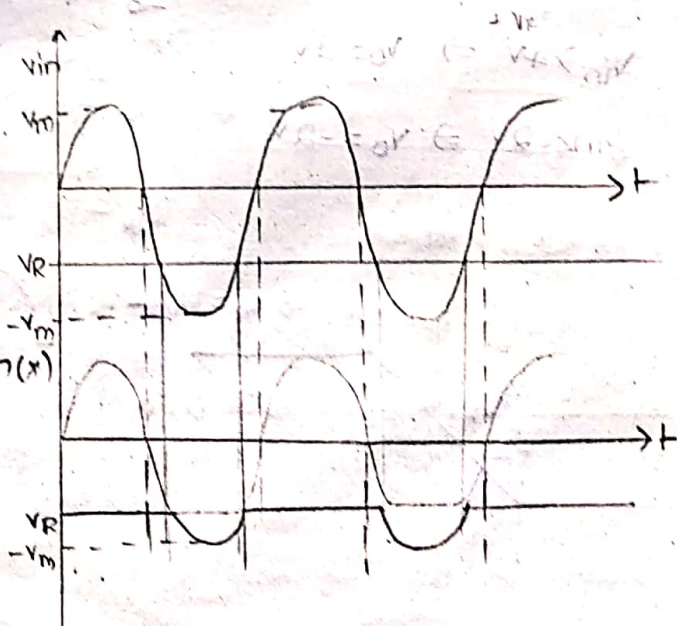
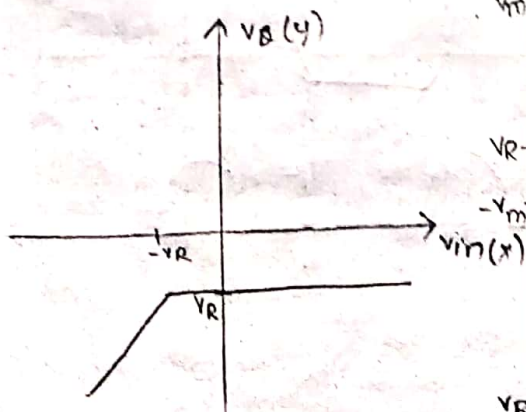


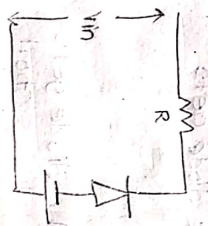
when $v_{in} > -V_R \Rightarrow$ The diode gets short open

$$V_o = -V_R$$

when $v_{in} < -V_R \Rightarrow$ the diode get short open

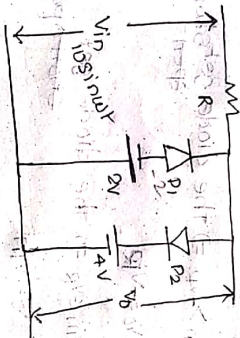
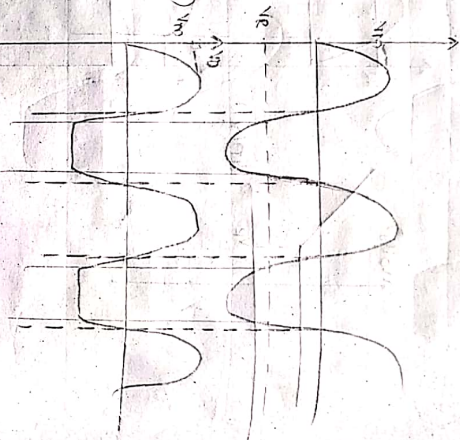
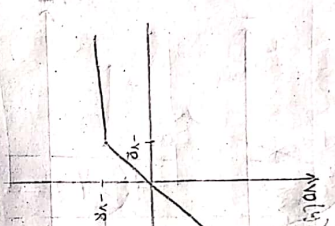
$$V_o = V_{in}$$



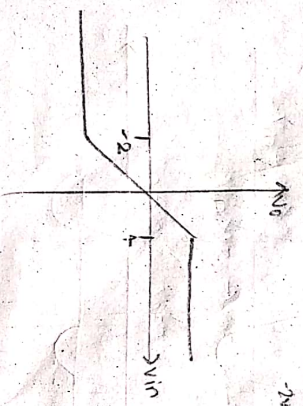
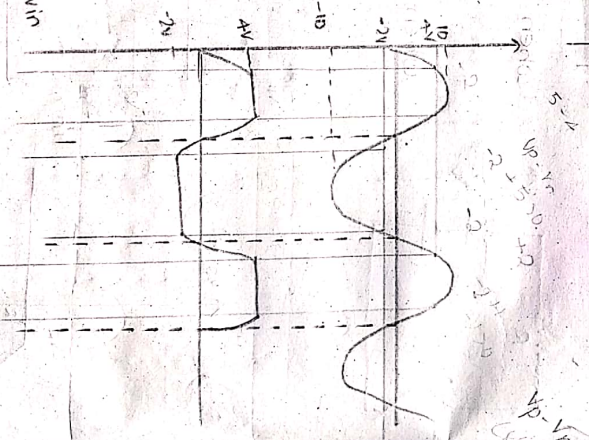


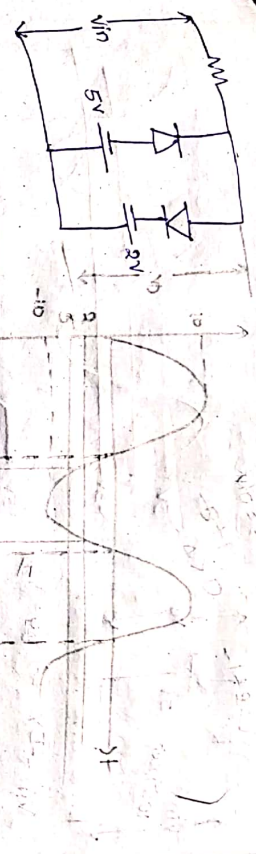
when $V_{in} > V_R \Rightarrow$ the diode gets short
 $V_o = V_{in}$

when $V_{in} < V_R \Rightarrow$ the diode get open
 $V_o = V_R$

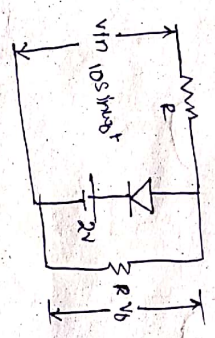
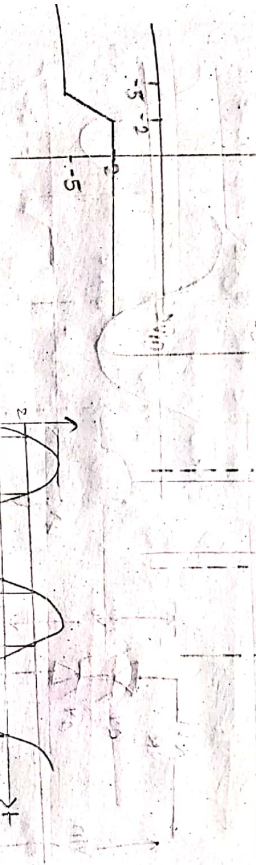


$V_{in} > 4V \Rightarrow V_o = 4V$
 $V_{in} < 4V \Rightarrow V_o = -8V$

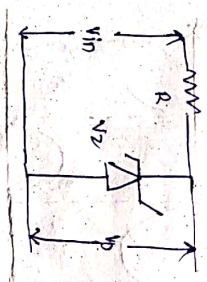
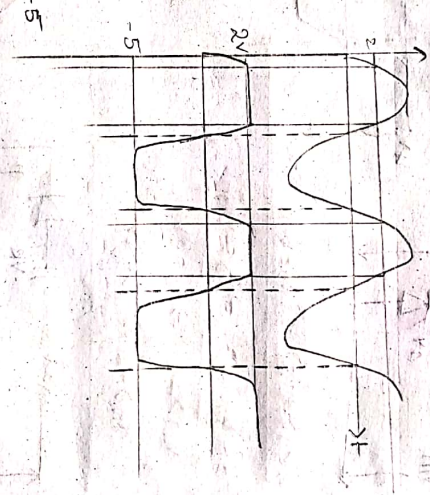




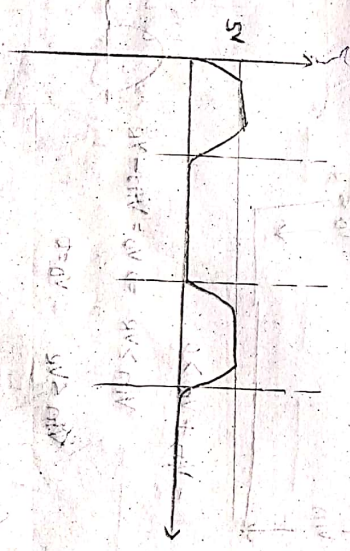
$V_{in} > -5V \Rightarrow V_b = -5V$
 $V_{in} < -5V \Rightarrow V_b = -2V$
 $V_{in} > -2V \Rightarrow V_b = -2V$

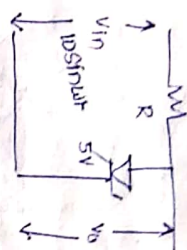


$V_{in} > 2V \Rightarrow V_b = 2V$
 $V_{in} < 2V \Rightarrow V_b = \frac{V_{in} \times R}{2R} = -5$



$V_{in} > V_z \Rightarrow V_b = V_z$
 $V_{in} < V_z \Rightarrow V_b = V_{in}$
 $V_{in} < 0 \Rightarrow V_b = 0V$



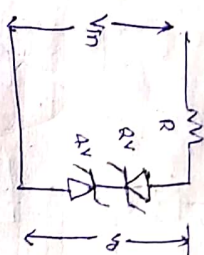
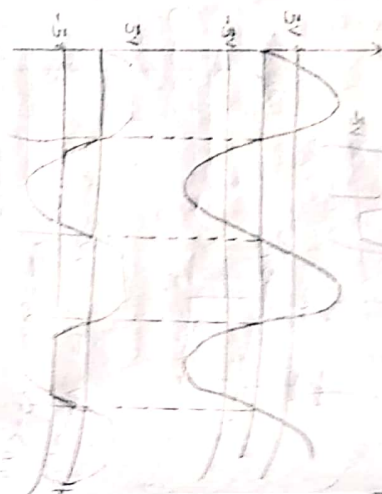


$$V_{in} < 5V \Rightarrow V_d = V_{in}$$

$$V_{in} > 5V \Rightarrow V_d = 5V$$

$$V_{in} < 0 \Rightarrow V_d = -V_{in}$$

$$V_{in} > 0 \Rightarrow V_d = 0$$

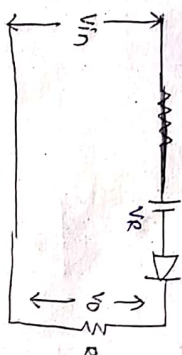
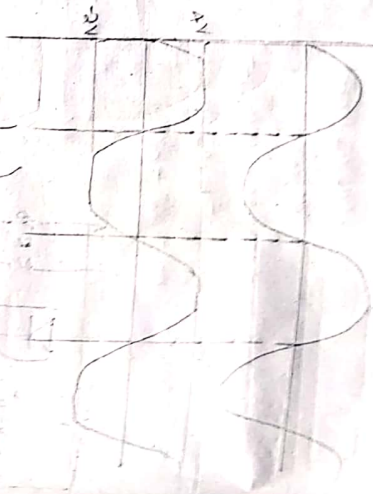


$$0 < V_{in} < 4V \Rightarrow V_d = V_{in}$$

$$V_{in} > 4V \Rightarrow V_d = 4V$$

$$V_{in} < 0 \Rightarrow V_d = -V_{in}$$

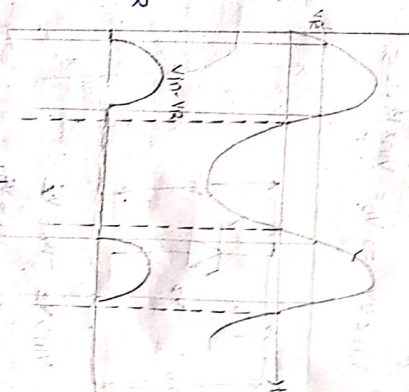
$$V_{in} > 4V \Rightarrow V_d = 4V$$

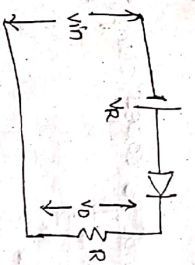


$$-V_{in} + V_R > 0$$

$$V_{in} > V_R \Rightarrow V_d = V_{in} - V_R$$

$$V_{in} < V_R \Rightarrow V_d = 0$$



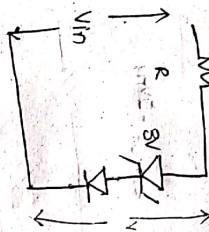
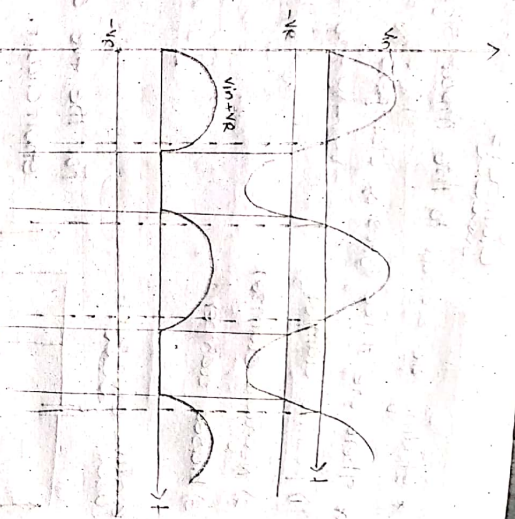


$$v_{in} > -V_R$$

$$v_o = v_{in} + V_R$$

$$v_{in} < -V_R$$

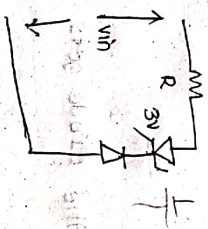
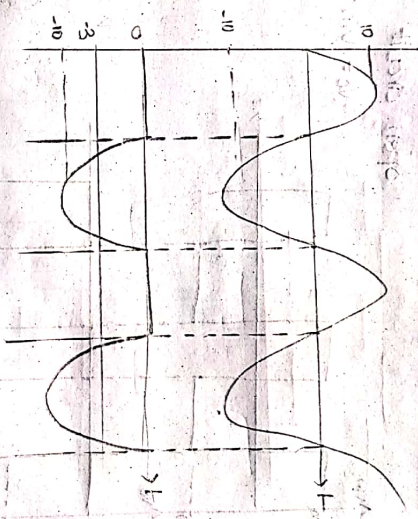
$$v_o = 0$$



$$v_{in} > 0 \quad v_o = v_{in}$$

$$0 < v_{in} < -3 \quad v_{in} = v_{in}$$

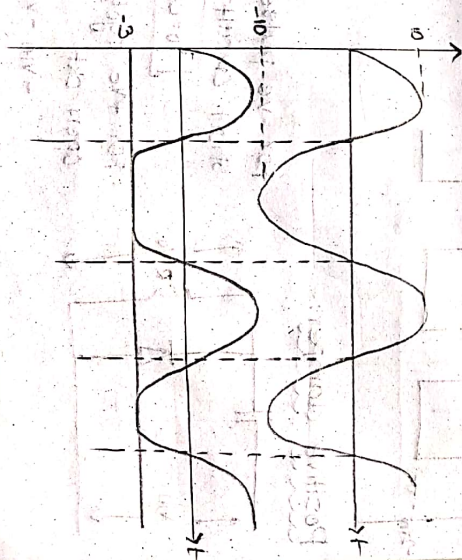
$$v_{in} > -3 \quad v_{in} = v_{in}$$



$$v_{in} > 0, \quad v_o = v_{in}$$

$$0 < v_{in} < -3, \quad v_o = v_{in}$$

$$v_{in} > -3, \quad v_o = v_{in}$$



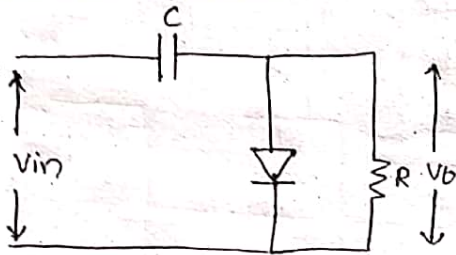
Clampers

* Adding dc signal to the input signal is called clamping.

* There are three types of clampers:

- 1) positive clamper
- 2) negative clamper
- 3) biased clamper

Negative clamper:-

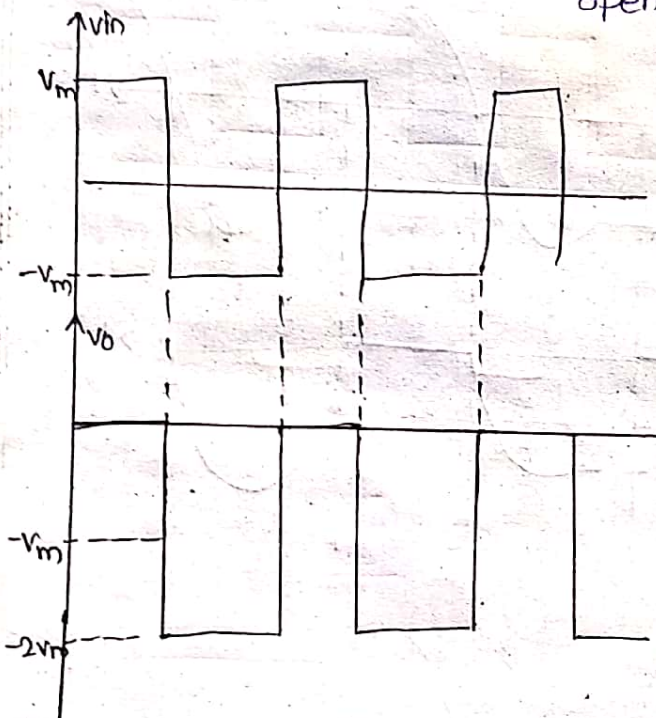


For the +ve cycle the diode is short circuit.

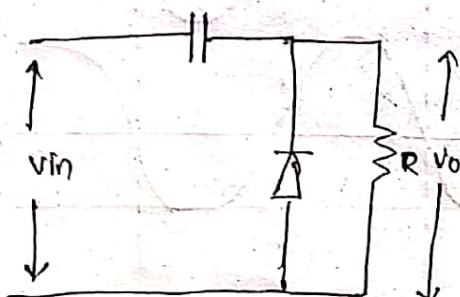
$$V_0 = 0V$$

For the -ve cycle the diode gets open circuit

$$V_0 = V_{in} - V_m \Rightarrow V_0 = -2V_m$$



Positive clamper:-



For -ve pulse the diode gets short circuit.

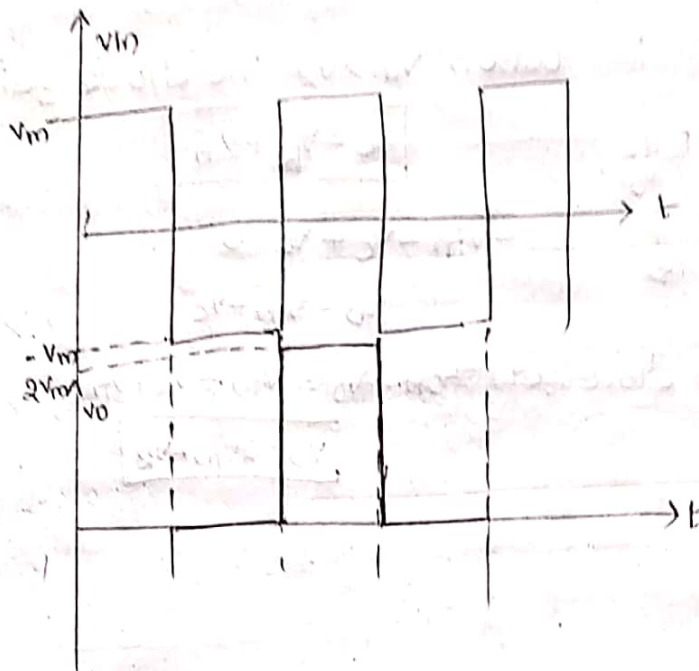
$$V_0 = 0V$$

For +ve cycle the diode acts as open ckt.

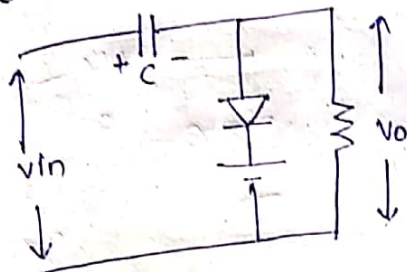
$$-V_{in} - V_m + V_0 = 0$$

$$V_0 = V_{in} + V_m$$

$$V_0 = 2V_m$$



Biased clamper:-



when $v_{in} > V_R$ the diode gets short.

$$V_o = V_R$$

when $v_{in} < V_R$ the diode gets open

$$-v_{in} + V_C + V_R = 0$$

$$V_C = V_m - V_R$$

$$-v_{in} + V_m + V_o = 0$$

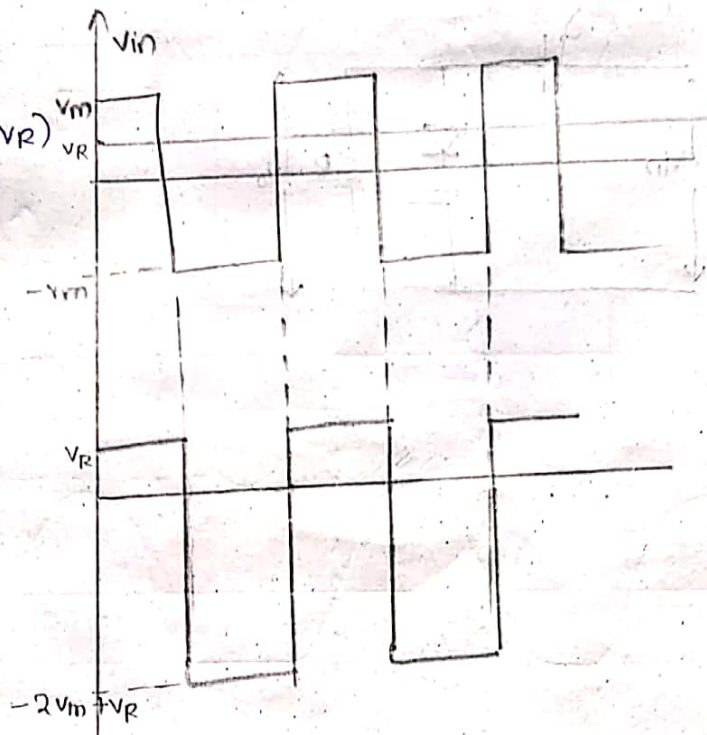
$$V_o = ?$$

$$-v_{in} + V_C + V_o = 0$$

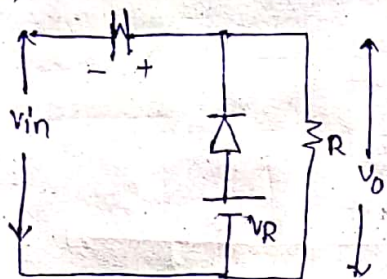
$$V_o = v_{in} - V_C$$

$$= -V_m - (V_m - V_R)$$

$$V_o = -2V_m + V_R$$



ii)



When $v_{in} > V_R$, the diode gets open

$$V_C = V_R + V_m$$

$$-v_{in} - V_C + V_o = 0$$

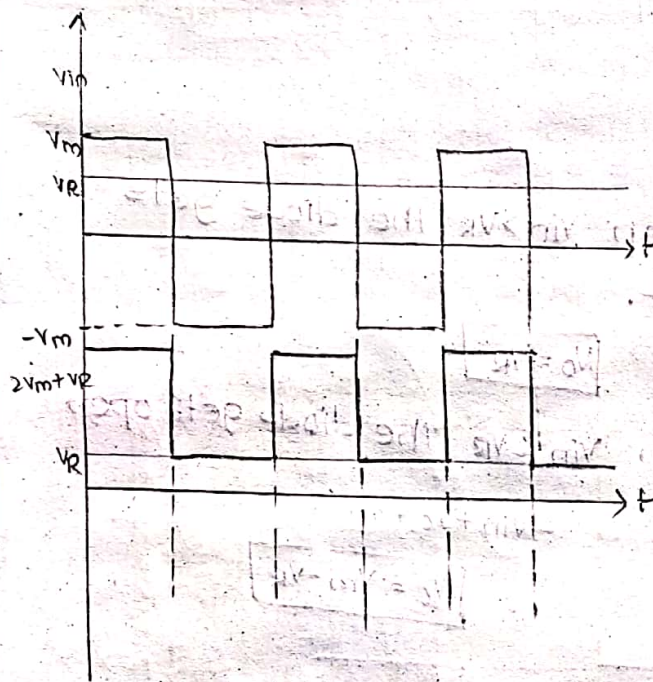
$$V_o = v_{in} + V_C$$

When $v_{in} < V_R$, the diode gets short

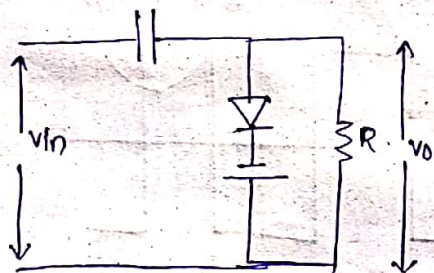
$$V_o = V_m + V_R + V_m$$

$$V_o = V_R$$

$$V_o = 2V_m + V_R$$



iii)



voltage Multi

* The output value of in

1. voltage Dou

2. voltage Trip

1. voltage Dou

* when we c the C₁ store and D₁ gets

* when we b D₁ gets short

$$-v_{in} - V_C$$

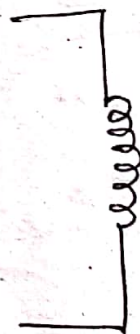
$$V_o' =$$

$$V_o'$$

By center tap

when you c D₁ gets short open and by V_m

when you the D₁ & short an



Voltage Multipliers:-

* The output of a given circuit is multiplied by a value of input signal is called voltage multipliers.

1. voltage Doubler

2. voltage Tripler.

1. voltage Doubler:-

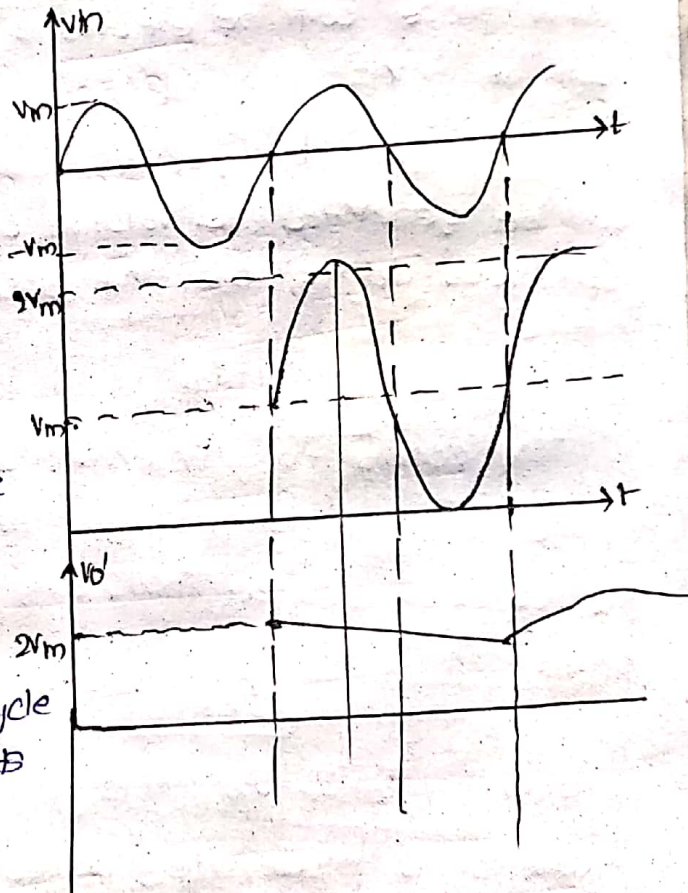
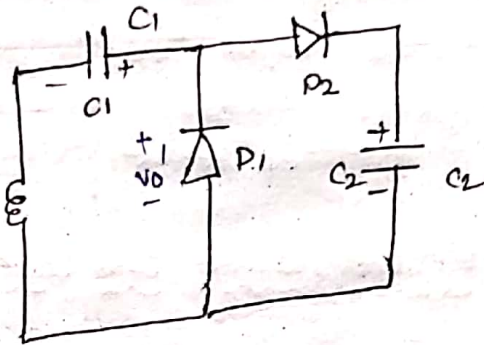
* when we apply -ve cycle the C_1 stores energy of V_m and D_1 gets short circuit.

* when we apply +ve cycle the D_1 gets open and D_2 gets short

$$-V_{in} - V_m = -V_o'$$

$$V_o' = V_{in} + V_m$$

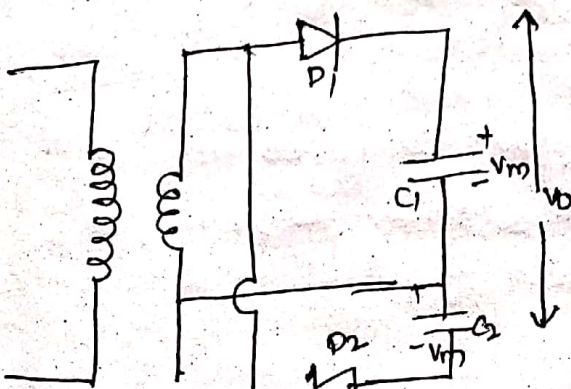
$$V_o' = 2V_m$$



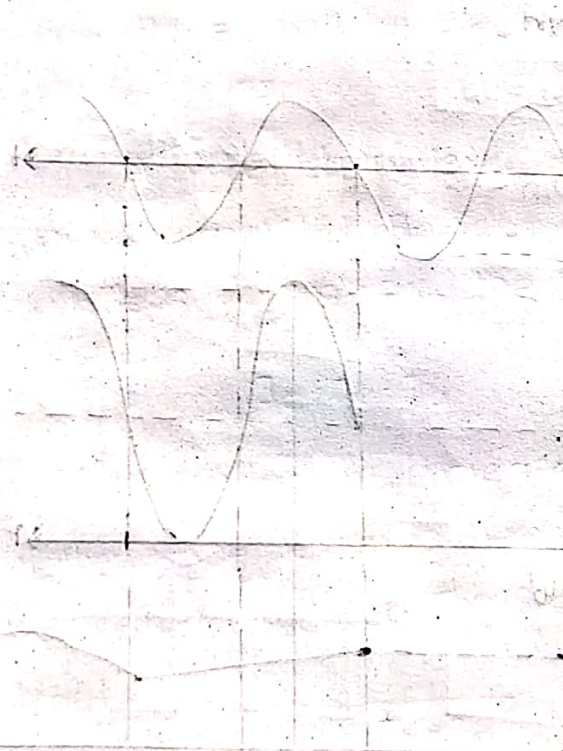
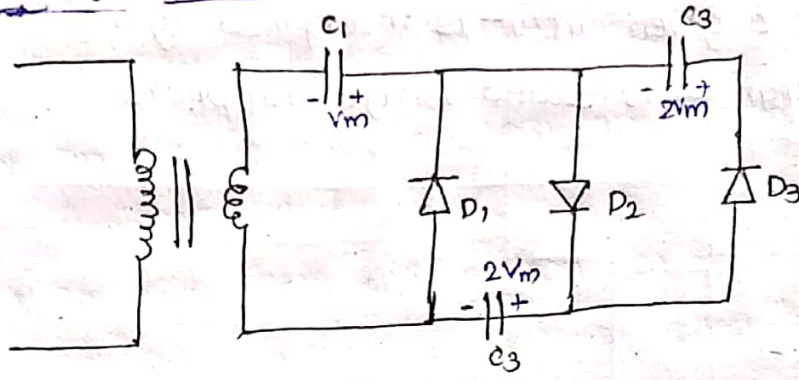
By center tap method:-

when you give +ve cycle the D_1 gets short and D_2 gets open and C_1 gets charged by V_m

when you give -ve method cycle the D_1 gets open and D_2 gets short and C_2 gets short.



Voltage Tripler:-



$$V_{out} = V_m - V_m$$

$$V_{out} = V_m$$

$$V_{out} = 2V_m$$

Output voltage

Input voltage

Output voltage

Input voltage

Output voltage

Input voltage

Output voltage

