UNIT-2

Diode Applications

Rectifier : A rectifier is a circuit/device that is used to convert AC voltage into pulsating DC voltage. filter converts pulsating DC to pure DC.

→ Rectifier is the main part of DC power supply.

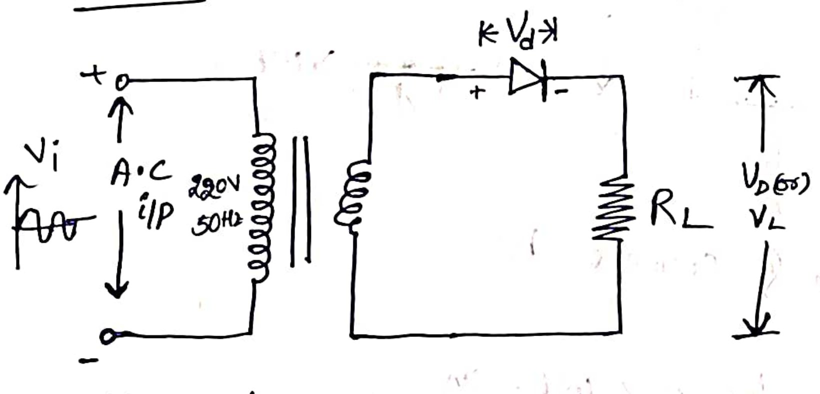
→ pn junction diode conducts only in one direction. It conducts when forward biased & doesn't conduct in reverse bias. Hence it is used to convert a.c supply to d.c supply (rectifier).

→ Rectifiers are of 3-types.

1. Half wave Rectifier
2. Full wave Rectifier
3. Bridge Rectifier.

Half Wave Rectifier : A rectifier with step down transformer, one pn-diode and load resistance R_L is said to be "Half wave Rectifier".

Circuit:



→ Transformer couples the AC voltage to rectifier ckt.

→ Step down transformer, steps down the AC voltage into required i/p voltage to diode.

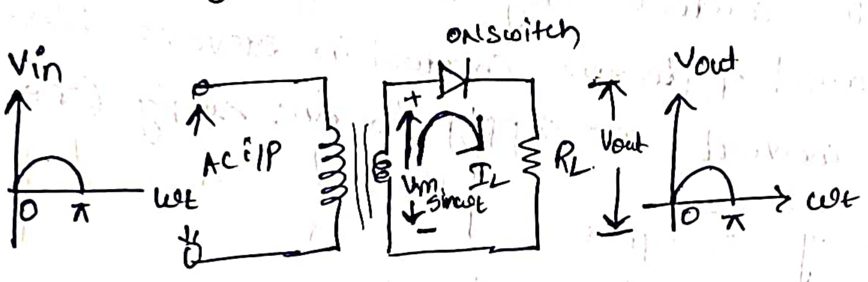
Operation : ① For (+ve) half cycle

→ During (+ve) half cycle of i/p, diode will be forward biased and it conducts.

→ Hence current in ckt flows clock wise.

→ Current flowing through load Resistor R_L produces an O/P voltage. * output across load is same as that of input.

$\boxed{V_{out} = V_{in}}$

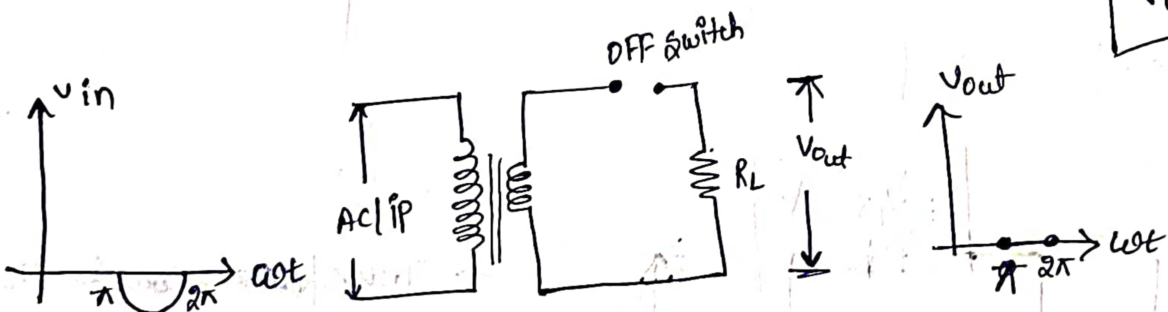


② For (−ve) half cycle.

→ During (−ve) half cycle of i/p, diode will be reverse biased and it doesn't conducts.

→ Hence there is no current flow in the ckt.

$\boxed{V_{out} = 0}$



→ Let the input voltage & current be

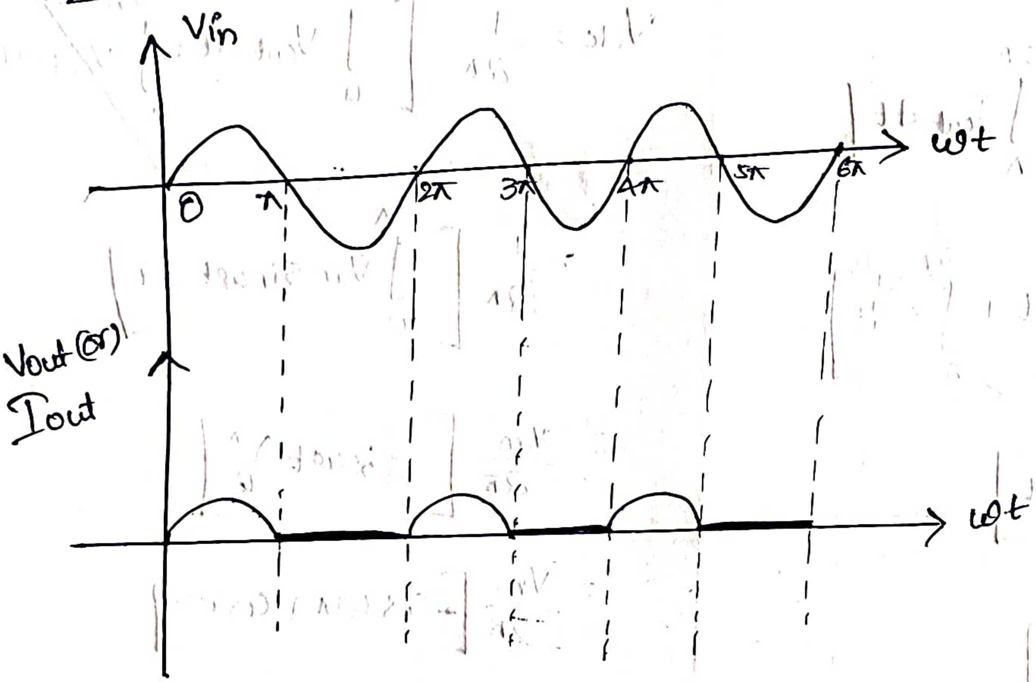
$V_{in} = V_m \sin\omega t$ for $0 \leq \omega t \leq 2\pi$

$I_{in} = I_m \sin\omega t$ for $0 \leq \omega t \leq 2\pi$ then output voltage & current be

$$V_{out} = V_m \sin\omega t \quad \text{for} \quad 0 \le \omega t \le \pi$$
$$= 0 \quad \text{for} \quad \pi \le \omega t \le 2\pi.$$

$$I_{out} = I_m \sin\omega t \quad \text{for} \quad 0 \le \omega t \le \pi$$
$$= 0 \quad \text{for} \quad \pi \le \omega t \le 2\pi.$$

Waveforms



Parameters:

1. D.C (or) Average current (I_{dc}) (or) I_{avg}
2. D.C (or) Average voltage (V_{dc}) (or) V_{avg}
3. Rms (or) AC current (I_{rms})
4. RMS (or) AC voltage (V_{rms})
5. D.C output power (P_{dc})
6. A.C input power (P_{ac})
7. Efficiency (η)
8. percentage of Regulation
9. Ripple factor (γ (or) $R_{(\infty)}$)
10. Form factor (FF)
11. peak factor (PF)
12. Transformer utilization factor (TUF)
13. Peak inverse voltage (PIV)

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① D.C Current (or) Average current (I_{dc})

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I_{out}\, dt$$

from graph

$I_{out} = I_m \sin\omega t$ for $0 \le \omega t \le \pi$

0 for $\pi \le \omega t \le 2\pi$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_{out}\, dt + \int_{\pi}^{2\pi} I_{out}\, dt\right]$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t\, dt + \cancel{\int_{\pi}^{2\pi} 0\, dt}\right]$$

$$= \frac{1}{2\pi}\left[I_m \int_0^{\pi} \sin\omega t\, dt\right]$$

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

$$= \frac{I_m}{2\pi}\left[-\cos\omega\pi + \cos\omega(0)\right]$$

$$= \frac{I_m}{2\pi}\left[-(-1) + 1\right] \quad \left[\because \begin{array}{l}\cos n\pi = -1 \\ \cos 0 = 1\end{array}\right]$$

$$= \frac{\cancel{2} I_m}{\cancel{2}\pi}$$

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

② DC voltage (or) Average voltage (V_{dc}):

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_{out}\, dt$$

from graph

$V_{out} = V_m \sin\omega t$ for $0 \le \omega t \le \pi$

$= 0$ for $\pi \le \omega t \le 2\pi$

$$V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} V_{out}\, dt + \cancel{\int_{\pi}^{2\pi} V_{out}\, dt}\right]$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t\, dt\right]$$

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

$$= \frac{V_m}{2\pi}\left[-\cos\omega\pi + \cos\omega(0)\right]$$

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

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

③ Rms (or) AC current (I_{rms})

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I_{out})^2 \, d\omega t}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_{out}^2 \, d\omega t + \cancel{\int_{\pi}^{2\pi} I_{out}^2 \, d\omega t}^{\,0}\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_m^2 \sin^2\omega t \, d\omega t\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[I_m^2 \int_0^{\pi}\left[\frac{1-\cos 2\omega t}{2}\right] d\omega t\right]}$$

$\left[\because \sin^2\theta = \frac{1-\cos 2\theta}{2}\right]$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\int_0^{\pi} d\omega t - \int_0^{\pi} \cos 2\omega t \, d\omega t\right]}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[(\omega t)_0^{\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{\pi}\right]}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\pi - 0 - \frac{1}{2}[\sin 2\pi - \sin 0]\right]}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\pi - \frac{1}{2}[0-0]\right]}$$

$$= \sqrt{\frac{\cancel{\pi} I_m^2}{4\cancel{\pi}}} = \cancel{\sqrt{\left(\frac{I_m}{2}\right)^{\cancel{2}}}}$$

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

⑤ DC Output power (P_{dc})

$$P_{dc} = V_{dc} \cdot I_{dc}$$

$$= (I_{dc} \cdot R_L)(I_{dc})$$

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

⑥ AC input power (P_{ac})

$$P_{ac} = V_{rms} \cdot I_{rms}$$

$$= [I_{rms}(R_f+R_L)] I_{rms}$$

$$\boxed{P_{ac} = I_{rms}^2 (R_f+R_L)}$$

$$= \frac{I_m^2 (R_f+R_L)}{4}$$

⑦ Efficiency: (% η): Efficiency of a rectifier is defined as the ratio of DC power delivered to the load to AC i/p power from secondary winding of transformer

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

$$= \frac{\frac{I_m^2 R_L}{\pi^2}}{\frac{I_m^2 (R_f+R_L)}{4}}$$

$$= \frac{\cancel{I_m^2} R_L}{\pi^2} \times \frac{4}{\cancel{I_m^2}(R_f+R_L)} \times 100$$

$$= \frac{4 R_L}{\pi^2 (R_f+R_L)} \times 100$$

As $R_L >> R_f$

$$\%\eta = \frac{4 \cancel{R_L}}{\pi^2 \cancel{R_L}} \times 100$$

$$\boxed{\%\eta = 40.6\%}$$

⑧ % of Regulation:

The variation of D.C o/p voltage as a function DC load current is called "Regulation".

$$\%\ \text{Regulation} = \frac{V_{no\text{-}load} - V_{full\ load}}{V_{full\ load}} \times 100$$

→ $V_{no\text{-}load}$ is the voltage across the load terminals when load current is zero i.e $I_{dc}=0$

→ $V_{full\text{-}load}$ is voltage across the load terminals when load current is maximum

$$V_{NL} = \frac{V_m}{\pi},$$

$$V_{FL} = \frac{V_m}{\pi} - I_{dc} R_f \text{(or)}$$

After simplification

$$\boxed{\%\ \text{Regulation} = \frac{R_f}{R_L} \times 100}$$

$$V_{FL} = \frac{V_m R_L}{\pi(R_L + R_f + R_s)}$$

⑨ Ripple factor :- output of Rectifier is pulsating DC i.e it contains both AC & DC components.

→ The AC component present in pulsating DC is called as "ripple".

→ The amount AC content present in pulsating DC is measured by "ripple factor".

→ ripple factor is a purity measuring factor of O/P of rectifier.

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

$$= \sqrt{\left(\frac{\cancel{I_m}}{2} \times \frac{\pi}{\cancel{I_m}}\right)^2 - 1}$$

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

$\boxed{\gamma \simeq 1.21}$ for HWR.

→ Ripple factor should be as minimum as possible.

*→ Ripple factor can be reduced by using filter circuit.

⑩ Form factor : The ratio of rms current to dc current.

$$FF = \frac{I_{rms}}{I_{dc}}$$

$$= \frac{\cancel{I_m}/2}{\cancel{I_m}/\pi} = \pi/2$$

$\boxed{FF = 1.57}$

⑪ Peak factor : ratio of max value of current to rms current

$$PF = \frac{I_m}{I_{rms}} = \frac{\cancel{I_m}}{\cancel{I_m}/2}$$

$\boxed{PF = 2}$

⑫ Transformer utilization Factor (TUF)

→ TUF indicates the amount of utilization of transformer in the circuit.

→ TUF is defined as the ratio of d.c power delivered to the load to a.c power rating of the transformer.

$$TUF = \frac{\text{D.C power delivered}}{\text{AC power rating at secondary}}$$

WKT $P_{dc} = \frac{I_m^2 R_L}{\pi^2}$

→ P_{ac} for secondary is $\frac{V_m I_m}{2\sqrt{2}} = \frac{I_m^2(R_f + R_L)}{2\sqrt{2}}$

$$TUF = \frac{I_m^{\cancel{2}} R_L}{\pi^2} \times \frac{2\sqrt{2}}{V_m \cancel{I_m}}$$

$$TUF = \frac{2\sqrt{2}\, R_L\, I_m}{V_m\, \pi^2}$$

Disadvantages of HWR:

→ Ripple factor is very high (1·21)

→ Rectification efficiency is very low (40·6%)

→ TUF is very low i.e transformer is not fully utilized.

Full Wave Rectifier :- The ripple factor of HWR can be reduced using FWR.

→ Full wave rectifier conducts during both positive & negative half cycles of i/p a.c supply.

→ For full wave rectification two diodes are used in the ckt.

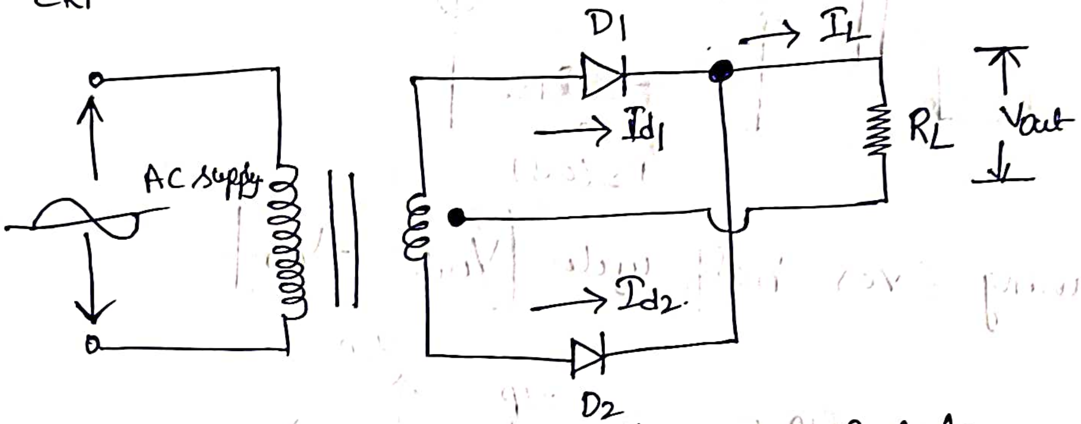
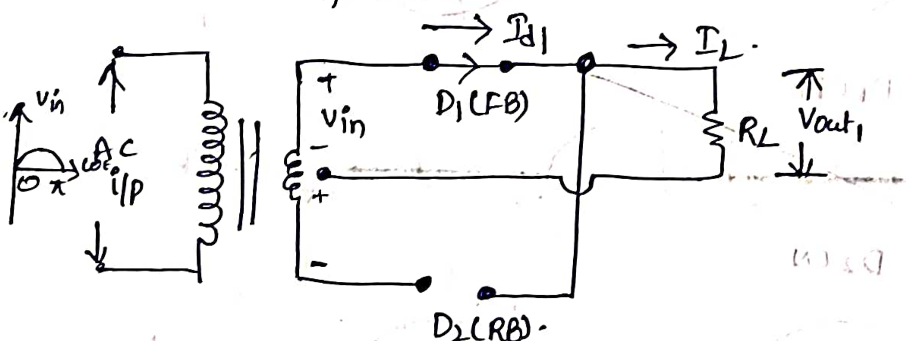


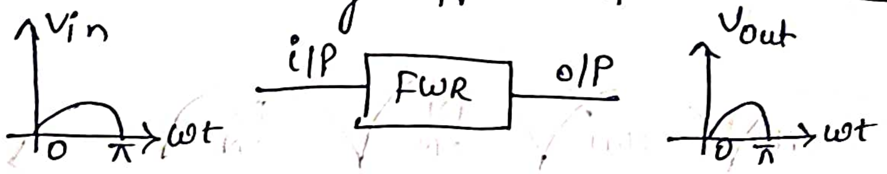
fig : full wave Rectifier.

Operation : Case (1)

→ During (+ve) half cycle of AC i/p voltage the diode D_1 will be forward biased and hence conducts. D_2 will be reverse biased so D_2 acts as open ckt and will not conduct.

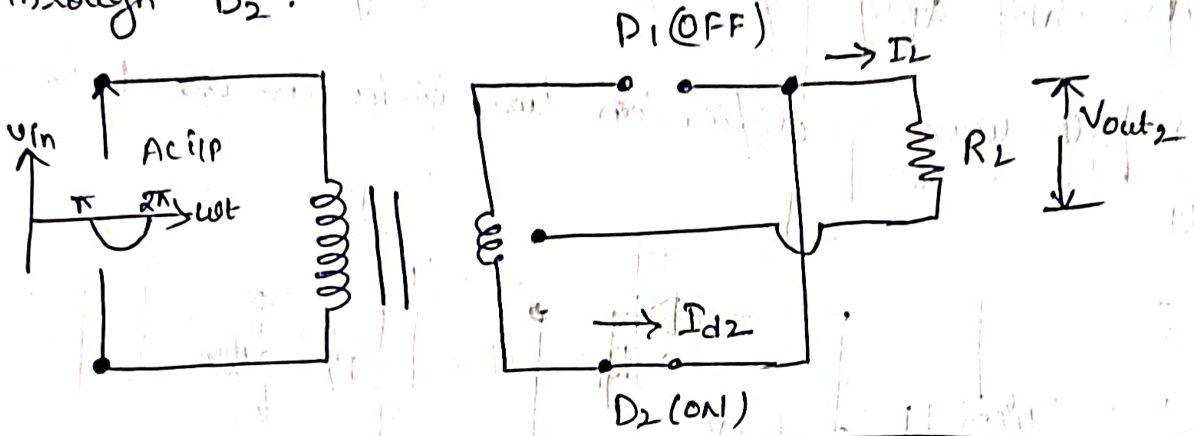


→ During (+ve) half cycle voltage across load (or) o/p voltage is same as that of applied i/p. $\boxed{V_{out_1} = V_{in}}$

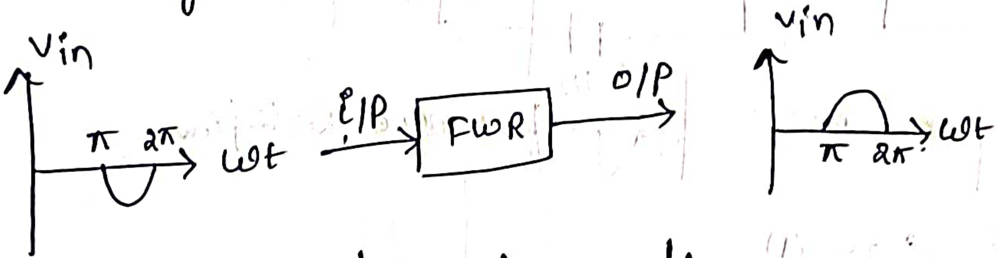


Case (2):

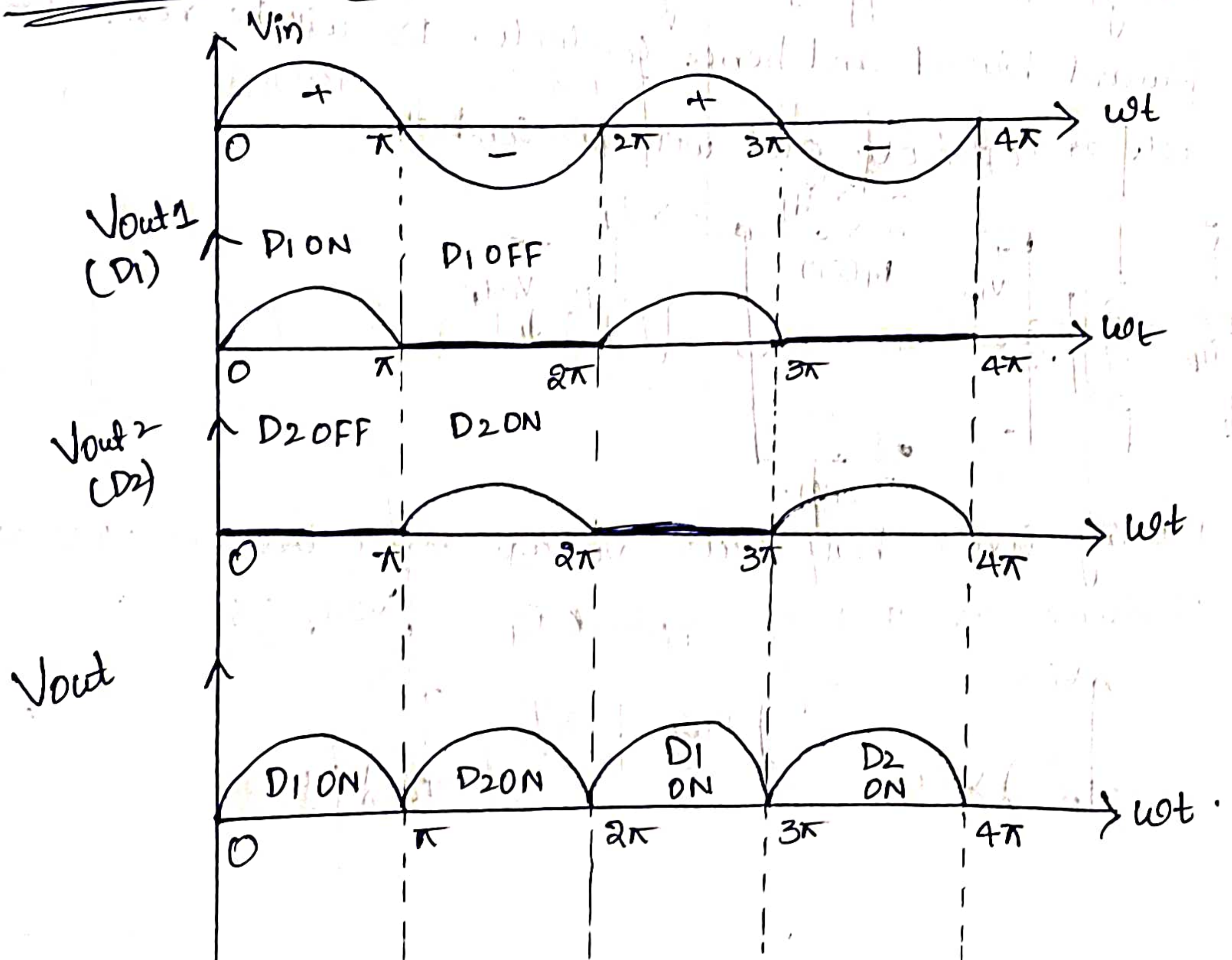
→ During (-ve) half cycle of i/p. D_1 will be reverse biased and D_2 will be forward biased. The diode current passes through D_2.



→ During (-ve) half cycle $\boxed{V_{out_2} = -V_{in}}$



Input & Output Waveforms & equations:



From wave forms

$$V_{out} = V_m \sin\omega t \quad \text{for } 0 \le \omega t \le \pi$$

$$V_{out} = -V_m \sin\omega t \quad \text{for } \pi \le \omega t \le 2\pi$$

Illy

$$I_{out} = I_m \sin\omega t \quad \text{for } 0 \le \omega t \le \pi$$

$$I_{out} = -I_m \sin\omega t \quad \text{for } \pi \le \omega t \le 2\pi.$$

Parameters:

1. DC (or) Average current (I_{dc})
2. DC (or) Average voltage (V_{dc})
3. AC (or) Rms current (I_{rms})
4. AC (or) Rms voltage (V_{rms})
5. DC out put power (P_{dc})
6. AC input power (P_{ac})
7. Efficiency (% η)
8. % of Regulation
9. Ripple factor
10. Form factor
11. Peak factor
12. Transformer utilization Factor (TUF)
13. Peak inverse voltage (PIV)

① DC (or) Average current (I_{dc})

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I_{out}\, d\omega t.$$

WKT

$$I_{out} = I_m \sin\omega t \quad \text{for } 0 \le \omega t \le \pi$$
$$= -I_m \sin\omega t \quad \text{for } \pi \le \omega t \le 2\pi$$

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} I_{out}\, d\omega t + \int_{\pi}^{2\pi} I_{out}\, d\omega t\right]$$

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

$$= \frac{I_m}{2\pi}\left[(-\cos\omega t)_0^{\pi} - (-\cos\omega t)_{\pi}^{2\pi}\right]$$

$$= \frac{I_m}{2\pi}\left[-\cos\pi + \cos 0 - [-\cos 2\pi + \cos\pi]\right]$$

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

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

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

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

$\cos\pi = -1$

$\cos 2\pi = 1$

$\cos 0 = 1$

$\cos n\pi = +1$ (or) -1 depends on 'n'

② DC (or) Avg voltage (V_{dc})

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_{out}\, d\omega t.$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_{out}\, d\omega t + \int_{\pi}^{2\pi} V_{out}\, d\omega t\right]$$

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

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

$$= \frac{V_m}{2\pi}\left[-\cos\pi + \cos 0 - [-\cos 2\pi + \cos\pi]\right]$$

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

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

$$= \frac{\cancel{4}^{2} V_m}{\cancel{2}\pi}$$

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

③ Rms (or) AC current (I_{rms}):-

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I_{out})^2 \, d\omega t}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_{out}^2 \, d\omega t + \int_{\pi}^{2\pi} I_{out}^2 \, d\omega t\right]}$$

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

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

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\int_0^{\pi} d\omega t - \int_0^{\pi} \cos 2\omega t \, d\omega t + \int_{\pi}^{2\pi} d\omega t - \int_{\pi}^{2\pi} \cos 2\omega t \, d\omega t\right]}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[(\omega t)_0^{\pi} - \left(+\frac{\sin 2\omega t}{2}\right)_0^{\pi} + (\omega t)_{\pi}^{2\pi} - \left(+\frac{\sin 2\omega t}{2}\right)_{\pi}^{2\pi}\right]}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\pi - 0 - \frac{1}{2}[+\sin 2\pi - \sin 0] + 2\pi - \pi - \frac{1}{2}[+\sin 4\pi - \sin 2\pi]\right]}$$

$$[\because \sin\pi = \sin n\pi = \sin 0 = 0]$$

$$\left[\ldots - \frac{1}{2}[\overset{0}{\cancel{0+0}}] + \pi - \frac{1}{2}[\overset{0}{\cancel{0+0}}]\right]$$

④ Rms (or) AC voltage (V_{rms})

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (V_{out})^2 \, d\omega t}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} V_{out}^2 \, d\omega t + \int_{\pi}^{2\pi} V_{out}^2 \, d\omega t\right]}$$

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

$$= \sqrt{\frac{V_m^2}{2\pi}\left[\int_0^{\pi} \frac{1-\cos 2\omega t}{2} \, d\omega t + \int_{\pi}^{2\pi} \frac{1-\cos 2\omega t}{2} \, d\omega t\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\int_0^{\pi} d\omega t - \int_0^{\pi} \cos 2\omega t \, d\omega t + \int_{\pi}^{2\pi} d\omega t - \int_{\pi}^{2\pi} \cos 2\omega t \, d\omega t\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[(\omega t)_0^{\pi} - \left(-\frac{\sin 2\omega t}{2}\right)_0^{\pi} + (\omega t)_{\pi}^{2\pi} - \left(-\frac{\sin 2\omega t}{2}\right)_{\pi}^{2\pi}\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\pi - 0 - \frac{1}{2}\cancel{\left[\sin 2\pi - \sin 0\right]}^{0} + 2\pi - \pi - \frac{1}{2}\cancel{\left[\sin 4\pi - \sin 0\right]}^{0}\right]}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\pi + \pi\right]} = \sqrt{\frac{\cancel{2} V_m^2 \cancel{\pi}}{\cancel{4}_2 \cancel{\pi}}} = \frac{V_m}{\sqrt{2}}$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

⑤ Dc output power (P_{dc}):

$$P_{dc} = V_{dc} \cdot I_{dc}$$

$$= (I_{dc} \times R_L) I_{dc}$$

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

$$= \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$\boxed{P_{dc} = \frac{4I_m^2}{\pi^2} R_L}$$

⑥ Ac input power (P_{ac}):

$$P_{ac} = V_{ac} \cdot I_{ac} \text{ (or) } V_{rms} \cdot I_{rms}$$

$$= I_{rms} (R_f + R_L) \cdot I_{rms}$$

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

$$= \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_L)$$

$$\boxed{P_{ac} = \frac{I_m^2 (R_f + R_L)}{2}}$$

⑦ Efficiency (% η)

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

$$= \frac{4\cancel{I_m^2}}{\pi^2} R_L \times \frac{2}{\cancel{I_m^2}(R_f+R_L)} \times 100$$

$$= \frac{8}{\pi^2} \frac{R_L}{R_L + R_f} \times 100$$

as $R_L >> R_f$

$$= \frac{8}{\pi^2} \times \frac{\cancel{R_L}}{\cancel{R_L}} \times 100$$

$$\%\eta = \frac{8}{\pi^2} \times 100$$

$$\boxed{\%\eta \simeq 81.2\%}$$

⑧ % of Regulation

→ variation of DC o/p ~~power~~ voltage as a function of load current is called "Regulation".

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

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

$$V_{FL} \simeq \frac{2V_m}{\pi} \left[\frac{R_L}{R_L + R_f + R_s}\right] \times 100$$

$$= \frac{\frac{2V_m}{\pi} - \frac{2V_m}{\pi}\left[\frac{R_L}{R_L+R_f+R_s}\right]}{\frac{2V_m}{\pi}\left[\frac{R_L}{R_L+R_f+R_s}\right]} \times 100$$

$$= \frac{\cancel{R_L} + R_f + R_s - \cancel{R_L}}{\cancel{R_L+R_f+R_s}} \times \frac{\cancel{R_L+R_f+R_s}}{R_L} \times 100$$

$$= \frac{R_f + R_s}{R_L} \times 100$$

as $R_f >> R_s$

$$\boxed{\%\ \text{Reg} = \frac{R_f}{R_L} \times 100}$$

⑨ Ripple factor.

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

$$= \sqrt{\left(\frac{\cancel{I_m}}{\sqrt{2}} \times \frac{\pi}{2\cancel{I_m}}\right)^2 - 1}$$

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

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

$$\boxed{\gamma = 0.482}$$

→ γ is reduced for FWR than HWR.

⑩ Form factor:

$$FF = \frac{I_{rms}}{I_{DC}}$$

$$= \frac{\cancel{I_m}}{\sqrt{2}} \times \frac{\pi}{2\cancel{I_m}}$$

$$= \frac{\pi}{2\sqrt{2}}$$

$$\boxed{FF = 1.11}$$

⑪ peak factor

$$PF = \frac{\cancel{I_m}}{\cancel{I_{dc}}}$$

$$= \cancel{I_m} \times \frac{\pi}{2\cancel{I_m}}$$

$$=$$

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

$$= \cancel{I_m} \times \frac{\sqrt{2}}{\cancel{I_m}}$$

$$\boxed{PF = 1.41}$$

⑫ TUF:

→ Because of usage of center tapped transformer TUF for FWR is calculated for primary and secondary coils seperately and then average of TUF is determined.

$$\text{Secondary TUF} = \frac{P_{dc}}{P_{ac}}$$

WKT $P_{dc} = 4I_m^2 R_L/\pi^2$, $P_{ac} = \frac{I_m^2(R_f + R_L)}{2}$

$$= \frac{4\cancel{I_m^2} R_L}{\pi^2} \times \frac{2}{\cancel{I_m^2}(R_f + R_L)}$$

$$= \frac{8}{\pi^2} \frac{R_L}{R_L + R_f}$$

As $R_L >> R_f$

$$TUF(\text{secondary}) = \frac{8}{\pi^2} = 0.812$$

TUF (for primary)

$= 2 \times$ TUF of HWR

$= 2 \times 0.287$

$= 0.574$

$$\text{TUF(FWR)} = \frac{\text{TUF(secondary)} + \text{TUF (primary)}}{2}$$

$$= \frac{0.812 + 0.574}{2}$$

$$\boxed{\text{TUF} = 0.693}$$

$\therefore$ 69.3% transformer is utilized by FWR.

(13) PIV: Voltage drop across diode when diode is reverse biased is "PIV".

for FWR $\boxed{PIV = 2V_m}$

Advantages

→ Ripple factor is low

→ Efficiency is high

→ TUF is high.

Disadvantages

→ It requires 2 diodes

→ Centre tap transformer is used whose cost is high.

→ More circuit complexity.

→ high PIV rating.

→ high PIV diodes are larger in size & too much costlier

Bridge Rectifier :- A full wave rectifier with 4 diodes, Which are arranged in the form of an electrical bridge is known as "Bridge Rectifier".

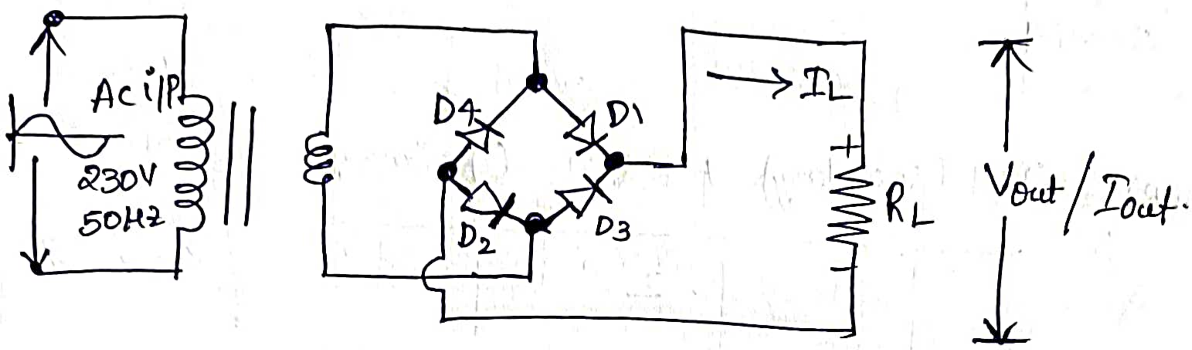


fig: Bridge rectifier.

→ Required AC i/p is given across one diagonal of bridge & rectified O/P is taken across another diagonal of bridge.

→ Bridge rectifier doesn't make use of centre tap transformer.

→ Operation:

Case(1):→ During (+ve) half cycle of AC i/p signal, diodes D_1 & D_2 will be forward biased and D_3 & D_4 will be reverse biased.

→ Diodes D_1 & D_2 allow the current to flow through R_L.

Case(2):→ During (-ve) half cycle of AC i/p signal, diodes D_1 & D_2 will be reverse biased and D_3 & D_4 will be forward biased.

→ Diodes D_3 & D_4 will allow the current to flow through R_L.

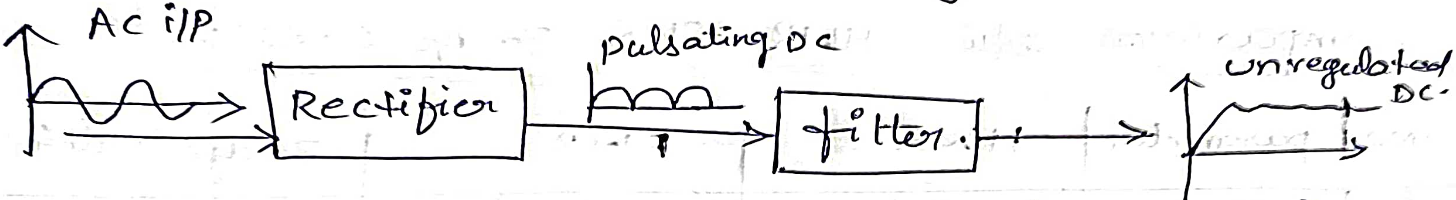
→ As bridge rectifier produces o/p for both (+ve) & (-ve) half cycles, it's input & o/p waveforms and the parameters are same as that of FWR. (Except TUF & PIV).

Comparision b/w HWR, FWR, Bridge Rectifier

S.NO	parameter	HWR	FWR	Bridge rectifier
1	I_{dc}	I_m/π	$2I_m/\pi$	$2I_m/\pi$
2	V_{dc}	V_m/π	$2V_m/\pi$	$2V_m/\pi$
3	I_{ac}/rms	$I_m/2$	$I_m/\sqrt{2}$	$I_m/\sqrt{2}$
4	V_{ac}/rms	$V_m/2$	$V_m/\sqrt{2}$	$V_m/\sqrt{2}$
5	P_{dc}	$I_m^2 R_L/\pi^2$	$4I_m^2 R_L/\pi^2$	$4I_m^2 R_L/\pi^2$
6	P_{ac}	$\frac{I_m^2(R_L+R_f)}{4}$	$\frac{I_m^2(R_L+R_f)}{2}$	* $\frac{I_m^2(R_L+2R_f)}{2}$ **
7	% η	40.6%	81.2%	81.2%
8	% Regulation	$R_f/R_L \times 100$	$R_f/R_L \times 100$	$R_f/R_L \times 100$
9	ripple factor	1.21	0.482	0.482
10	Form factor	1.57	2.21	2.21
11	Peak factor	2	1.41	1.41
12	TUF	28.7%	69.3%	81.2 **
13	PIV	V_m	$2V_m$	V_m **

Filters: output of a rectifier is pulsating DC i.e it Contains ripples (AC Component).

"filter is a ckt (or) device which reduces the ripple content and produces the unregulated DC o/p."



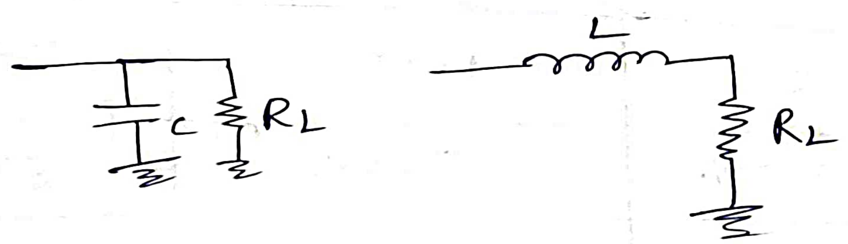
→ Capacitor & inductor and Combination of C&L can act as "filter"

→ Capacitor allows AC component and blocks DC component i.e it acts as closed ckt for AC & open ckt for DC.

→ Hence capacitor should always be connected in parallel to R_L.

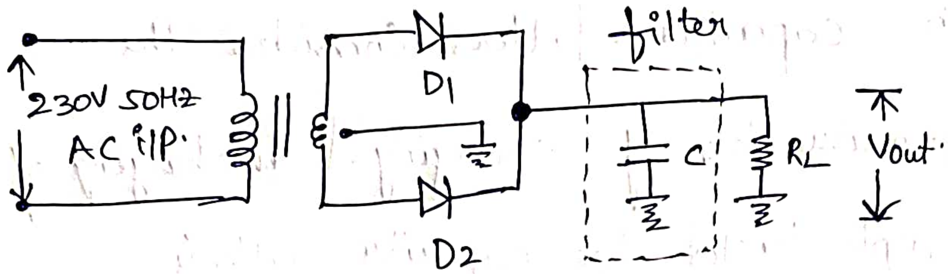
→ Inductor allows DC component and blocks AC Component i.e it acts as closed ckt for DC & open ckt for AC.

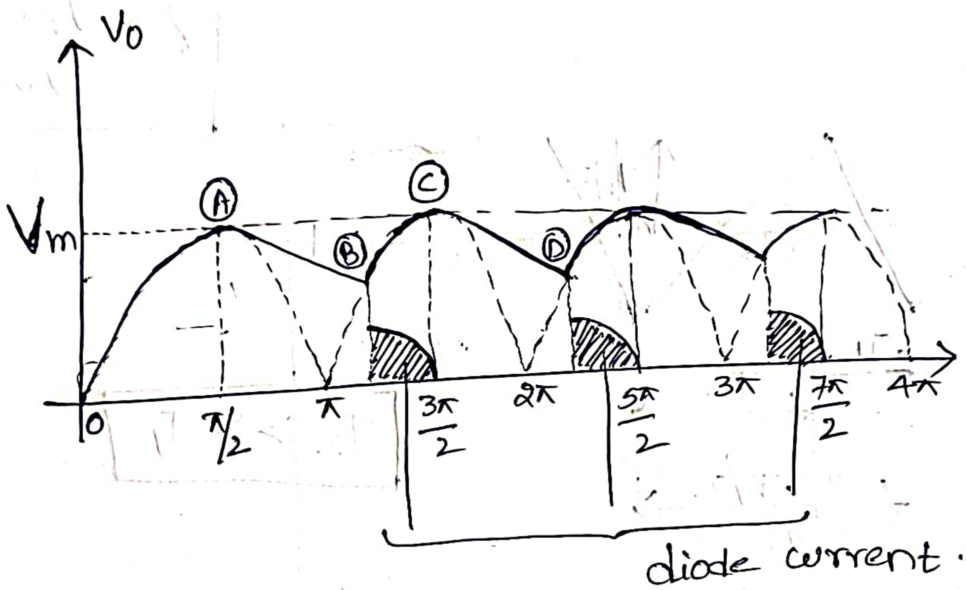
→ Hence ~~cap~~ inductor should be Connected in series to R_L.



→ Inductor filter is also called as "choke" filter.

Full Wave Rectifier with Capacitor filter :-





→ Immediately when power is turned on capacitor ~~starts~~ gets charged through D_1 to a value V_m during the 1st quarter cycle of rectified o/p voltage.

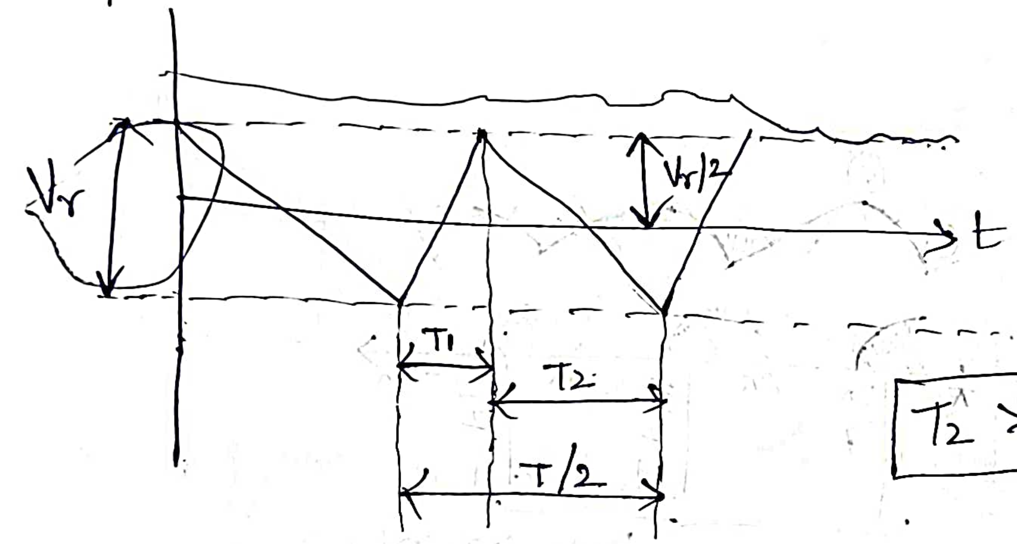
→ When capacitor is charged till V_m then D_1 will be reverse biased and capacitor gets discharged to a point (B) during the next quarter cycle of rectified o/p voltage.

→ At point (B) diode D_2 will be forward biased, hence capacitor gets charged to a point (C), during its charging time from (B) to (C), capacitor supplied diode current.

→ At point (C) diode D_2 will be reverse biased and capacitor starts discharging to point (D), and the process continues.

Derivation for ripple factor: To derive ripple factor for FWR with capacitor filter, Consider the triangular approximation of charging & discharging of Capacitor. Ripple factor for capacitor filter is

$$\boxed{\gamma = \frac{V_{rms}}{V_{DC}}}$$



$$\boxed{T_2 >> T_1}$$

$T/2 \rightarrow$ half of the time period of a.c i/p voltage.

$T_1 \rightarrow$ Time period for which diode is conducting

$T_2 \rightarrow$ Time for which diode is non conducting

$V_r \rightarrow$ peak to peak value of ripple voltage

$\rightarrow$ Charging time of capacitor

$\rightarrow$ Discharging time of capacitor.

V_{rms} for triangular wave is given by

$$V_{rms} = \frac{V_r}{2\sqrt{3}} \rightarrow (1)$$

During T_2, charge lost by capacitor (discharging amount) is

$$Q = CV_r \rightarrow (2)$$

9

But WKT.

$$i = \frac{dQ}{dt} \rightarrow (3)$$

Apply integration to (3) w.r.t 't' for (0 to T_2)

$$\int_0^{T_2} i\,dt = \int_0^{T_2} \frac{d(Q)}{dt}\,dt$$

$$\int_0^{T_2} i\,dt = Q$$

not required.

As integration gives dc value

$$I_{DC} T_2 = Q \rightarrow (4)$$

Compare (2) & (4)

$$C V_r = I_{DC} T_2$$

$$V_r = \frac{I_{DC} T_2}{C} \rightarrow (5)$$

from graph

$$T_1 + T_2 = T/2$$

as $T_2 >> T_1$

$$T_2 \approx T/2$$

Sub T_2 in (5)

$$V_r = \frac{I_{DC} T}{2C}$$

WKT $T = \frac{1}{f}$

$$V_r = \frac{I_{DC}}{2fC} \rightarrow (6)$$

Sub (6) in (1)

$$V_{rms} = \frac{I_{DC}}{4\sqrt{3} fC}$$

WKT $I_{DC} = \frac{V_{DC}}{R_L}$

$$V_{rms} = \frac{V_{DC}}{4\sqrt{3} fCR_L} \rightarrow (7)$$

ripple factor

$$\gamma = \frac{V_{rms}}{V_{DC}}$$

$$\gamma = \frac{\cancel{V_{DC}}}{4\sqrt{3} fCR_L \times \cancel{V_{DC}}}$$

$$\boxed{\gamma = \frac{1}{4\sqrt{3} fCR_L}}$$

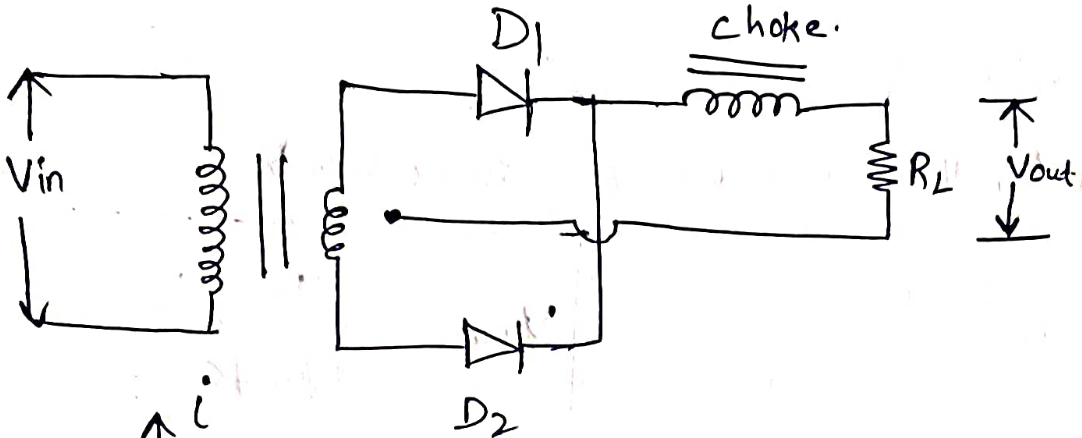
Ripple factor for Full wave Rectifier with Capacitor filter

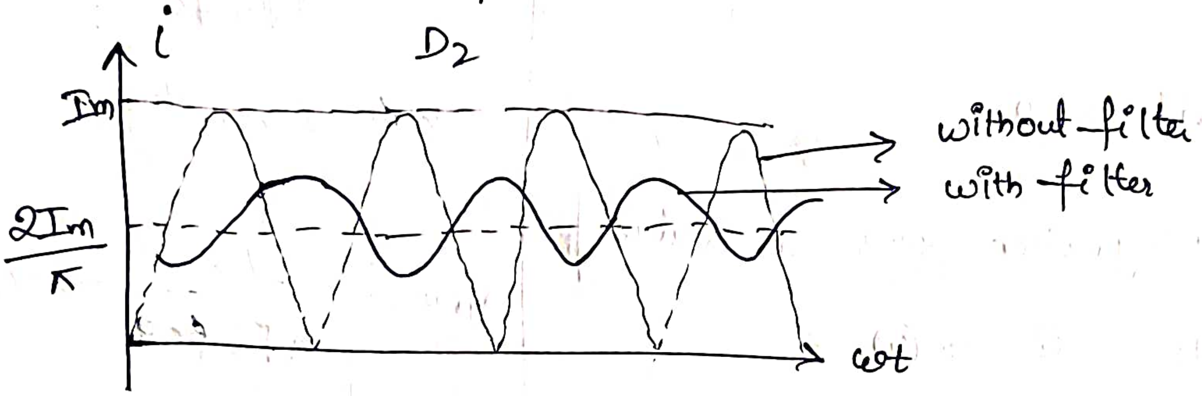
* Ripple factor for HWR with capacitor filter is

$$\boxed{\gamma = \frac{1}{2\sqrt{3} fCR_L}}$$

→ product CR_L is time constant of filter ckt.

Full wave Rectifier with inductor filter (or) choke filter:





→ out of FWR is pulsating DC, and is input to the filter (or) choke.

→ pulsating DC has both AC & DC Components.

→ Inductor acts as ON circut for DC Component and blocks AC Component.

→ Inductor/choke must be connected in series to R_L

Expression for ripple factor: Let 'γ' for choke filter

is $$\gamma = \frac{I_{rms}}{I_{dc}} \rightarrow (1)$$

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

$$I_{dc} = \frac{2I_m}{\pi} \rightarrow (3)$$

To derive I_m

Load current through FWR is given by

$$I_L = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi}\cos 2\omega t$$

wher I_m for FWR with choke is given by

$$I_m = \frac{V_m}{R_L + R_f + R_s + R_{choke}}$$

if $R_f = R_s = R_{choke} = 0$ then

$$I_m = \frac{V_m}{R_L}$$, sub I_m in ③

$$I_{dc} = \frac{2V_m}{\pi R_L} \rightarrow ④$$

* if ripple (or) AC component is presented by 2nd harmonic (2ω)

then

i) $$I_m = \frac{V_m}{\sqrt{R_L^2 + 4\omega^2 L^2}} \rightarrow ⑤$$

ii) $$I_{rms} = \frac{4 I_m}{3\sqrt{2}\pi} \rightarrow ⑥$$

Sub ⑤ in ⑥

$$I_{rms} = \frac{4}{3\sqrt{2}\pi} \cdot \frac{V_m}{\sqrt{R_L^2 + 4\omega^2 L^2}} \rightarrow ⑦$$

Sub ④ & ⑦ in ①

$$\gamma = \frac{\cancel{4}^{2}}{3\sqrt{2}\cancel{\pi}} \cdot \frac{\cancel{V_m}}{\sqrt{R_L^2 + 4\omega^2 L^2}} \cdot \frac{\cancel{\pi} R_L}{\cancel{2}\cancel{V_m}}$$

$$\gamma = \frac{2\cancel{4}}{3\sqrt{2}} \cdot \frac{R_L}{\sqrt{R_L^2\left[1 + \frac{4\omega^2 L^2}{R_L^2}\right]}}$$

$$= \frac{2\cancel{4}}{3\sqrt{2}} \cdot \frac{\cancel{R_L}}{\cancel{R_L}\cdot\sqrt{1 + \frac{4\omega^2 L^2}{R_L^2}}}$$

$$\gamma = \frac{2}{3\sqrt{2}} \cdot \frac{1}{\sqrt{1 + \frac{4\omega^2 L^2}{R_L^2}}}$$

Case (1):

if $\frac{4\omega^2 L^2}{R_L^2} << 1$ then

$$\gamma = \frac{2}{3\sqrt{2}} \cdot \frac{1}{\sqrt{1}}$$

$$\boxed{\gamma \simeq 0.472}$$ close to FWR without filter.

Case (2): if $\frac{4\omega^2 L^2}{R_L^2} >> 1$ then

$$\gamma = \frac{2}{3\sqrt{2}} \cdot \frac{1}{\sqrt{\frac{4\omega^2 L^2}{R_L^2}}}$$

$$= \frac{\cancel{2}}{3\sqrt{2}} \cdot \frac{1}{\frac{\cancel{2}\omega L}{R_L}}$$

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

Clipping Circuits: (or) Clippers:

→ Clipper is a non linear waveshaping circuit.

→ Clipper is a device/circuit used to remove certain portion of waveform near the (+ve) (or) (-ve) (or) at both (+ve) & (-ve) peaks.

→ Clippers are also called as: limiters (or) slicers (or) amplitude selectors.

→ Clippers are classified into 2 types.

1. shunt clippers
2. Series clippers.

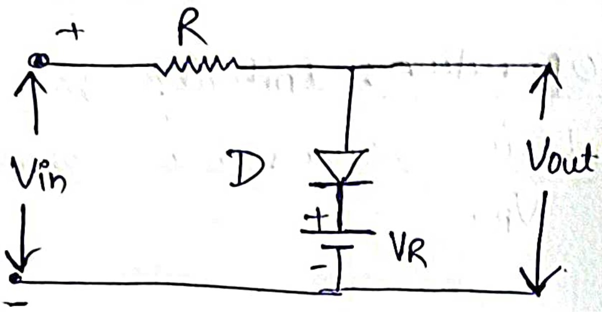
Shunt clippers: if the position of diode is in parallel with the output 'Vout' then it is said to be shunt clipper.

→ There are of 2 types

1) Shunt positive clipper with positive bias (or) with clipping above reference voltage 'V_R'

2) Shunt negative clipper with positive bias (or) with clipping below reference voltage 'V_R'.

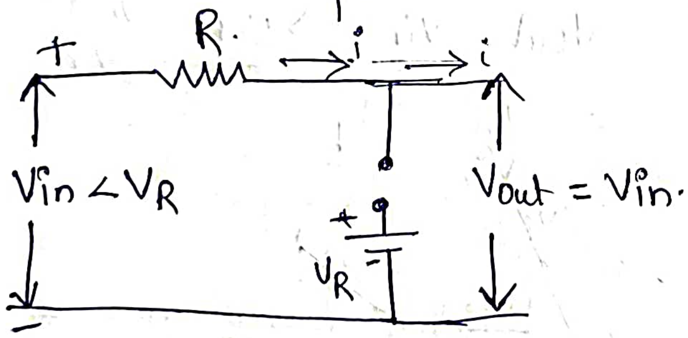
(1) Shunt positive clipper with bias (or) with clippling above reference voltage V_R



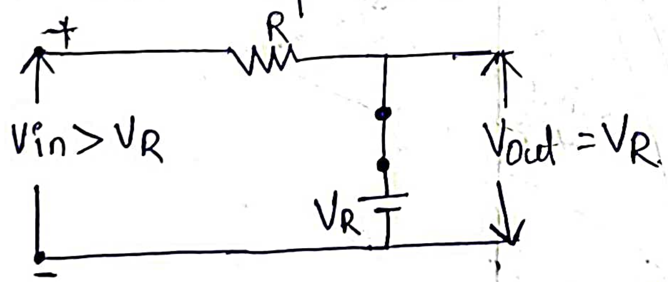
$V_{in} \rightarrow$ input volt
$V_{out} \rightarrow$ Reference v
$V_R \rightarrow$ Reference v battery vo

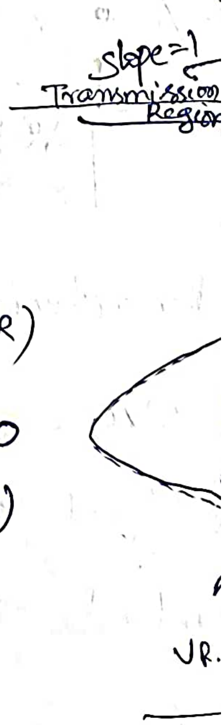
Operation: Initially diode D is Reverse biased

Case(1): for $V_{in} < V_R$, diode remains reverse b it can be replaced with OFF(or) OPEN switch. Vout said to be the transmi



Case(2): for $V_{in} > V_R$, diode will be forward biase it can be replaced with ON (or) Closed switch. Vou said to be clipping region



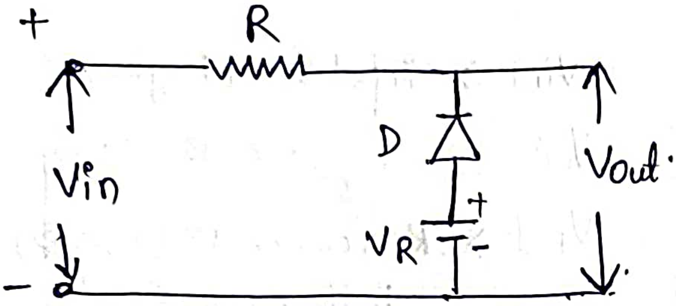


Transfer characteristic equations

1) $V_{out} = V_{in} \Rightarrow$ slope $= \frac{V_{out}}{V_{in}} = 1$ (for $V_{in} < V_R$)

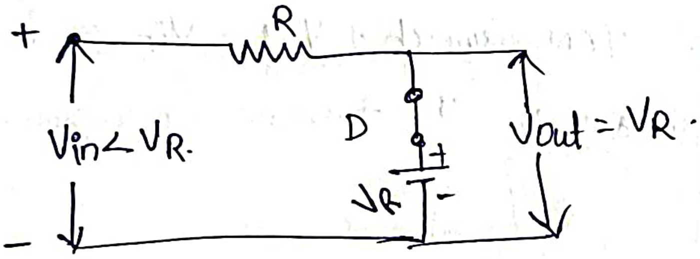
2) $V_{out} = V_R \Rightarrow$ as V_R is constant, slope $= 0$ (for $V_{in} > V_R$)

2) shunt negative clipper with bias (or) with clipping below Reference voltage V_R



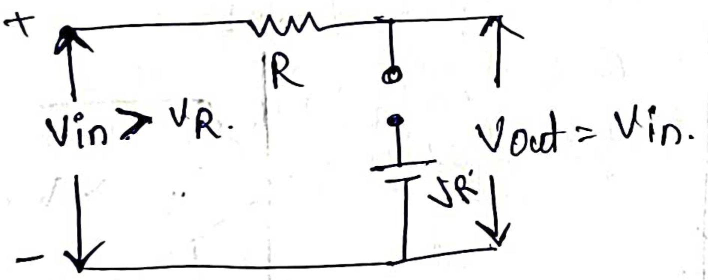
<u>operation</u>: Initially diode D is forward biased w.r.t V_R.

<u>Case(1)</u>: for $V_{in} < V_R$, diode remains forward biased. Hence it is replaced with 'ON' switch. $V_{out} = V_R$ - clipping Region



<u>Case (2)</u>: for $V_{in} > V_R$, diode will be reverse biased. Hence replaced with 'OFF' switch.

$V_{out} = V_{in}$. Transmission Region.



<u>Transfer characteristics</u>

(1) for $V_{in} < V_R$,

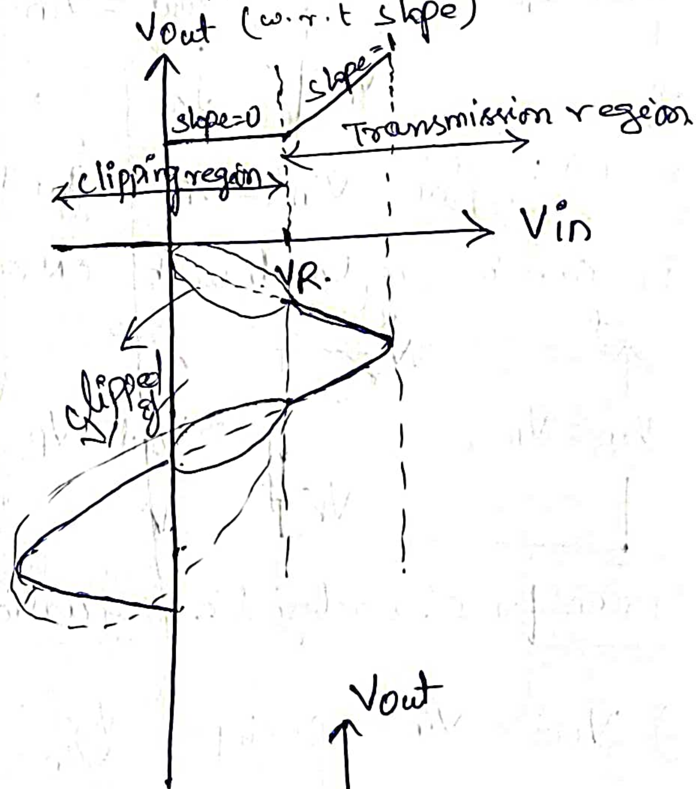
$V_{out} = V_R \Rightarrow$ slope $= \frac{V_{out}}{V_{in}} = \frac{V_R}{V_{in}}$

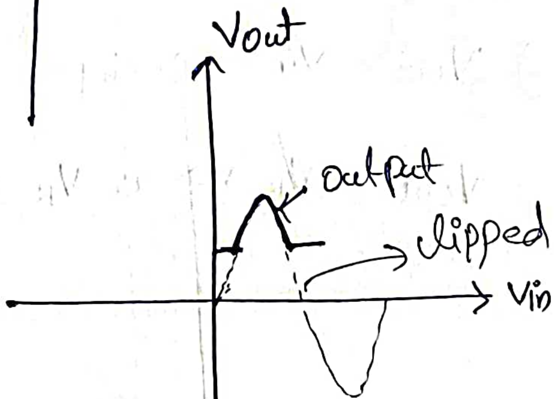
∴ as V_R is constant, slope = 0.

(2) for $V_{in} > V_R$,

$V_{out} = V_{in} \Rightarrow$ <u>slope</u> $= \frac{V_{out}}{V_{in}}$

$= \frac{V_{in}}{V_{in}} = 1$.





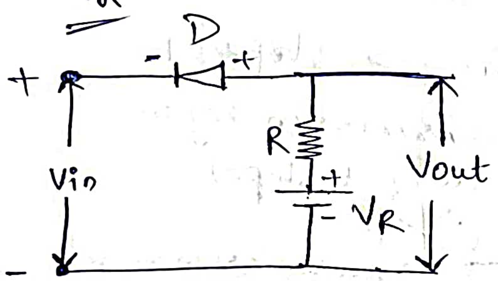
Series clippers: If diode is connected in series with input voltage V_{in} then it is said to be a series clipper.

Series clippers are analyzed in two cases.

(1) Series positive clipping with bias (or) with clipping above reference voltage 'V_R'.

(2) Series negative clippling with bias (or) with clipping below reference voltage 'V_R'.

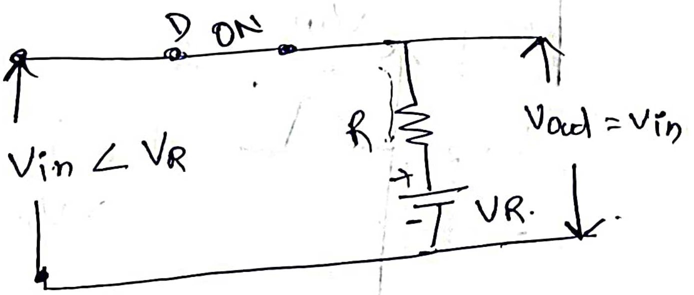
① **Clipping above Reference voltage 'V_R'**



Operation: Initially diode is forward biased w.r.t 'V_R'.

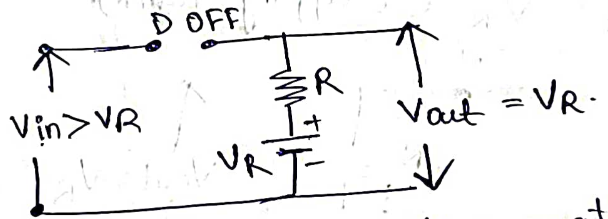
Case(1): for $V_{in} < V_R$, diode remains forward biased, Hence it is replaced with ON switch. (Transmission Region)

$V_{out} = V_{in}$



Case(2): for $V_{in} > V_R$, diode is reverse biased. Hence It is replaced with OFF switch.

$V_{out} = V_R$ (clipping Region).



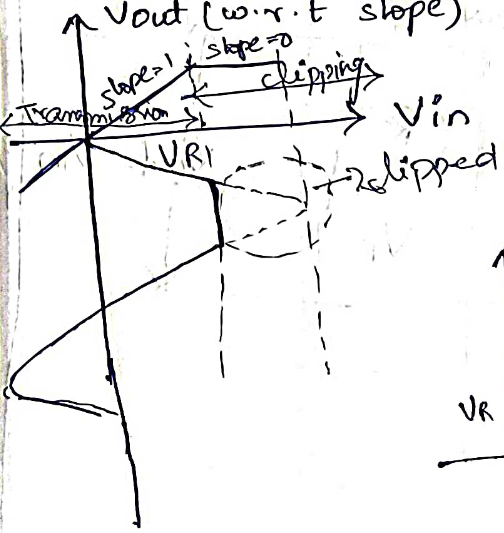
Transfer characteristic equations

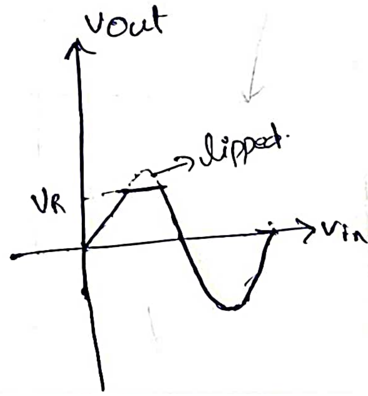
Case(1): for $V_{in} < V_R$.

$V_{out} = V_{in} \Rightarrow$ slope $= 1$ (Transmission)

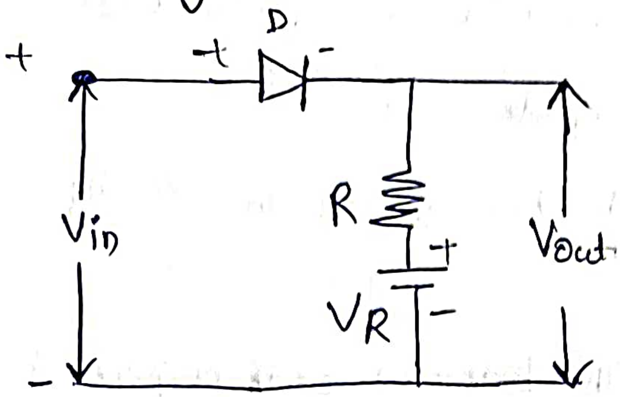
Case(2): for $V_{in} > V_R$

$V_{out} = V_R \Rightarrow$ slope $= 0$ (clipping)





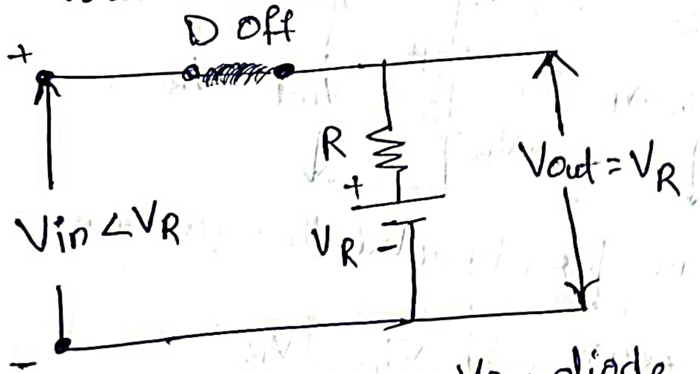
② Clipping below Reference voltage 'V_R'.



Operation: Initially diode is reverse biased w.r.t V_R.

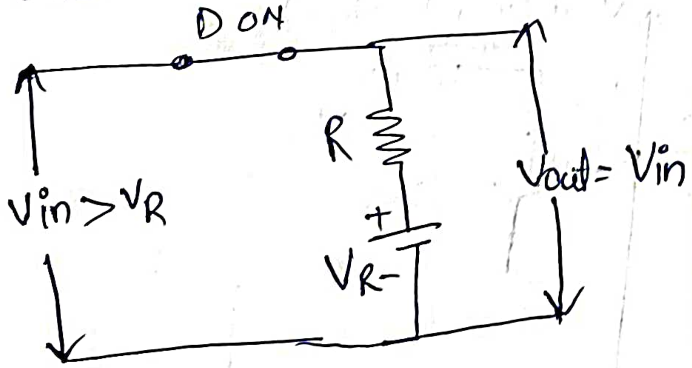
Case (1): for $V_{in} < V_R$, diode remains reverse biased. Hence it is replaced with OFF switch.

$V_{out} = V_R$ (clipping Region).



Case (2): for $V_{in} > V_R$, diode will be forward biased. Hence it is replaced with ON switch.

$V_{out} = V_{in}$ (transmission)



Transfer characteristics:-

① Case (1): for $V_{in} < V_R$

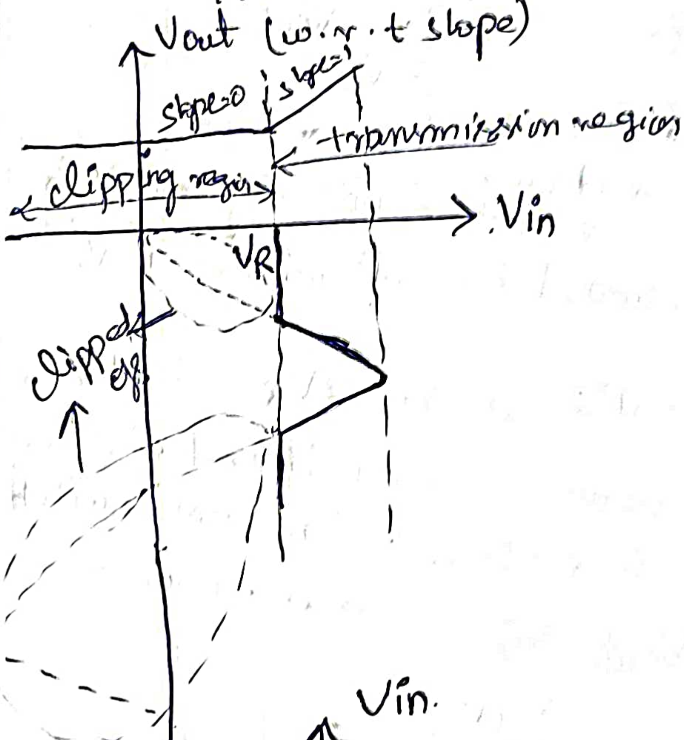
$V_{out} = V_R \Rightarrow$ slope = 0

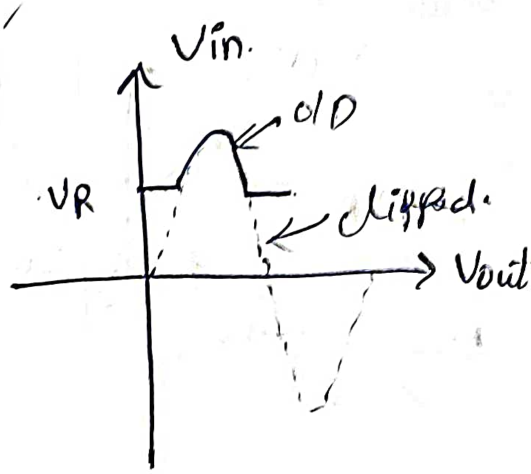
Clipping Region.

case (2): for $V_{in} > V_R$

$V_{out} = V_{in} \Rightarrow$ slope = 1

transmission Region.



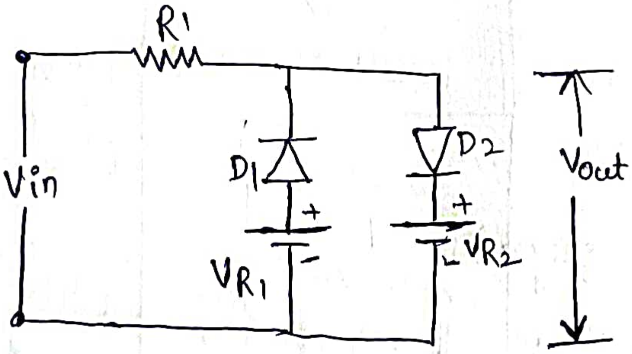


(A) Clipping at two independent Levels :- (or)

Dual / Combinational clipper :-

Diode clippers can be used in pairs to achieve clipping at two independent levels.

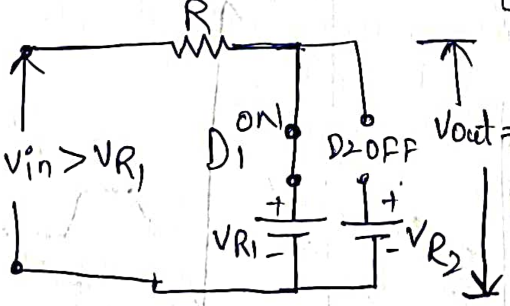
Case(1): Let diode D_1 is forward biased w.r.t 'V_{R_1}' & D_2 is reverse " " 'V_{R_2}' and both are in parallel to V_{out}.



Operation

Case(1): for $V_{in} < V_{R_1}$:

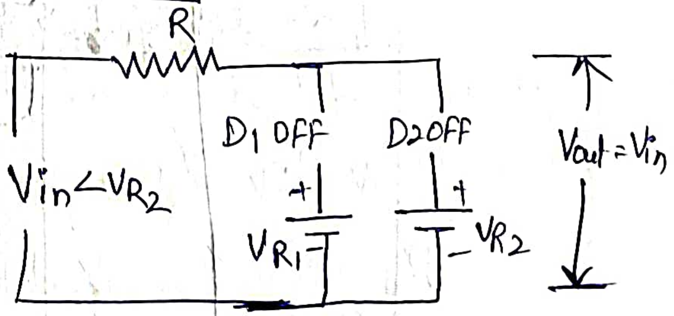
D_1 is forward biased and is replaced with 'ON' switch, D_2 is reverse biased and is replaced with 'OFF' switch. $\boxed{V_{out} = V_{R_1}}$ (Clipping Region)



Case(2): $V_{R_1} < V_{in} < V_{R_2}$ i.e

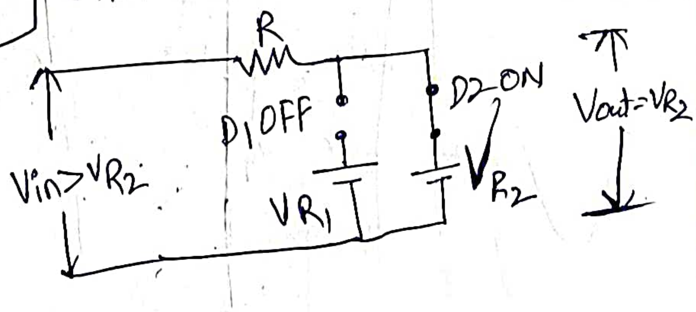
$V_{in} > V_{R_1}$ & $V_{in} < V_{R_2}$. In this case D_1 is reverse biased and is replaced with OFF switch. and D_2 remains reverse biased and is replaced with OFF Switch.

$\boxed{V_{out} = V_{in}}$ (transmission region).



Case(3): $V_{in} > V_{R_2}$.

D_2 is forward biased i.e ON switch and D_1 is reverse biased i.e OFF switch. $\boxed{V_{out} = V_{R_2}}$



Transfer characteristic equations

① for $V_{in} < V_{R1}$

$V_{out} = V_{R1} \Rightarrow$ slope $= 0$

clipping Region.

② for $V_{R1} \leq V$

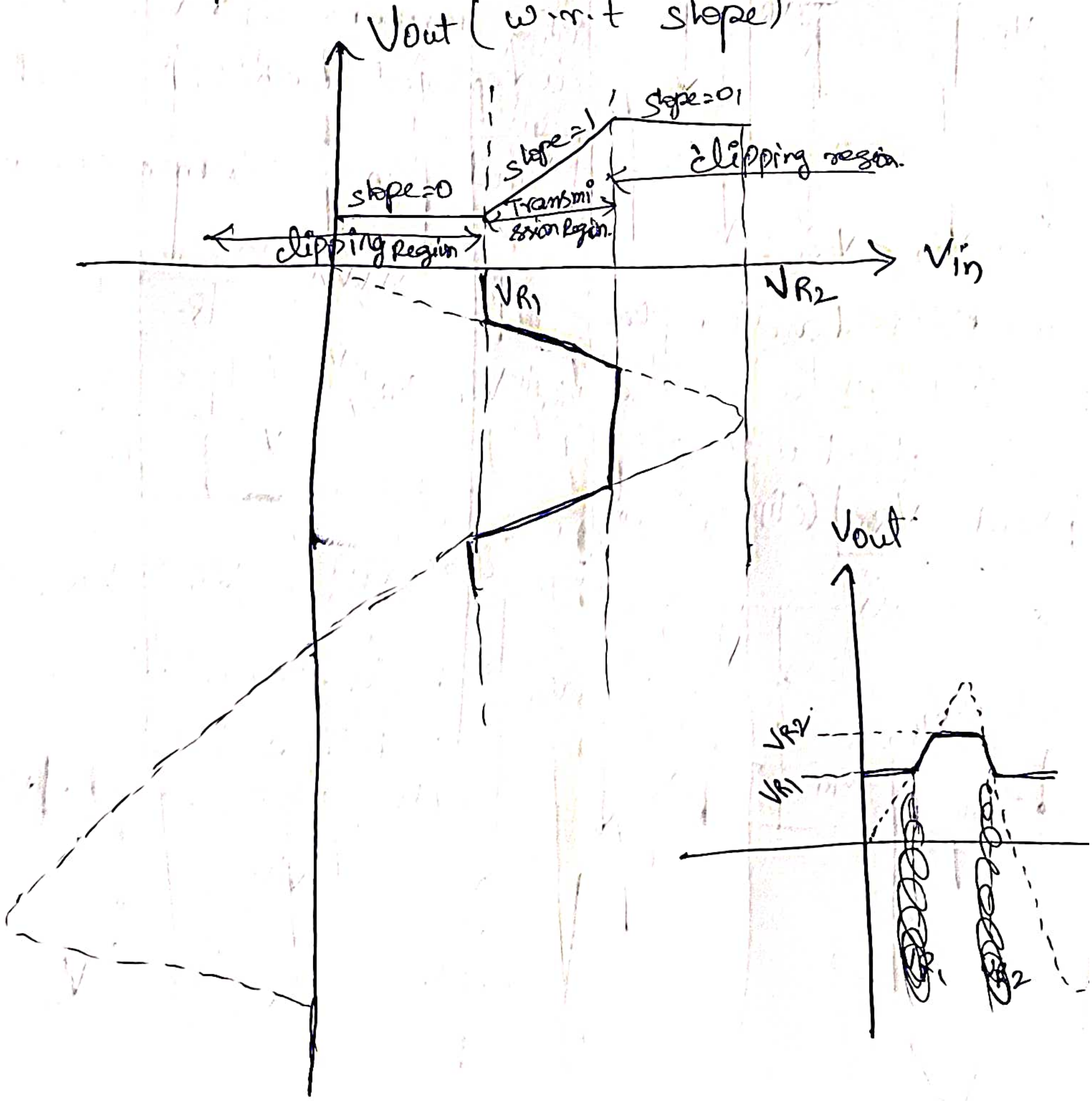
$V_{out} = V_{in} \Rightarrow$

Transmission

③ for $V_{in} > V_{R2}$

$V_{out} = V_{R2} \Rightarrow$ slope $= 0$

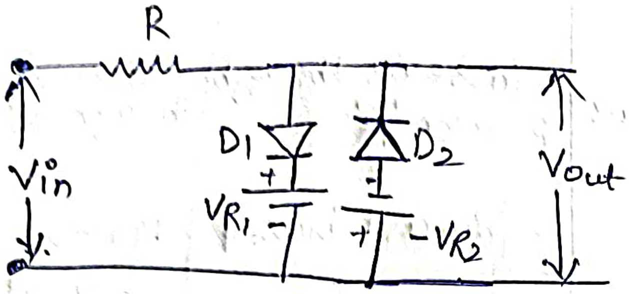
clipping Region.



Case(4): If i/p signal is to be clipped symmetrically at both (+ve) & (-ve) peaks, then V_{R_1} & V_{R_2} should be

$\boxed{V_{R_1} = -V_{R_2}}$ i.e both

D_1 & D_2 are reverse biased.



Operation: Initially both D_1 & D_2 are reverse biased.

case(1): for $V_{in} < -V_{R_2}$,

D1 Reverse biased, D2 forward biased

$V_{out} = -V_{R_2}$.

case(2): $-V_{R_2} < V_{in} < V_{R_1}$, i.e

$V_{in} > -V_{R_2}$ — D_2 Reversebiased

$V_{in} < V_{R_1}$ — D_1 Reversebiased

$\therefore V_{out} = V_{in}$.

case(3): for $V_{in} > V_{R_1}$,

D_1 — forward biased

D_2 — Reverse biased

$V_{out} = V_{R_1}$.

Transfer characteristics :

case (1): for $V_{in} < -V_{R_2}$

$V_{out} = -V_{R_2}$

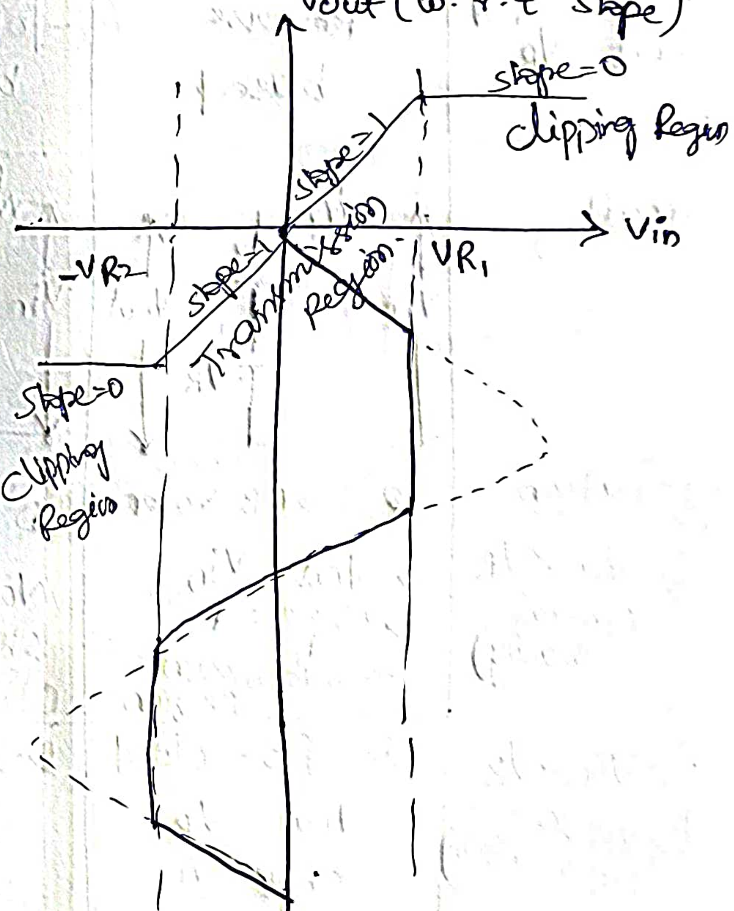
slope = 0.

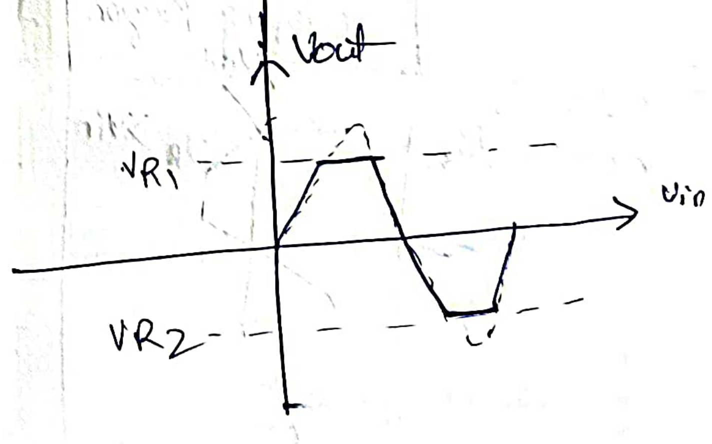
case(2): for $-V_{R_2} < V_{in} < V_{R_1}$

$V_{out} = V_{in}$, slope = 1

case(3): for $V_{in} > V_{R_1}$

$V_{out} = V_{R_1}$, slope = 0

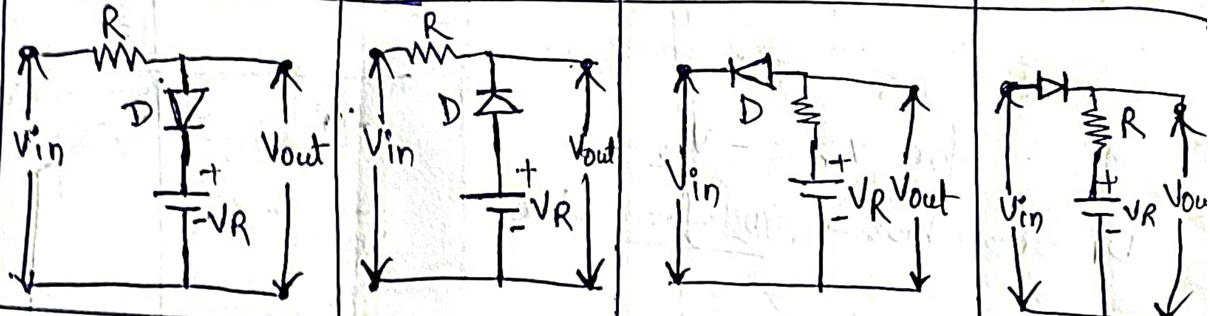




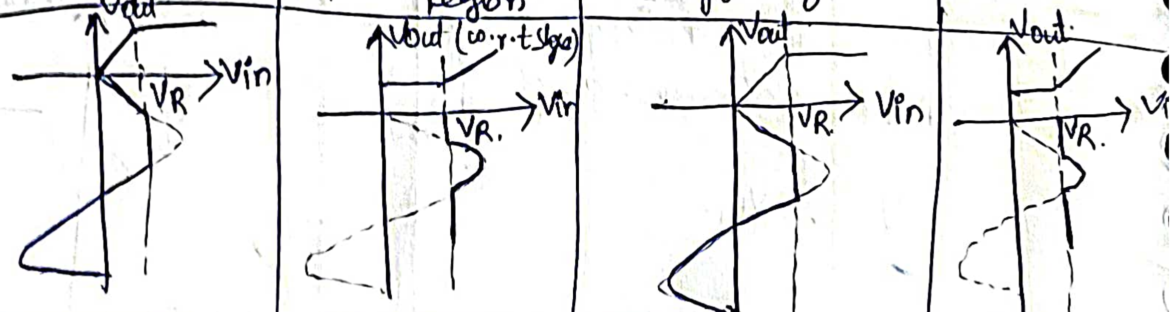
Comparison b/w types of clippers :-

parameters	shunt clippers		series clippers	
	Positive shunt (or) clipping above V_R	negative shunt (or) clipping below V_R	positive series (or) clipping above V_R	negative series (or) clipping below V_R
Connection of diode w.r.t i) Vout	parallel	parallel	~~series~~	~~series~~.
ii) Vin	in series through Resistor 'R'	in series through Resistor 'R'	direct series	direct series
iii) V_R	direct series	direct series	in series through Resistor 'R'	in series through 'R'
Initial biasing w.r.t 'V_R'	Reverse biased	forward biased	forward biased	Reverse biased.
operation i) $V_{in} < V_R$ (initial biasing)	→ D → RB → open → $V_{out} = V_{in}$ → slope = 1 Transmission Region.	D → FB → closed $V_{out} = V_R$ slope = 0 clipping Region.	D → FB → closed $V_{out} = V_{in}$ slope = 1 Transmission Region	D → RB → open $V_{out} = V_R$ slope = 0 clipping Region
ii) $V_{in} > V_R$ (inverse initial biasing)	D - FB - closed $V_{out} = V_R$ slope = 0 clipping Region	D → RB → open $V_{out} = V_{in}$ slope = 1 transmission Region.	D → RB → open $V_{out} = V_R$ slope = 0 clipping Region.	D → FB - close $V_{out} = V_{in}$ slope = 1

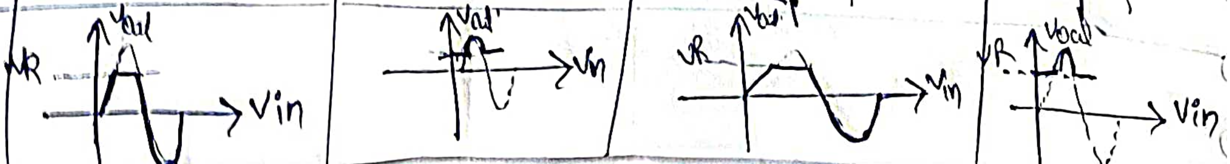
circuit.



transfer characteristics.



output waveform



Clampers : An electronic circuit which is used to shift (or) move DC level of signal to a desired level without affecting the shape of applied i/p signal is said to be "clamper circuit".

→ so a clamper ckt moves the signal either in upward direction (or) in downward direction.

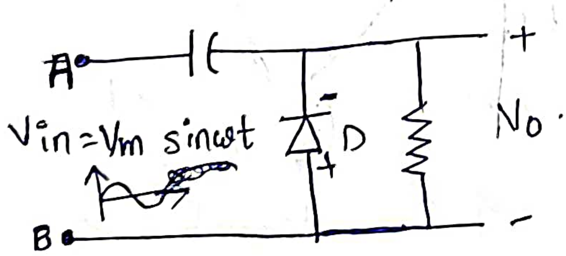
→ clamper circuit basically consists of a capacitor, diode and Resistor.

→ clampers are also called as AC signal level shifter / capacitor clamper / DC clamper

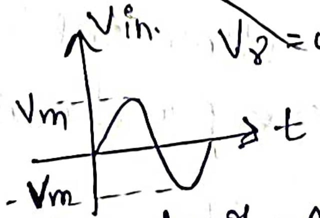
→ Clamper circuits are classified as

1. positive clamper ckt
2. negative clamper ckt
3. Biased clamper. ckt

Positive Clamper Circuit: The clamper circuit which introduces (+ve) DC value to the i/p signal is said to be "positive clamper circuit".



→ Let diode D is ideal then $V_\gamma = 0$, $R_f = 0$, $R_r = \infty$



Operation: During (-ve) half cycle of AC i/p signal, terminal A becomes -ve & B becomes +ve. Hence Diode will be forwardbiased and it acts as closed switch. Capacitor starts charging

→ Now capacitor starts charging in opposite polarity to that of the i/p signal polarity.

→ As i/p signal is (-ve) half cycle, capacitor charges in (+ve) direction. (+Vm) $(\frac{-}{} \| \frac{+}{})$. It charges upto a voltage of +Vm.

→ so voltage across capacitor is $V_c = V_m$

~~[Vout for (+ve) half cycle is Vout = Vc = Vm]~~

V_m → peak i/p value of signal.

(2) → During (+ve) half cycle of AC i/p signal, terminal A becomes (+ve) & B becomes (-ve), hence diode is reverse biased and acts as open switch.

→ Now capacitor ~~charge~~ starts discharging.

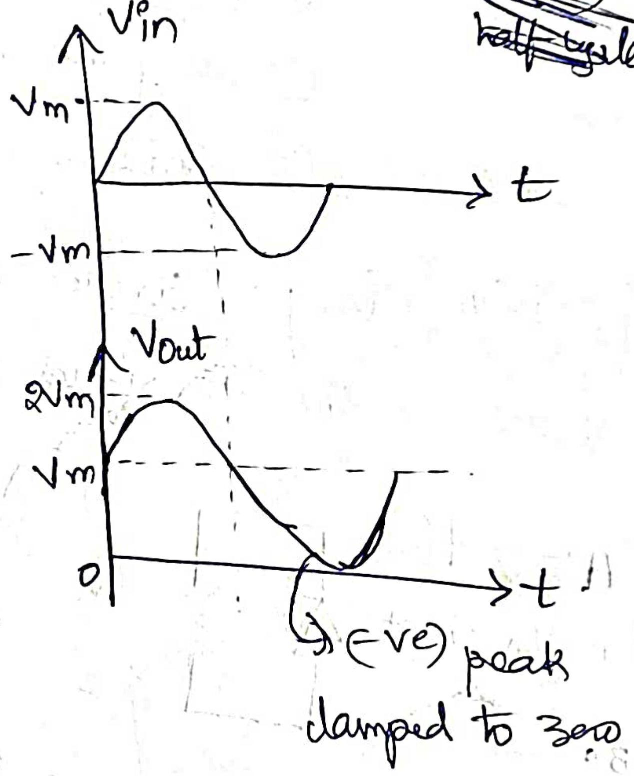
→ Voltage across R_L (or) output voltage is ~~for (+ve) half cycle~~.

$$V_{out} = V_{in} + V_c$$

→ as Vin is now (+ve) half cycle $V_{in} = +V_m$.

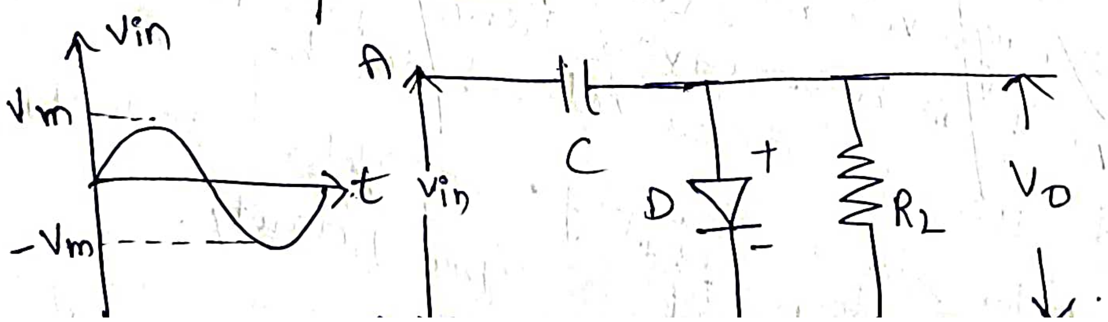
$$= V_m + V_m$$

$$\boxed{V_{out} = 2V_m}$$



→ The signal is shifted in upward direction. Hence ckt is said to be (+ve) clamper circuit.

<u>Negative clamper circuit</u>:



Operation :

(1) → During (+ve) half cycle, terminal A becomes (+ve) & B becomes (-ve), hence Diode D is forward biased, and it acts a closed switch.

→ Now capacitor starts charging, in opposite direction to that of applied i/p signal.

→ As (+ve) half cycle is i/p, capacitor charges in (-ve) direction to a value of $-V_m$.

→ So voltage across capacitor is $V_C = -V_m$. ~~[$V_{out} = V_C = -V_m$ for (+ve) half cycle]~~

(2) → During (-ve) half cycle terminal A becomes (-ve) & B becomes (+ve), hence diode D is reverse biased, and it acts as open switch.

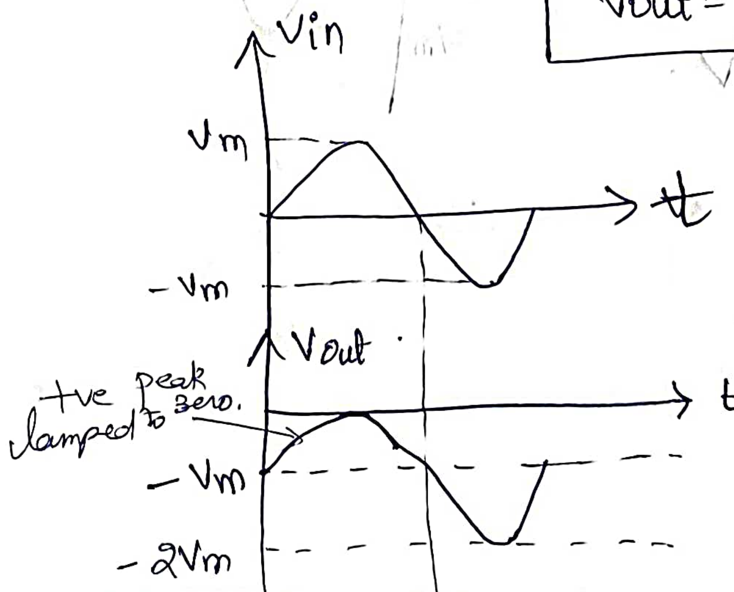
→ Now capacitor ~~than~~ starts discharging. ~~[for (-ve) half cycle]~~

→ Voltage across R_L is $V_{out} = V_{in} + V_C$

as Vin is (-ve) half cycle, $V_{in} = -V_m$.

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

$$\boxed{V_{out} = -2V_m}$$



→ As signal is shifted in downward direction, the clamper circuit is said to be (-ve) clamper ckt.

③ Biased clampers:

① positive biased clamper circuit

② negative biased clamper circuit.

Positive biased clamper circuit: if A D.C voltage source is biased to positive clamper then the resultant is said to be " positive biased clamper circuit".

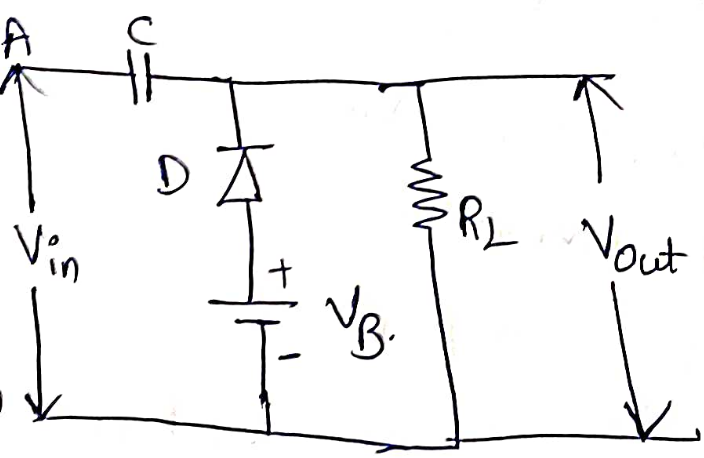
→ biased DC source can be (+ve) (or) (-ve).

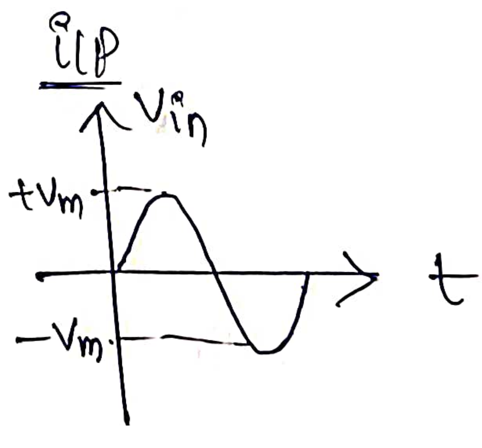
→ based on type of DC source biased, (+ve) biased clamper circuits are classified as

ⓐ positive ~~biased~~ clamper with positive bias

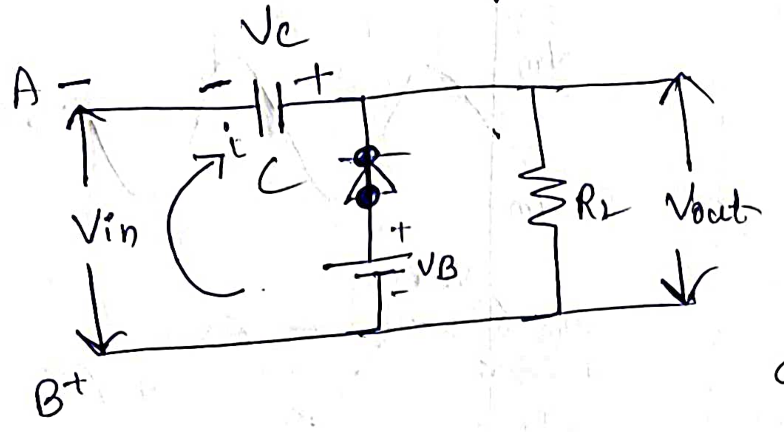
ⓑ " " " " negative bias.

Positive clamper with positive bias:





Operation : During (-ve) half cycle, the ckt will be



→ diode is forward biased due to both Vin & VB.
→ hence capacitor starts charging in opposite direction to that of i/p signal.

→ As diode is forward biased, voltage across capacitor is, Apply KVL to ckt.

$$-V_{in}+V_c-V_B=0 \Rightarrow V_c=V_m+V_B$$

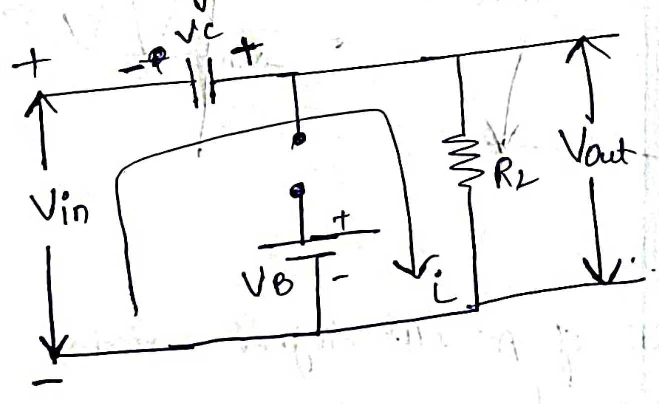
(or)

$$-V_m+V_C-V_B=0$$

$$V_C=V_{in}+V_B.$$

$$\boxed{V_c=V_m+V_B}$$

(8) → During (+ve) half cycle, ckt will be



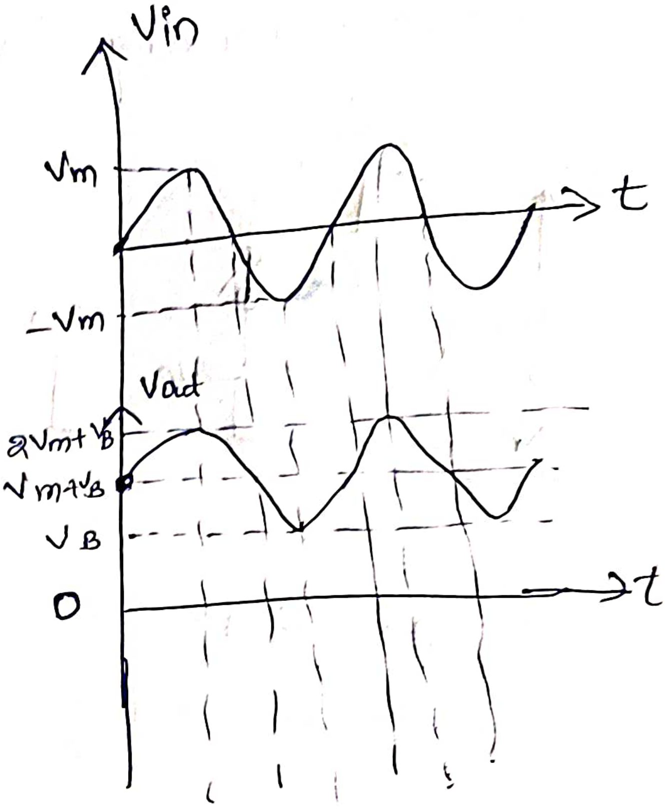
→ Initially 'D' is reverse biased w.r.t Vin & forward biased w.r.t VB.
→ By maintaining Vin > VB, diode will be reverse biased w.r.t both Vin & VB.

→ As diode acts as open ckt, output across RL (Vout) is calculated as, Apply KVL to ckt.

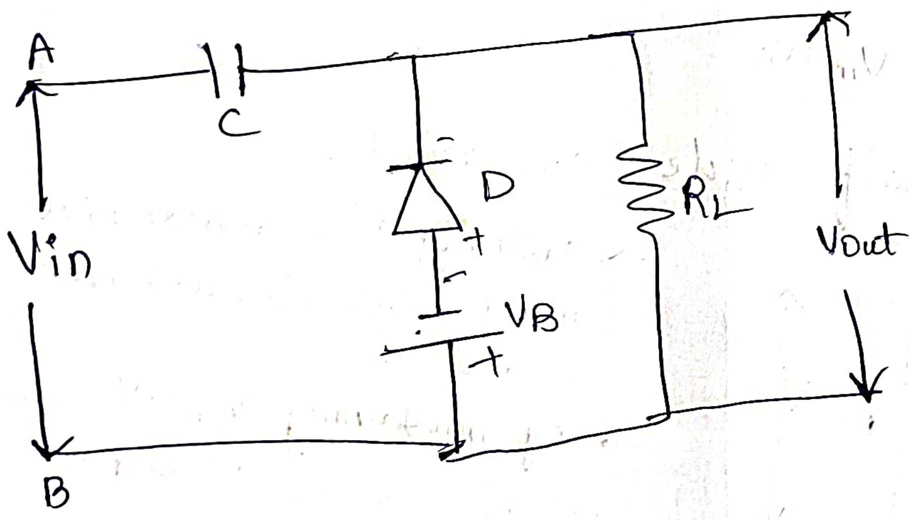
$$V_{in}+V_c=V_{out} \Rightarrow V_{out}=V_{in}+V_c.$$

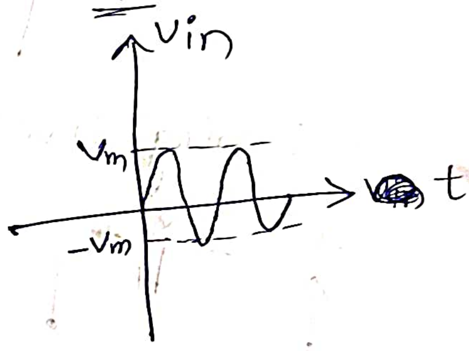
$$\boxed{V_{out}=V_{in}+V_m+V_B}$$

V_{in}	$V_{out} = V_{in} + V_m + V_B$.
0	$V_m + V_B$.
V_m	$2V_m + V_B$
$-V_m$	V_B.

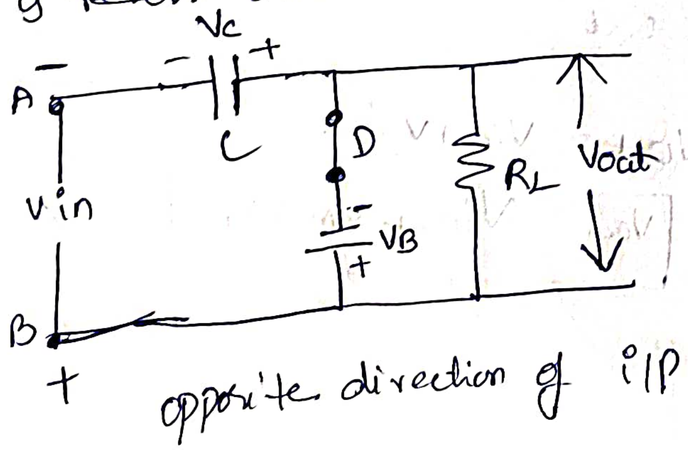


Positive clamper with negative bias





Operation: for (-ve) half cycle of AC i/p signal, diode is ~~reverse~~ forward biased w.r.t both V_{in}. By maintaining $V_{in} < -V_B$, diode is FB w.r.t both V_{in} & V_B.



→ as Diode is forward biased capacitor starts charging in opposite direction of i/p signal.

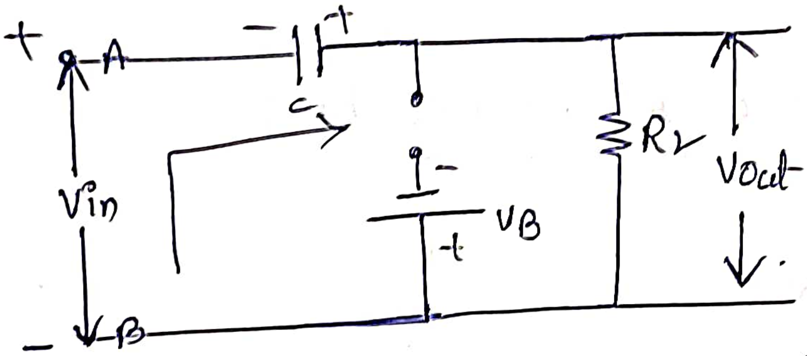
→ To calc 'V_c' apply KVL to ckt

$$-V_{in} + V_c + V_B = 0$$

$$-\overset{\text{VP}}{V_m} + V_c + V_B = 0$$

$$\boxed{V_c = V_m - V_B}$$

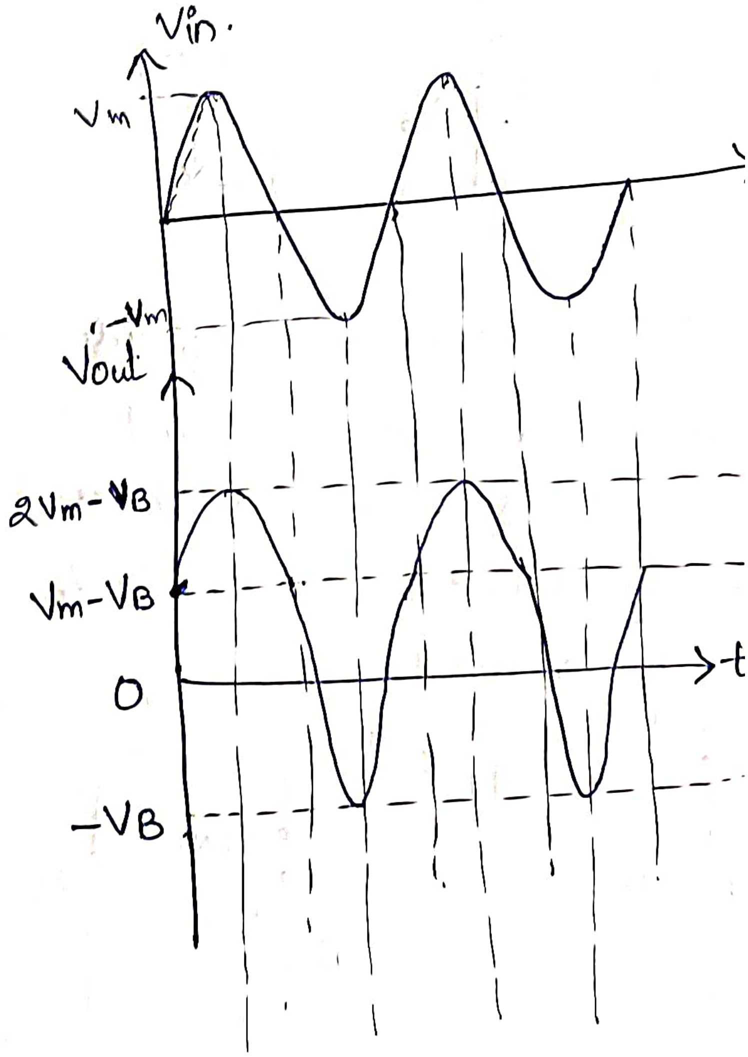
⇒ for (+ve) half cycle diode is reverse biased w.r.t both V_{in} & V_B. capacitor discharges and V_{out} is calculated by applying KVL to below ckt.



$$V_{in} + V_c = V_{out}.$$

$$\boxed{V_{out} = V_{in} + V_m - V_B}$$

V_{in}	$V_{out} = V_{in} + V_m - V_B$
0	$V_m - V_B$
V_m	$2V_m - V_B$
$-V_m$	$-V_B$.



<u>Negative biased clamper circuit</u>:- If a D.C voltage source is biased to negative clamper then the resultant is said to be "negative biased clamper circuit".

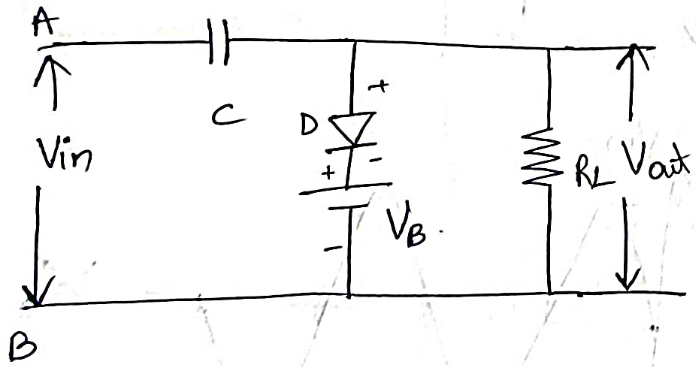
→ Biased DC source can be (+ve) (or) (-ve).

→ Based on type of DC source biased, (-ve) biased clamper circuits are classified as

① Negative clamper circuit with positive bias

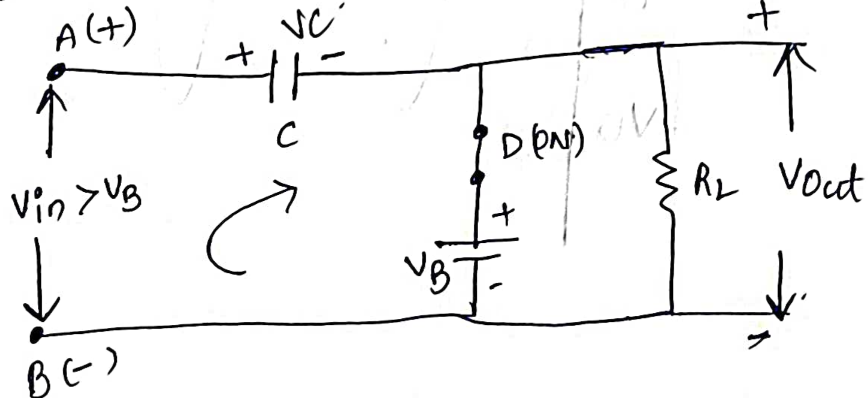
② Negative " " " negative bias.

Negative clamper circuit with positive bias.



<u>operation</u>: During (+ve) half cycle terminal A becomes (+ve) & B becomes (-ve), as a result Diode is forward biased due to Vin & is reverse biased due to V_B.

→ By maintaining $V_{in} > V_B$, Diode can be forward biased due to V_B also.



→ As D is forward biased due to (+ve) half cycle, Capacitor charges to (-ve) direction

~~$V_C = V_m$~~

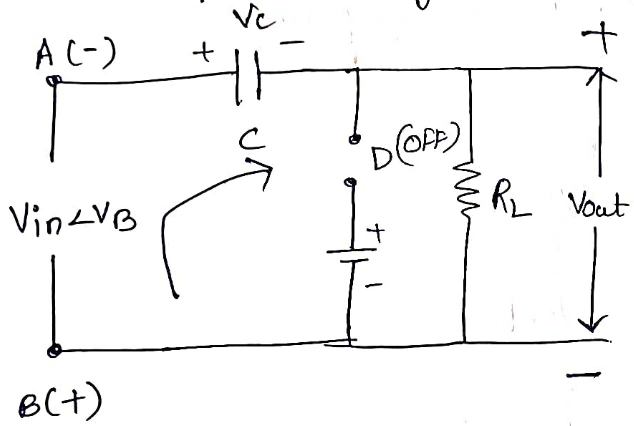
Apply KVL to ckt

$V_{in} - V_C - V_B = 0$

$V_C = V_{in} - V_B$

$V_C = V_m - V_B \rightarrow (1)$ [As capacitor charges].

(2) → During (-ve) half cycle, Diode is reverse biased due to V_{in} & V_B. Apply KVL to ckt.



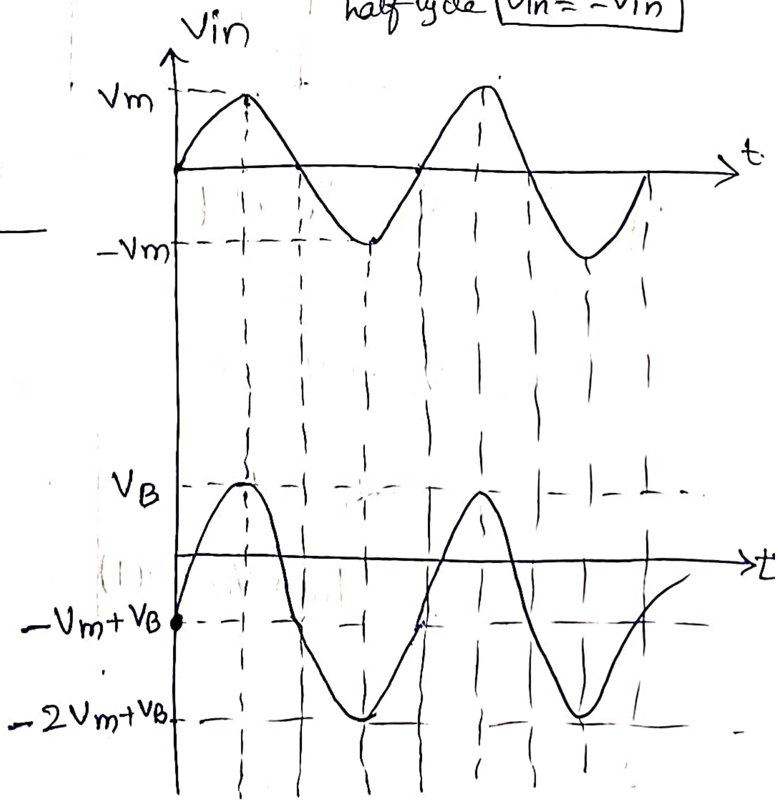
$-V_{in} - V_C - V_{out} = 0$

$V_{out} = -V_{in} - V_C$

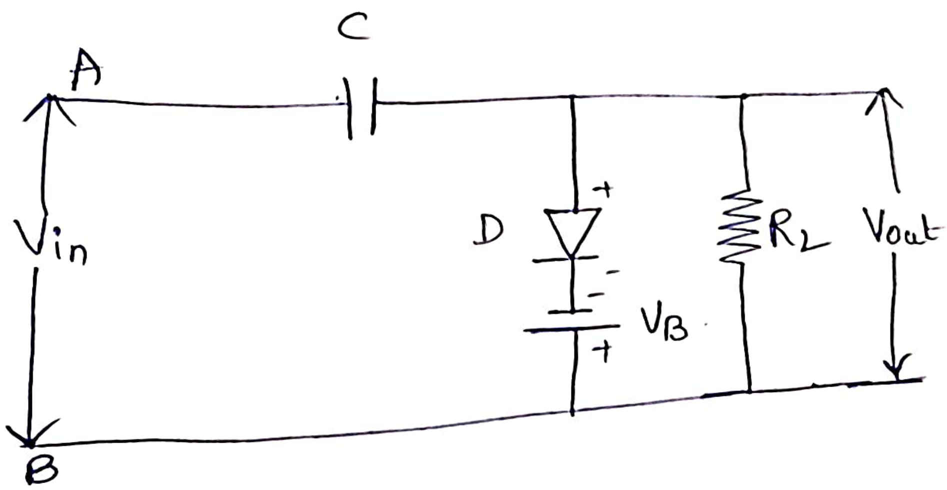
$V_{out} = -V_{in} - V_m + V_B$ (from (1))

~~if $V_{in} = +V_{in}$~~ As i/p is (-ve) half cycle $\boxed{V_{in} = -V_{in}}$

V_{in}	$V_{out} = +V_{in} - V_m + V_B$
0	$-V_m + V_B$
V_m	$+V_B$
$-V_m$	$-2V_m + V_B$

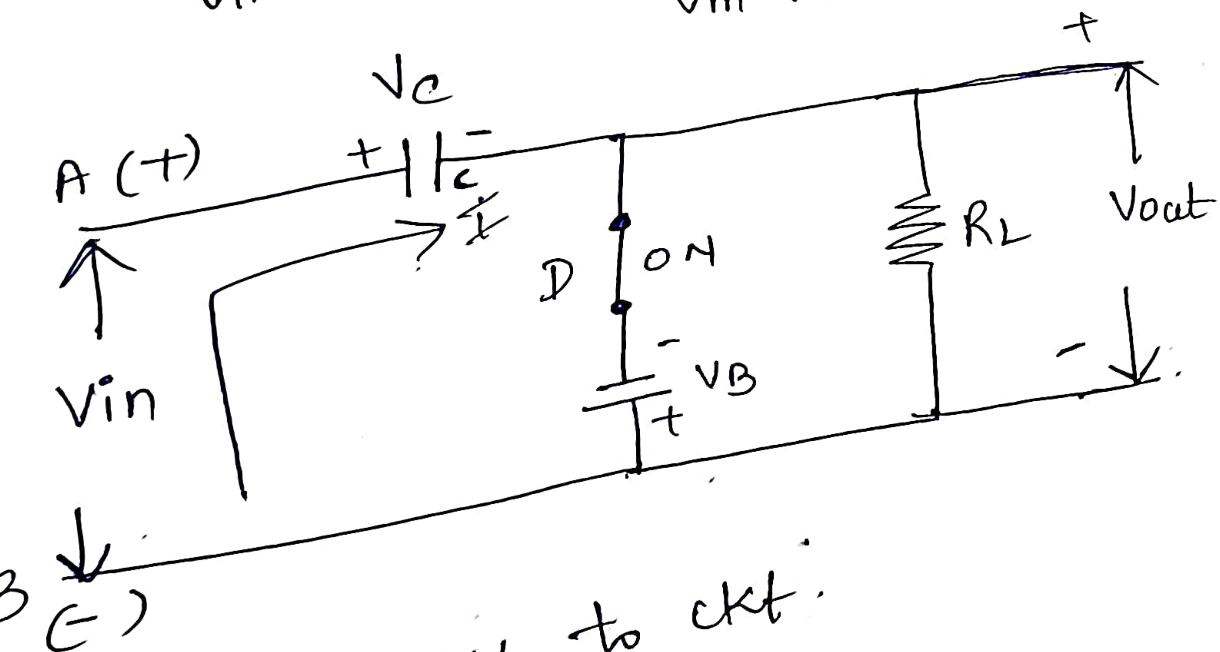


Negative clamper circuit with negative bias :



Operation :

(1) → During (+ve) half cycle, Diode is forward biased du[e]... Hence capacitor starts charging in (-ve) d[irection]... Vin & VB. Vm value.



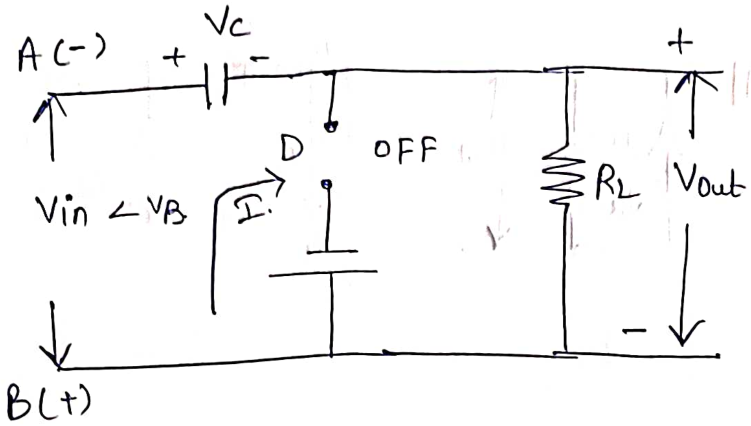
Apply KVL to ckt:

$$V_{in} - V_C + V_B = 0$$

$$V_C = V_{in} + V_B$$

$$V_C = V_m + V_B \rightarrow (1)$$

(2) → During (-ve) half cycle, diode is reverse biased due to V_{in}. By maintaining $V_{in} < V_B$, diode can be reverse biased due to V_B also.



Apply KVL to ckt.

$$-V_{in} - V_C - V_{out} = 0$$

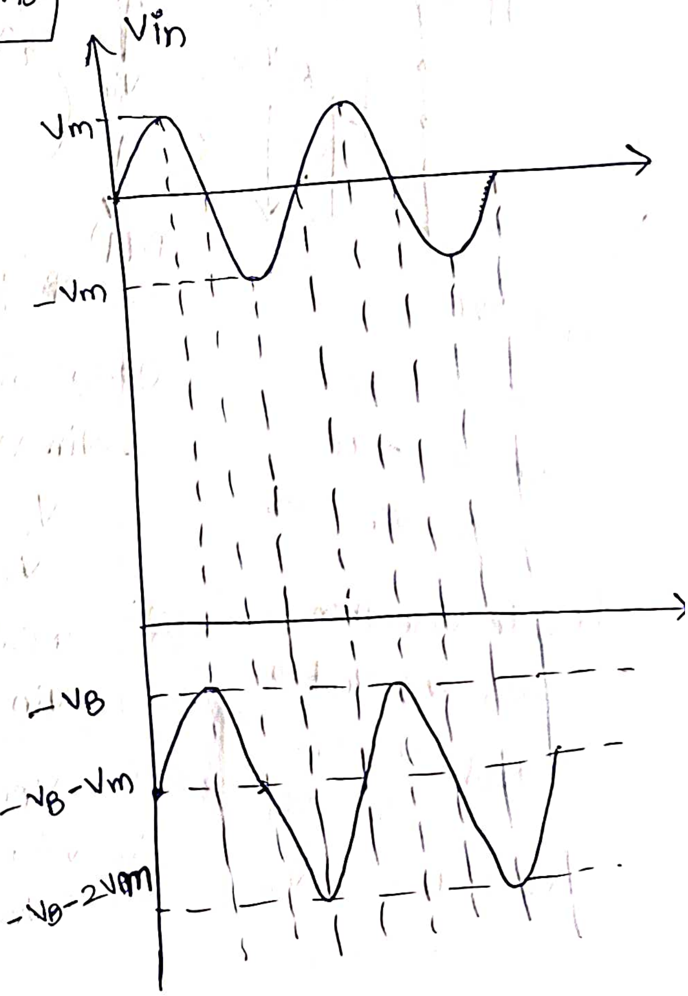
$$V_{out} = -V_{in} - V_C$$

$$V_{out} = -V_{in} - V_m - V_B.$$

* Let $-V_{in} = V_{in}$ then (as V_{in} is (-ve) half cycle $V_{in} = -V_{in}$).

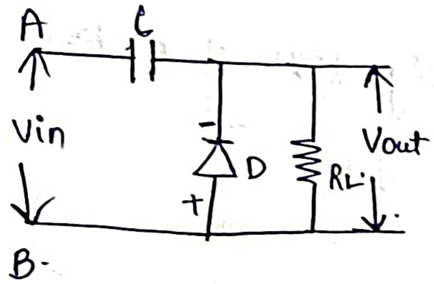
$$\boxed{V_{out} = V_{in} - V_m - V_B.}$$

V_{in}	$V_{out} = V_{in} - V_m - V_B$
0	$-V_m - V_B.$
V_m	$-V_B$
$-V_m$	$-2V_m - V_B.$



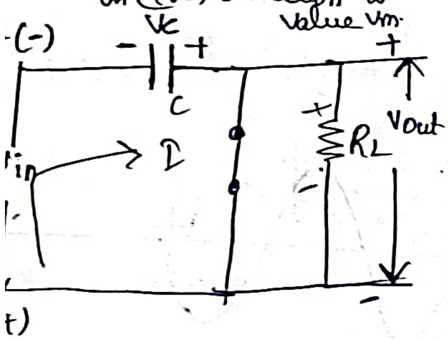
Reference only!

Positive clamper.



→ From ckt it can be observed that 'D' is forward biased for (-ve) half cycle i.e terminal A should be (-ve) &
B " " (+ve)

→ so capacitor charges in (+ve) direction to a value Vm.



Apply KVL

for calc Vc then

$-V_{in} + V_c = 0$

$V_c = V_{in} = V_m$

for calc Vout then.

$-V_{in} + V_c - V_{out} = 0$

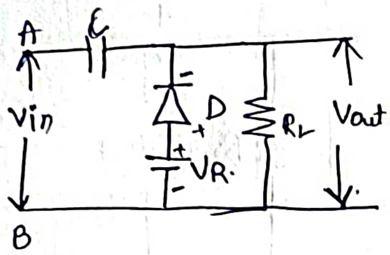
$V_{out} = V_c - V_{in}$

$= V_m - V_{in}$

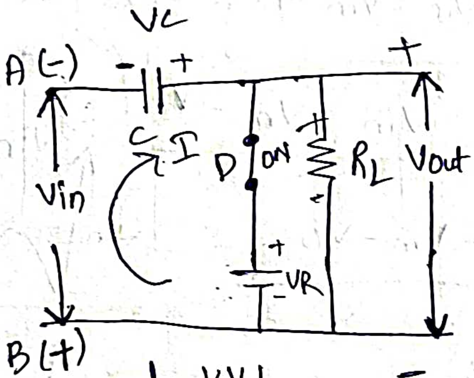
(-ve) halfcycle $V_{in} = -V_{in}$

$\therefore V_{out} = V_m + V_{in}$

positive clamper with (+ve) bias



forward biased due to both Vin & VR.



Apply KVL

① for calc Vc

$-V_{in} + V_c - V_R = 0$

$V_c = V_{in} + V_R$

$V_c = V_m + V_R$

② for calc Vout

$-V_{in} + V_c - V_{out} = 0$

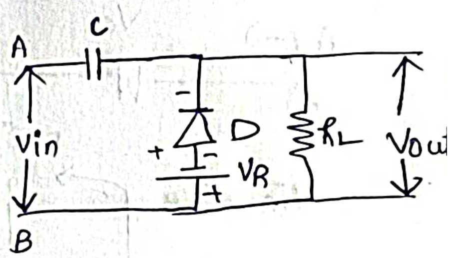
$V_{out} = -V_{in} + V_c$

for (-ve) halfcycle $V_{in} = -V_{in}$

$V_{out} = V_{in} + V_c$

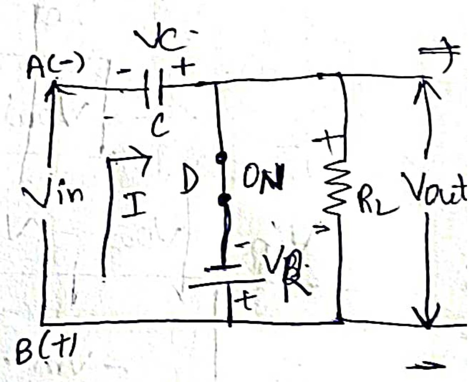
$= V_{in} + V_m + V_R$

positive clamper with (-ve) bias



forward biased due to Vin & RB due to VR.

⇒ By maintaining $V_{in} \geq V_R$, D can be FB due to VR also



Apply KVL

① for calc Vc

$-V_{in} + V_c + V_R = 0$

$V_c = V_{in} - V_R$

$V_c = V_m - V_R$

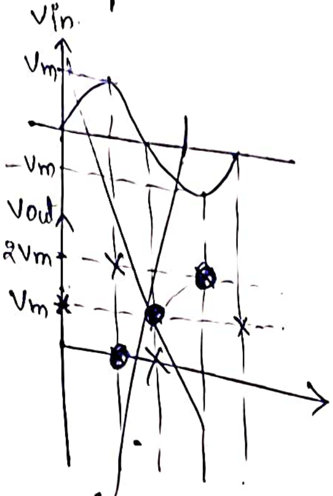
② for calc Vout

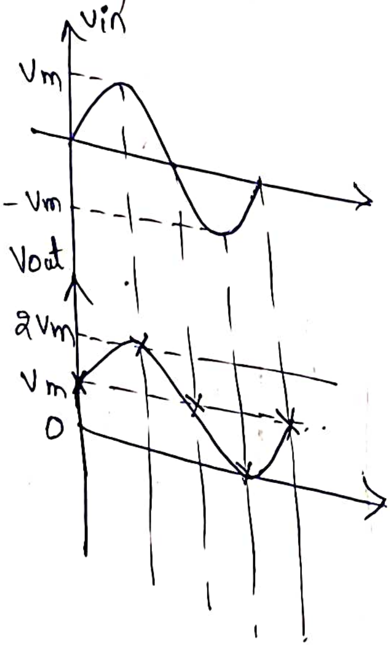
$-V_{in} + V_c - V_{out} = 0$

$V_{out} = -V_{in} + V_c$

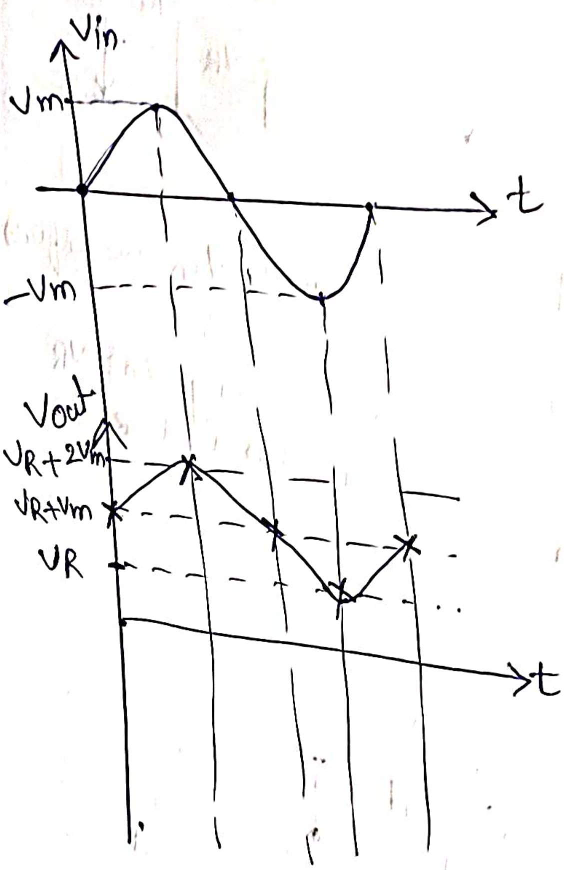
$V_{in} = -V_{in}$

V_{in}	$V_{out} = V_m + V_{in}$
0	V_m
V_m	$2V_m$
$-V_m$	0



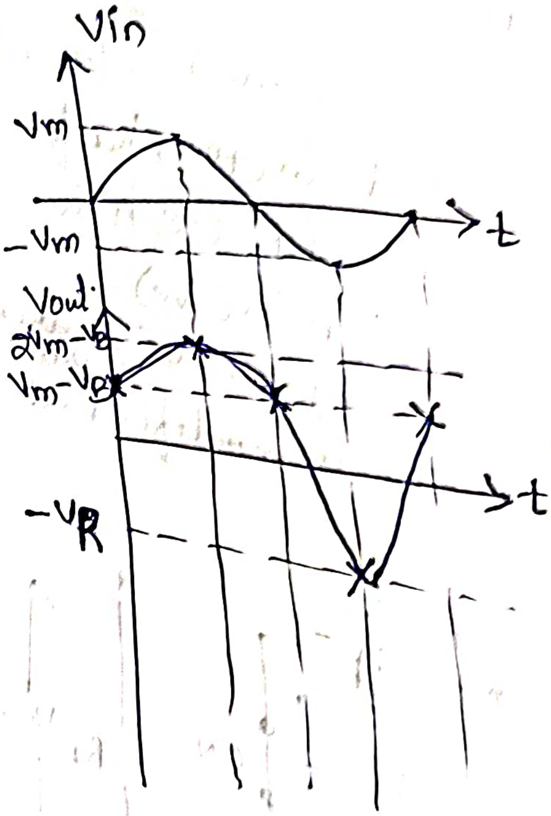


V_{in}	$V_{out} = V_{in} + V_m + V_R$
0	$V_m + V_R$
V_m	$2V_m + V_R$
$-V_m$	V_R



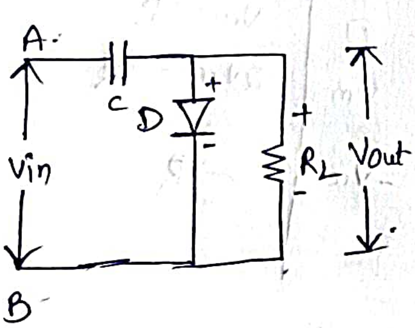
$V_{out} = V_{in} + \ldots$
$= V_{in} + V_m - V_R$

V_{in}	$V_{out} = V_{in} + V_m - V_R$
0	$V_m - V_R$
V_m	$2V_m - V_R$
$-V_m$	$-V_R$

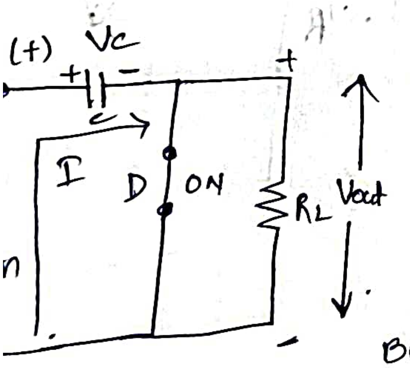


Reference only

Negative clamper



→ Diode can be forward biased for (+ve) half cycle of i/p i.e A is (+ve) & B is (-ve).
→ 'c' charges in (-ve) direction to Vm
→ ckt is modified as.



Apply KVL

for calculating Vc

$V_{in} - V_C = 0$

$V_C = V_{in} = +V_m$

~~[illegible]~~

calculating Vout. (direction)

$V_{in} - V_C - V_{out} = 0$

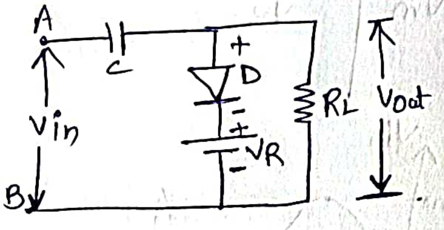
$V_{out} = V_{in} - V_C$

(+ve) half cycle

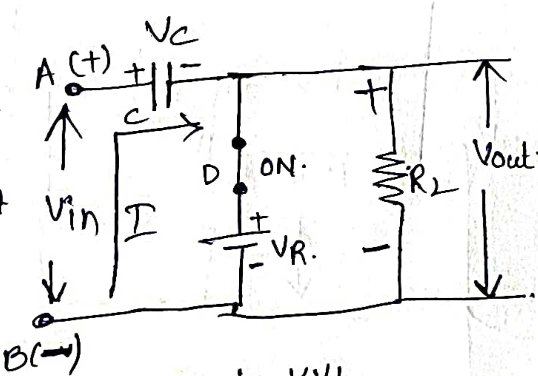
$V_{in} = +V_{in}$

$\boxed{V_{out} = V_{in} + V_m}$

Negative clamper with (+ve) bias



→ FB due to Vin (+ve half cycle)
RB due to VR.
→ By maintaining $V_{in} > V_R$
D can be FB due to VR also.



Apply KVL.

① for Calc Vc.

$V_{in} - V_C - V_R = 0$

$V_C = V_{in} - V_R$

$\boxed{V_C = V_m - V_R}$

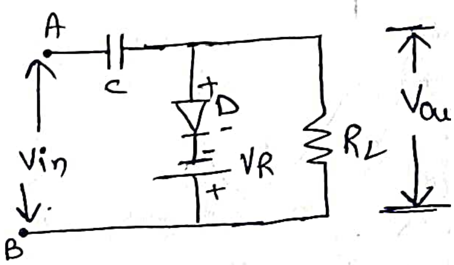
② for Calc Vout

$V_{in} - V_C - V_{out} = 0$

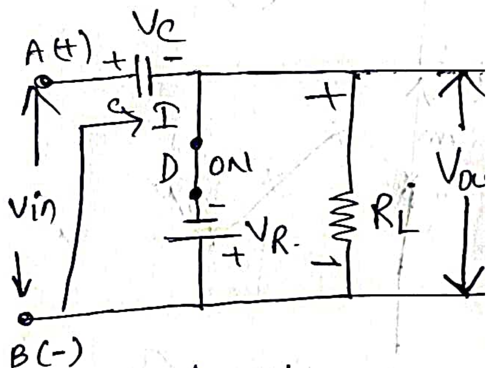
$V_{out} = V_{in} - V_C$

$\boxed{V_{out} = V_{in} - V_m + V_R}$

Negative clamper with (-ve) bias.



→ FB due to both Vin (+ve half cycle) & VR.



Apply KVL

① for calc Vc

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

$V_C = V_{in} + V_R$

$\boxed{V_C = V_m + V_R}$

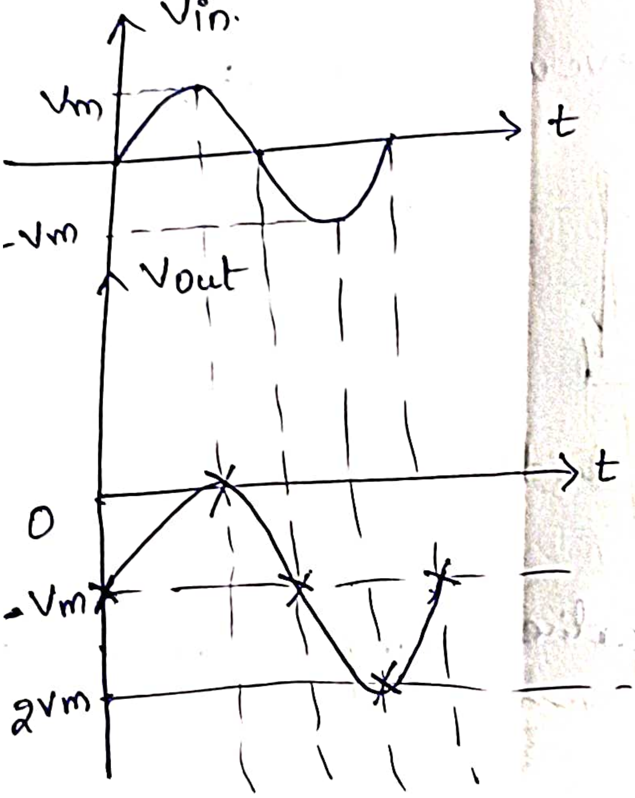
② for calc Vout

$V_{in} - V_C - V_{out} = 0$

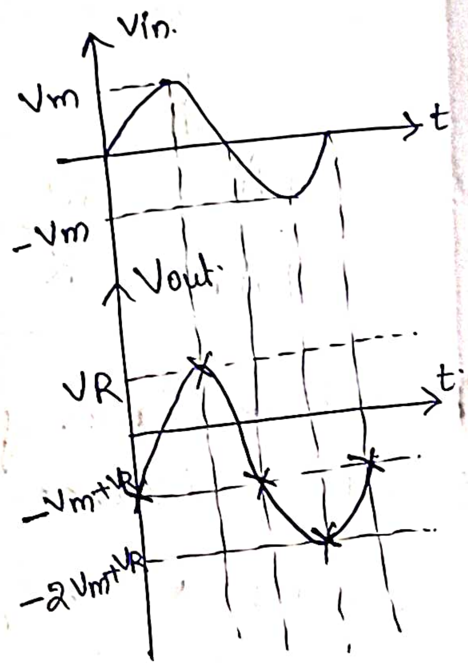
$V_{out} = V_{in} - V_C$

$\boxed{V_{out} = V_{in} - V_m - V_R}$

Vin	Vout = Vin − Vm
0	−Vm
Vm	0
−Vm	−2Vm



Vin	Vout = Vin − Vm + VR.
0	−Vm + VR
Vm	VR
−Vm	−2Vm + VR.



Vin	Vout =
0	−V
Vm	
−Vm	

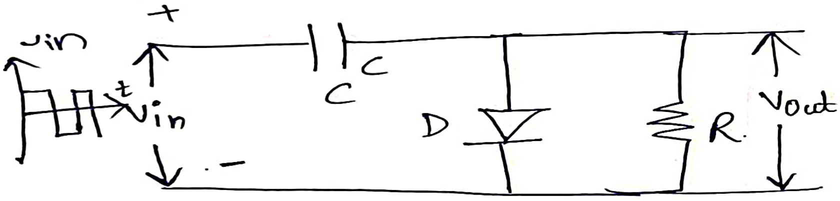
Clamping circuit theorem :-

Statement: Under steady state condition, the ratio of area under output curve in forward direction (when diode conducts) to the area under output curve in reverse direction (when diode doesn't conduct") is given by

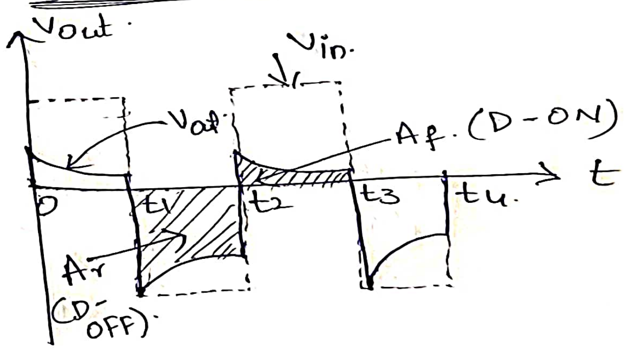
$$\boxed{\frac{A_f}{A_r} = \frac{R_f}{R}}$$

$R_f \rightarrow$ forward resistance of diode.
$R \rightarrow$ Shunt resistance.

Proof: Let us consider a negative clamper circuit with square wave as an AC i/p.



O/P wave form



Case(1): From graph it can be observed that

Case(1): During t_1 to t_2, diode is OFF, i.e it is reverse biased. Hence capacitor discharges so charge is lost during t_1 to t_2: Lost charge is given by $q = \int_{t_1}^{t_2} i_r \, dt$ where

$i_r = \frac{V_r}{R}$.

$$q = \int_{t_1}^{t_2} \frac{V_r}{R} dt$$

$$q = \frac{1}{R} \int_{t_1}^{t_2} V_r dt$$

$$q = \frac{1}{R} [A_r] \rightarrow (1)$$

Case (2): During t_2 to t_3, diode is ON, i.e., it is forward biased. Hence capacitor charges. So capacitor regains the lost charge. Regained charge is given by

$$q' = \int_{t_2}^{t_3} i_f \, dt \text{ where}$$

$$i_f = \frac{V_f}{R_f}.$$

$$q' = \int_{t_2}^{t_3} \frac{V_f}{R_f} dt$$

$$= \frac{1}{R_f} \int_{t_2}^{t_3} V_f \, dt$$

$$q' = \frac{1}{R_f} [A_f] \rightarrow (2)$$

* under steady state condition.

lost charge = regained charge.

eqn (1) = eqn (2)

$$\frac{A_r}{R} = \frac{A_f}{R_f}.$$

$$\therefore \boxed{\frac{A_f}{A_r} = \frac{R_f}{R.}}$$ Hence proved the clamping ckt theorem.

Problems: A 2:1 step-down ratio is used to supply a HWR ckt from 230V, 50Hz, supply to an 8 KΩ resistive load. Transformer secondary resistance is 8 Ω. While diode forward resistance is 60Ω. Calculate the maximum, average, rms values of current as well as the ripple factor, DC output voltage, rectification efficiency, % Regulation.

Sol: Given

$N_1 : N_2 = 2:1$ $\frac{N_1}{N_2} = \frac{2}{1}$	AC i/p: 230V, 50 Hz ↓ Vrms (primary coil).	$R_L = 8\,K\Omega$ $R_s = 8\,\Omega$ $R_f = 60\,\Omega$

Calc ① I_m, ② I_{avg}, ③ I_{rms}, ④ γ, ⑤ V_{dc}, ⑥ η. ⑦ % regulation.

WKT.

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

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

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

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

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100.$$

here

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

$$(\text{rated}) = \frac{I_m^2 (R_f + R_L)}{4}$$

WKT

$$I_m = \frac{V_m}{R_L + R_f + R_s} \quad \text{where}$$

$$\boxed{V_m = \sqrt{2} \times \frac{\text{AC i/p voltage (at primary coil)} \times N_2}{N_1}}$$

$$= \sqrt{2} \times \frac{230 \times 1}{2}$$

$$= \sqrt{2} \times 115 = 162.15\,V$$

$$\boxed{V_m = 162.15\,V}$$

①

$$I_m = \frac{162.15}{8 \times 10^3 + 60 + 8} = 20\,mA$$

$$\boxed{I_m = 20\,mA}$$

(1)

$I_{avg} = I_{dc} = \frac{20\times10^{-3}}{\pi} = \underline{6.36mA}$

(3)

$I_{rms} = \frac{20\times10^{-3}}{2} = \underline{10mA}$

$\gamma = \sqrt{\left(\frac{10\times10^{-3}}{6.36\times10^{-3}}\right)^2 - 1}$

$= \sqrt{(1.572)^2 - 1}$

$= \sqrt{2.471 - 1}$

$= \sqrt{1.471}$

$= 1.21$

$V_{dc} = \frac{V_m}{\pi} = \frac{162.15}{\pi}$

$= 51.6V$

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

$P_{dc} = \frac{I_m^2 R_L}{\pi^2} = \frac{(20\times10^{-3})^2 \times 8\times10^3}{\pi^2}$

$= \frac{1018.59 \times 10^{-6} \times 10^3}{\pi}$

$= 324.22 \times 10^{-3}$

$P_{dc} = 0.324W$

$P_{ac} = \frac{I_m^2 (R_f + R_L)}{4}$

as Rs is also given

$P_{ac} = \frac{I_m^2}{4}(R_f + R_L + R_s)$

$= \frac{(20\times10^{-3})^2}{4} \times [8\times10^3 + 8 + 60]$

$= \cancel{100\times10^{-6}\times} [$

$0.8W$

$\eta = \frac{0.324}{0.8} \times 100$

$= 40\%.$

(7) % Regulation $=$

$\frac{R_f}{R_L} \times 100$

$= \frac{60}{8\times10^3} \times 100$

$= \frac{6\times10^3}{8\times10^3}$

$= 0.75\%$

(2) The 80mA DC is supplied via HWR ckt to a 200Ω load. Find the transformer's rms voltage, DC o/p voltage, PIV rating of diode, & PIV rating of rectifier.

Sol: Give $I_{dc} = 80mA$, $R_L = 200\Omega$.

Find. $V_{rms} = ?$ PIV of diode $(V_m/\sqrt{2})$ & rectifier (V_m)

$V_{dc} = ?$

WKT

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

$80 \times 10^{-3} = \frac{I_m}{\pi}$

$I_m = 251\ mA$.

~~$I_{rms} = \frac{I_m}{2} = \frac{251 \times 10^{-3}}{2}$~~

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

WKT $V = IR$

$V_m = I_m R_L$

$V_m = 251 \times 10^{-3} \times 200$

$\boxed{V_m = 50.26\ V.}$

→ PIV of ~~diode~~ Half

$V_{rms} = \frac{50.26}{2} = 25.13V$

$V_{dc} = \frac{50.26}{\pi} = 15.99V.$

PIV of ~~rectifier~~ diode is

$PIV(rect) = \frac{V_m}{\sqrt{2}} = \frac{50.26}{\sqrt{2}}$

$= 35.53V$

③ How much AC i/p power from the secondary of transformer must be used in HWR to supply 600W of DC power to the load. What would a full wave rectifier's AC i/p power be for same load?

Sol: Given $P_{dc} = 600\ W$

$P_{ac} = ?$ for HWR & FWR.

WKT for HWR

$\%\eta = 40.6\% = \frac{P_{dc}}{P_{ac}} \times 100$

$40.6 = \frac{600}{P_{ac}} \times 100$

$P_{ac} = \frac{600}{40.6} \times 100$

$\boxed{P_{ac} = 1477.83W}$ HWR.

for FWR

$\%\eta = 81.2\% = \frac{P_{dc}}{P_{ac}} \times 100$

$81.2 = \frac{600}{P_{ac}} \times 100$

$P_{ac} = \frac{600}{81.2} \times 100$

$\boxed{P_{ac} = 738.91W}$

④ A transformer with a center-tapped secondary winding feeds a full wave rectifier ckt. From either end of secondary to center tap, the rms voltage is 25V. Given a load of 2kΩ and a diode with forward resistance of 4Ω and a secondary resistance of 10Ω. Determine the power delivered to the load, the percentage of regulation at full load, the rectification efficiency, and the secondary's TUF.

Sol: Given data

$V_{rms} = 25V$,

$R_L = 2K\Omega$.

$R_f = 4\Omega$

$R_s = 10\Omega$.

To find

① P_{dc}

② % Regulation.

③ η

④ TUF (secondary).

WKT for FWR

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

$$25 = \frac{V_m}{\sqrt{2}}$$

$$V_m = 25\sqrt{2} = 35.25V.$$

① $P_{dc} = \frac{4 I_m^2}{\pi^2} R_L$.

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

$$= \frac{35.25V}{2\times10^3 + 4 + 10}$$

$$I_m = 17.5 mA$$

$$P_{dc} = \frac{4\times(17.5\times10^{-3})^2\times2\times10^3}{\pi^2}$$

$$= 0.248W.$$

② % Regulation $= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$.

$$= \frac{R_f}{R_L}\times100 \quad [\text{for } R_f > R_s]$$

But it is Given that

$R_s > R_f$.

$\therefore$ % Regulation $= \frac{R_f + R_s}{R_L} \times 100$

$$= \frac{4+10}{2\times10^3}\times100$$

$$= \frac{\cancel{14}\,7}{\cancel{2\times1000}}\times100$$

$$= 0.7\%.$$

③ $\eta = \frac{P_{dc}}{P_{ac}} \times 100$

$$P_{ac} = \frac{I_m^2 (R_L + R_f)}{2}$$

as R_s is also given

$$P_{ac} = \frac{I_m^2 (R_L + R_f + R_s)}{2}$$

$$= \frac{(17.5\times10^{-3})^2 (2\times10^3 + 4 + 10)}{2}$$

$$= (0.000153)(2014) = 0.308W$$

$$\eta = \frac{0.248}{0.308}\times100$$

$$= 80.5\%.$$

④ TUF (secondary) = η

$= 80.5\%$

⑤ A resistive load is supplied with a DC current of 12A from a 40 V (rms) sinusoidally fluctuating alternating supply by the fourier semiconductor diodes employed in a bridge rectifier circuit, each of which has a forward resistance of 0.2 Ω and infinite reverse resistance. Find out the ckt's efficiency and load's resistance.

Sol:

$I_{DC} = 12A$

$V_{rms} = 40V$

$R_f = 0.2$

$\eta = ?$

$R_L = ?$

IKT for bridge rectifier.

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

$12 = \frac{2I_m}{\pi}$

$I_m = \frac{12 \times \pi}{2}$

$I_m = 18.84A$

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

$40 = \frac{V_m}{\sqrt{2}}$

$V_m = 40\sqrt{2}$

$V_m = 56.56V$

for bridge rectifier.

$I_m = \frac{V_m}{R_L + 2R_f + R_s}$

Let $R_s = 0$

$18.84 = \frac{56.56}{R_L + 2(0.2)}$

$R_L + 0.4 = \frac{56.56}{18.84}$

$\boxed{R_L = 2.6\Omega}$

$\Rightarrow \eta = \frac{P_{dc}}{P_{ac}} \times 100$

$P_{dc} = \frac{4I_m^2}{\pi^2} R_L = 374.02W$

$P_{ac} = \frac{I_m^2 (R_L + 2R_f)}{2} = 532.41W$

$\eta = 70.25\%$

⑥ A full wave rectifier is powered by 50Hz, 100 V source (rms). It is attached to a load that uses an 80μF filter capacitor and draws 40mA. Determine ripple voltage's "rms" value and DC output voltage. Calculate ripple factor as well.

Sol: Given data

$f = 50Hz$

$V_{rms} = 100V$

$C = 80\mu F$

$I_{dc} = 40mA$.

12.31433

$V_{r(rms)} = ?$ V_{rms} of ripple ~~voltage~~

$V_{r(dc)} = ?$ V_{dc} of ripple ~~voltage~~

$\gamma = ?$

$$V_{r(rms)} = \frac{I_{dc}}{4\sqrt{3} fC} = \frac{40\times10^{-3}}{4\sqrt{3}\times50\times80\times10^{-6}} = \cancel{138.9V}\ 2.88V$$

(or) $\gamma = \frac{V_{r(rms)}}{V_{r(dc)}}$ $= 20.73\times$

$$V_{r(dc)} = V_m - \frac{I_{dc}}{4fC}$$

WKT for FWR.

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

$$100 = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = 141.4V$$

$$V_{r(dc)} = 141.4 - \frac{40\times10^{-3}}{4\times50\times80\times10^{-6}}$$

$= 138.9V$.

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

WKT

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

~~141.4 =~~

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

$$40\times10^{-3} = \frac{2I_m}{\pi}$$

$$I_m = \frac{40\times10^{-3}\times\pi}{2} = 0.0628$$

62.83 mA.

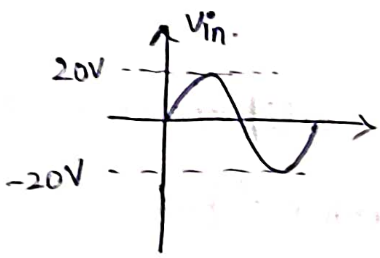
$V_m = \frac{0.0628}{R_L}$

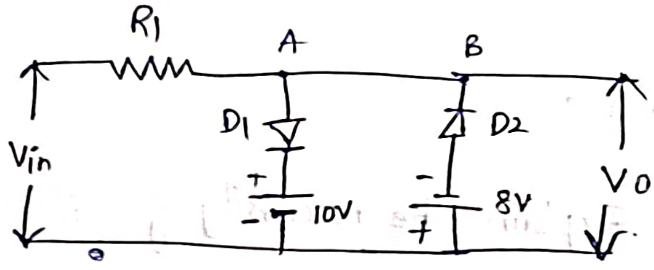
$141.4 = \frac{0.0628}{R_L}$

$R_L = 0.000444$

0.444×10^{-3}

7. The figure shows two-way clipper. Determine its o/p waveform. Assume diode drop of 0.7V.





Sol: from graph $V_m = 20V$

$V_{R1} = 10V$

$V_{R2} = -8V$.

Case (1): for $V_{in} > V_{R1}$, D_1-ON, D_2-OFF,

$\therefore V_o = V_{R1} + \text{diode drop}$ $\Rightarrow$ $V_o \neq V_{in}$ $\therefore$ slope = 0

$= 10 + 0.7 = 10.7V$.

Case (2): for $V_{in} < V_{R2}$, D_1-OFF, D_2-ON

$V_o = \cancel{(V_{R2} + \text{diode drop})}\ V_{R2} - \text{diode drop}$ (-ve Vreference voltage)

$= \cancel{8}\ -8 - 0.7$

$V_o = -8.7V$ $\Rightarrow$ $V_o \neq V_{in}$ $\therefore$ slope = 0.